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A Horse of a Different Color: Specifying With Precision Infants' Mappings of Novel Nouns and Adjectives

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A precisely controlled automated procedure confirms a developmental decalage: Infants acquiring English link count nouns to object categories well before they link adjectives to properties. Fourteen- and 18-month-olds ($n = 48$ at each age) extended novel words presented as count nouns based on category membership rather than shared properties. When the same words were presented as adjectives, infants revealed no preference for either category- or property-based extensions. The convergence between performance in this automated procedure and in more interactive tasks is striking. Perhaps more importantly, the automated task provides a methodological foundation for (a) exploring the development of form–meaning links in infants acquiring languages other than English and (b) investigating the time course underlying infants' mapping of novel words to meaning.

Infants' first words are greeted with special joy, perhaps because we share with Confucious the intuition that ''the beginning of wisdom is to call things by their right name.'' This, after all, is no simple matter. Many different words can be applied to the same scene and different kinds of words (e.g., nouns, adjectives, verbs) highlight different aspects of that scene (e.g., object categories, object properties, events). Successful word learning therefore requires identification of a novel words' grammatical form, discovery of its appropriate referent, and its appropriate extension to new referents.

Some propose that an early link between nouns and object categories provides the foundation for the acquisition of other links between grammatical forms and meanings (Dixon, 1982; Gentner, 1982; Gleitman, 1990; Huttenlocher & Smiley, 1987; Maratsos, 1998; Talmy, 1985; Waxman, 1999a; Waxman & Lidz, 2006; Wierzbicka, 1986). Because adjectives regularly derive meaning from the nouns they modify (e.g., a hard mattress vs. a hard test), and because verbs derive meaning from the relations among nouns (e.g., A chases B vs. B chases A), predicates (both adjectives and verbs) are interpreted in conjunction with accompanying nouns (Dixon, 1982).

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There is now considerable empirical support for this theoretical perspective (e.g., Childers & Tomasello, 2006; Echols & Marti, 2004; Gasser & Smith, 1998; Gentner, 1982; Hall & Moore, 1997; Imai, Haryu, & Okada, 2005; Smith, Jones, & Landau, 1992; Waxman & Booth, 2001; Waxman, Lidz, Braun, & Lavin, 2008). Take for example, Booth and Waxman (2003). In this study, 14-month-old infants were introduced to four toy objects, all from the same object category and embodying the same property (e.g., purple horses). The experimenter labeled these objects either with novel nouns (e.g., ''These are blickets'') or adjectives (''These are blickish''). Next, in a contrast phase, infants viewed an object from a different category and embodying a different property (e.g., an orange carrot). The experimenter noted that this contrast object was ''not a blicket'' (noun condition) or ''not a blickish one'' (adjective condition). Finally, the experimenter introduced two test objects: a category match from the same object category as the familiarization objects but embodying a different property (e.g., a green horse) and a property match from a contrasting object category but embodying the now-familiar property (e.g., a purple chair). When infants in the noun condition were asked to ''find another blicket,'' they strongly favored the category match. Yet when infants in the adjective condition were asked to ''find another blickish one,'' they showed no preference for either test object (also see Waxman, 1999b; Waxman & Booth, 2001). Interestingly, however, there were hints, evident in some analyses, and on some stimulus sets, that 14-month-olds might

have begun to link adjectives specifically to object properties.

The current experiment was designed to address two interrelated goals. First, we sought to clarify whether 14-month-olds, who clearly link count nouns specifically to object categories, might also appreciate that adjectives map specifically to object properties. Second, we sought to develop an automated version of the live interactive task featured in previous research (Booth & Waxman, 2003; Waxman & Booth, 2001, 2003). Although there are reasons to suspect that an automated task might be less engaging than a ''live'' task in which infants manipulate toy objects directly while interacting with a lively experimenter, there are also distinct advantages to developing an automated task (see Golinkoff, Hirsh-Pasek, Cauley, & Gordon, 1987; Hollich et al., 2000; Tincoff & Jusczyk, 1999; Werker, Cohen, Lloyd, Casasola, & Stager, 1998).

First, automation offers greater control over stimulus presentation. In the interactive task, the experimenter spoke directly to the infant while presenting the objects. Although her comments were carefully scripted, it was inevitable that minor variations in timing and pitch contour occurred. Similarly, although the protocol called for precise timing in the presentation of objects, infants varied in their willingness to relinquish toys, leading inevitably to minor variations in trial duration.

Second, the automated version places fewer behavioral demands on infants. It requires only 3 min of sustained attention (vs. 10 min in the interactive task) and requires infants to simply look at the materials (vs. select one of the test objects and place it in the experimenter's hand in the interactive task).

Third, the automated version supports a more precise analysis of the time course underlying infants' responses. Analyses of infants' eye movements have provided insight into the rapidity with which they orient toward an image that corresponds to a familiar word. Between 15 and 18 months, infants initiate such a response within 300 ms after the word has been uttered (Fernald, Pinto, Swingley, Weinberg, & McRoberts, 1998). By 18–24 months, infants respond more rapidly, in some cases initiating a response even before the entire word has been uttered (Fernald, Swingley, & Pinto, 2001; Swingley, Pinto, & Fernald, 1999). The current experiment will reveal how infants deploy their visual attention in response to newly learned words, in the context of a more challenging experimental task.

Finally, the automated procedure provides an ideal platform for cross-linguistic investigations aimed at discovering how infants' interpretations of novel words are shaped by their ambient language. For example, although there is evidence that preschool-aged children's extensions of novel adjectives varies across languages (Waxman & Guasti, 2008; Waxman, Senghas, & Benveniste, 1997), there is as yet no evidence regarding the developmental antecedents to this cross-linguistic difference in infants. One difficulty in developmental cross-linguistic investigations is that adults' styles of interacting with infants vary considerably across cultures (Kidwell & Zimmerman, 2006; Ochs & Sheiffelin, 1995; Scheiffelin & Ochs, 1986). An automated task offers the advantage of permitting researchers to introduce linguistic materials from virtually any language (by changing the audiotaped instructions from English), without sacrificing precise experimental control and without introducing variations in adult–infant interaction styles.

We therefore developed a fully automated intermodal preferential looking procedure (see Golinkoff et al., 1987; Hollich et al., 2000; Tincoff & Jusczyk, 1999; Werker et al., 1998) that closely mirrors the structure of the interactive tasks featured in our previous work (Booth & Waxman, 2003; Waxman & Booth, 2001). If performance in this automated version converges with that in the previous interactive tasks, then 14- and 18-month-old infants should map novel nouns specifically to object categories (and not object properties). If this is the case, we can then consider the developmental trajectory of the adjective–property link in the more precisely controlled conditions of the current investigation. If the ''hints'' of an early emerging adjective–property link hold up, then 14-month-olds should map novel adjectives specifically to object properties (and not object categories). If 14-month-olds have not yet established this link, then they should map adjectives broadly to both object categories and object properties. Evidence from 18-month-olds will further specify the developmental trajectory underlying the establishment of an adjective-property link. By analyzing infants' visual responses as the task unfolds, we will begin to delineate the time course underlying infants' efforts to map novel words to meaning.

Method

Participants

Forty-eight infants (27 females) with a mean age of 13.97 months (range = 13.55–14.47 months) and 48 infants (24 females) with a mean age of 18.01 months (range = 17.5–18.65 months) were recruited from Evanston, Illinois and its surrounding communities. All were acquiring English as their native language

and were primarily from Caucasian middle- to upper-middle-class families. Mean Macarthur – Bates Communicative Development Inventory (MBCDI; Fenson et al., 1993) scores at 14 and 18 months were 14.02 words (range = 0 – 84) and 101.62 words (range = 5 – 321), respectively. An additional 22 infants (twelve 14-month-olds and ten 18-month-olds) were excluded due to failure to attend on at least 50% of trials (n = 12), fussiness (n = 5), and technical difficulties (n = 5).

Materials

Visual stimuli. We created 44 digital pictures (organized into four sets of 11 pictures; see Table 1). Each set included eight familiarization images. To maximize the generalizability of our findings and to closely parallel previous research using the interactive procedure (Booth & Waxman, 2003; Waxman & Booth, 2001), each set included four images from the same basic-level category (e.g., four purple horses) and four familiarization images from the same superordinate-level category (e.g., four purple animals). The contrast image depicted an object from a contrasting category, embodying a contrastive property (e.g., an orange carrot). The two test images included a familiar-category member shaded with a new color (e.g., a green horse) and a novel category member shaded with the familiar color (e.g., a purple chair). All images were presented against a white background.

Linguistic stimuli. A female native speaker of American English produced the linguistic stimuli using infant-directed speech. Her utterances were recorded in a sound-attenuated booth, edited to control timing, duration, peaks, and so forth, and then synchronized with the visual stimuli. Auditory stimuli varied across conditions (see the following).

Procedure

After caretakers completed the MBCDI in a playroom, they were escorted with their infant into a testing room. The infant sat 1.8 m in front of a 155-cm screen and directly below a hidden speaker. The caretaker, seated behind the infant in a separate chair, was able to view the stimuli but was instructed not to talk or to influence the infant's attention. The experimenter then moved behind the screen to control the stimulus presentation. A video camera above the screen recorded infants' looking. Sessions lasted approximately 3 min.

Each infant completed the entire procedure four times, each time with a different set of stimuli (see Table 1). Each trial included three phases: familiarization, contrast, and test. See Figure 1. Each infant viewed basic-level familiarization images on two trials and superordinate-level familiarization images on the remaining two trials. Trial order was counterbalanced; half of the infants in each condition began with a basic-level trial.

To begin each trial, a giggling infant appeared at the center of the screen for 4 s. Infants were randomly assigned to a noun, adjective, or no word condition. All infants saw exactly the same videos but heard different audio tracks. We describe the procedure for a trial in the noun condition as an example. See Figure 1 for full details.

Familiarization phase (24 s). Four images were presented. To maximize opportunities for direct comparison and thus to facilitate rapid learning, these images were presented in pairs, with one image on either side of the screen (Kovack-Lesh & Oakes, 2007; Namy & Gentner, 2002). The first pair appeared for 4 s. Infants heard, ''These are *blickets*.'' One image then disappeared, leaving the other visible for 4 s, as infants heard ''This one is a *blicket*.'' Next, that image disappeared, and the other member of the pair returned (on its original side of the screen) for 4 s, as infants heard ''and this one is a *blicket*.'' The second pair of images was then presented in the same fashion.

Contrast phase (8.5 s). The contrast image (e.g., an orange carrot) was presented for 4.25 s accompanied by an audio track projecting a distinctly disappointed tone (e.g., ''Uh oh! This one is not a *blicket*.'') A second

Table 1
Complete List of Stimuli

	Familiarization			
Set	Basic level	Superordinate level	Contrast	Test
1	4 purple horses	4 purple animals: dog, lion, duck, frog	Orange carrot	Green horse versus purple chair
2	4 green apples	4 green fruits: grapes, pear, lemon, banana	Brown hat	Red apple versus green cup
3	4 red birds	4 red animals: cat, duck, fish, elephant	Yellow boot	Blue bird versus red hammer
4	4 blue cars	4 blue vehicles: motorcycle, plane, helicopter, bus	Orange	Red car versus blue butterfly

Familiarization Phase		Contrast Phase		Test Phase
				
Noun Look at these! This one is a blicket . This one is a blicket.	Look at these! This one is a blicket. This one is a blicket.	Uh-oh, this one is not a blicket!	Yay! This one is a blicket!	Look at these! Find the blicket!
Adjective Look at these! This one is blickish. This one is blickish.	Look at these! This one is blickish. This one is blickish.	Uh-oh, this one is not blickish!	Yay! This one is blickish!	Look at these! Find the blickish one!
No Word Look at these! Look at this one. Look at this one.	Look at these! Look at this one. Look at this one.	Uh-oh, look at this one!	Yay! Look at this one!	Look at these! Find one now!

Figure 1. An example of the phrases used to introduce stimuli in each phase of the experiment.

image, selected randomly from the familiarization stimuli (e.g., a purple dog) was then presented for 4.25 s accompanied by an audio track projecting a cheerful tone (e.g., "Yay, this one *is* a *blicket*."). We included the contrast phase here, and in the original interactive task, to clarify that the novel words could not be applied indiscriminately (i.e., they applied to some, but not all, images). Importantly, because the contrast object represented a different object category (e.g., it was not an animal) and embodied a different object property (e.g., it was not purple), the contrast object itself could not bias infants to favor either a category-based or a property-based construal of the materials.

Test phase (8 s). Two test images were presented simultaneously, one on either side of the screen, accompanied by a test question (e.g., "Look at these! Find the *blicket*!"). The *category test object* was from the same category as the familiarization images but embodied a different property (e.g., green horse); the *property test object* was from a different category but embodied the same property as the familiarization images (e.g., purple chair). The images remained visible in silence for 4 s after completion of the test question. This constituted the response period. Note that at test, the novel noun was in phrase final position but that the novel adjective was in phrase medial position. We adopted these phrasings because to analyze the time course of infants' attention, it was important that the duration of the test question be comparable across all conditions. Previous work established that infants' interpretations of novel words in this paradigm hold up whether words are presented in a final or medial position (Booth & Waxman, 2003).

Coding

Videotaped sessions were coded off-line with sound removed to ensure that coders, who were blind to the hypotheses and to the right–left position of the test images, were also blind to condition assignment (Hollich, 2005; Noldus Information Technology, 2003). For each frame (0.033 s) of the response period, coders identified whether the infant's eyes were oriented to the left, right, or neither image. A primary coder rated all infants. A second coder independently rated 24 infants, 4 per condition, per age. Consistency between coders

(computed for each trial and then averaged across trials) was excellent (92.31% agreement; Cohen's $\kappa = .88$).

Results

Figure 2 displays infants' visual attention in each condition throughout the response period. Notice that infants in all conditions showed an initial preference for the familiar-category test object, all $ts(31) > 2.10$, $ps < .05$, in the first second of the response period. Although not pictured here, this preference was also evident prior to the onset of the response period, suggesting that it does not represent a meaningful response to the test question. The reasons for this preference might derive from the specific stimuli or procedure utilized here or from an intrinsic tendency for infants to attend to categories. Future research will be necessary to disambiguate these alternatives. For now, this overall preference affirms the importance of using the no word control condition (instead of chance) as the baseline comparison point in the current analyses.

To identify the point at which performance among the conditions diverged, we calculated, for each infant and each trial, the proportion of attention devoted to the category test image (dividing attention to the category test image by attention to both test images, combined) for each 1-s window within this period (see Table 2). We submitted these proportions to a series of analyses of variance, one for each 1-s window, with condition (noun vs. adjective vs. no word) and age (14 vs. 18 months) as between-subject factors and level (basic vs. superordinate) as a within-subjects factor. We set a conservative alpha level of .01 to compensate for multiple comparisons. There were no main effects or interactions in either the first, second, or fourth windows. However, in the third window, there was a significant main effect for condition, $F(2, 85) = 4.96$, $\eta_p^2 = .09$, but no effects involving age or level.''

A closer look at performance in this third window revealed that, as predicted, infants showed a stronger tendency to attend to the category test image in the noun condition ($M = 0.72$, $SE = 0.04$) than in either the adjective ($M = 0.53$, $SE = 0.04$), $t(62) = 3.74$, $d = .93$, or no word ($M = 0.53$, $SE = 0.05$), $t(62) = 2.85$, $d = .73$, conditions. There was no difference between these latter two conditions. Finally, nonparametric analyses of individual infants' response patterns converged well with the group analysis. See Table 3. Significantly more infants favored the category match in the noun condition than in either the adjective, $\chi^2(1, N = 64) = 19.32$, $p < .01$, or no word condition, $\chi^2(1, N = 64) = 19.32$, $p < .01$. There was no difference between the latter two conditions, where infants' responses were distributed more evenly.

There was no correlation in any condition between productive vocabulary and performance. Further, based on a median split of the data on productive vocabulary at each age, the performance of high- and low-vocabulary infants did not differ.

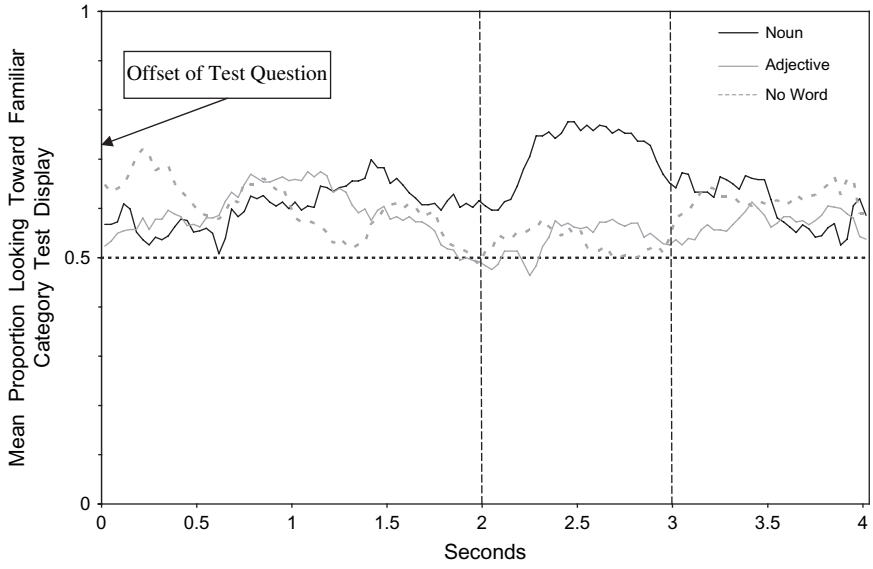

Figure 2. Average distribution of attention across each frame of the response period for each condition.
Note. Chance responding is indicated by the horizontal dashed line. Responses falling above this line indicate attention to the familiar category test object. Responses falling below this line indicate attention to the familiar property test object.

Table 2
Mean Proportion of Attention (and Standard Error) Devoted to the Familiar Category Test Image for Each Condition, Age, and 1-S Response Window

Condition	Second 1	Second 2	Second 3	Second 4
14 months				
Noun	0.59 (0.05)	0.58 (0.06)	0.66 (0.05)	0.56 (0.07)
Adjective	0.59 (0.05)	0.54 (0.06)	0.51 (0.04)	0.54 (0.05)
No word	0.69 (0.04)	0.56 (0.08)	0.48 (0.06)	0.60 (0.07)
18 months				
Noun	0.59 (0.04)	0.68 (0.05)	0.78 (0.05)	0.66 (0.05)
Adjective	0.61 (0.04)	0.62 (0.06)	0.56 (0.06)	0.57 (0.07)
No word	0.60 (0.06)	0.58 (0.07)	0.59 (0.09)	0.63 (0.07)

Discussion

Infants' performance on this precisely controlled task converges beautifully with previous research utilizing an interactive procedure to illuminate their emerging abilities to distinguish nouns from adjectives and to map each grammatical form appropriately to meaning. Indeed, the effect sizes obtained for key results in the automated version were comparable to those of the interactive task. Infants at both 14 and 18 months mapped count nouns specifically to object categories. However, they did not map adjectives specifically to object properties. This supports the view that there is a developmental decalage, in which infants establish a link between nouns and object categories before they establish a link between adjectives and object properties. Moreover, the absence of an age effect reveals that this decalage is considerable, spanning more than 4 months.

Although we suspect that under more supportive conditions, 14- and 18-month-olds might map a novel adjective successfully to an object property (e.g., if adjectives are presented in a wider range of syntactic frames; Gleitman & Gillette, 1999, or if baseline preferences are eliminated), it is clear from the current work that a robust link between adjectives and properties does not emerge until sometime after 18 months of age (Waxman & Markow, 1998). A goal for future work will be to pinpoint this developmental achievement more precisely.

Table 3
Number of Infants in Each Condition Preferring the Category Match (i.e., Directing at Least 55% of Attention to the Category Match), Property Match (i.e., Directing Less Than 45% of Attention to the Category Match), or Neither Test Image (i.e., Directing Between 45% and 55% Attention to the Category Match) During the Third Second of the Response Period

Condition	Category match	No preference	Property match
Noun	28	0	4
Adjective	12	9	11
No word	15	4	13

In addition to amplifying previous evidence, the precisely controlled automated version also moves us forward in (at least) two distinct directions. First, it offers sufficient temporal sensitivity to specify the time course over which infants' map novel words to meaning. Other researchers have documented the time course over which infants map familiar words to familiar objects (Fernald et al., 1998, 2001; Swingley et al., 1999). The current investigation represents a first step toward specifying the time course underlying infants' mapping of *novel* words. The evidence suggests that mapping familiar words takes infants only a fraction of a second (Fernald et al., 1998); mapping novel words in the current task required a full 2 s. There are a number of cognitive processes that likely ensued during this period, as infants sought to (a) compare the word presented at test with that presented during familiarization, (b) identify or recollect the grammatical form of the word, (c) compare the test images to each other and to those presented during familiarization, and (d) map the word to one of the two test images (both of which bore a relation to the familiarization images). A goal for future work will be to further specify the temporal characteristics of each of these component processes by varying the range of cues available during familiarization and the options presented at test. Age-related changes in the time course of responses will be of particular interest as investigations proceed.

Second, the automated procedure provides a platform for cross-linguistic developmental work aimed at identifying how the links between grammatical form and meaning are shaped by the structure of the infants' native language. This question is especially compelling in the arena of adjective acquisition. Languages vary considerably in the extent to which this grammatical category is developed. In some, like

English and Spanish, adjectives constitute a large, open-class grammatical category, whereas in others, like Bantu languages, only a handful of words can be classified as adjectives (Baker, 2001; Dixon, 1982; Waxman et al., 1997). This being the case, it stands to reason that the ways in which adjectives are extended must be tuned by their use in the ambient language (Waxman & Guasti, 2008). The methodology that we have described here offers potential for examining this tuning process in a precisely controlled manner across diverse language communities. Of course, it remains to be seen whether it can be used effectively in cultures in which infants (and perhaps adults) are not typically exposed to audiovisual media.

In sum, the current experiment provides strong converging evidence for a developmental decalage in which infants acquiring English establish a link between count nouns and object categories well in advance of a link between adjectives and object properties. This evidence is consistent with the view that infants' interpretation of adjectives must build on the prior establishment of a link between nouns and object categories, especially because adjectives derive their meaning from the nouns that they modify (Bolinger, 1967; Dixon, 1982; Klibanoff & Waxman, 2000; Mintz & Gleitman, 2002; Wierzbicka, 1986). Perhaps more exciting, the current work sets the stage for pursuing more detailed investigations of the time course underlying infants' word learning and more comprehensive programs of cross-linguistic research.

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