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A Horse of a Different Color:

Specifying with precision infants' mappings for novel nouns and adjectives

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Abstract

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 extended novel words presented as count nouns on the basis of shared category membership, as opposed to shared properties. When the same words were presented as adjectives, infants revealed no preference for 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 (1) extending the research on the development of form-meaning links to infants acquiring languages other than English, and (2) investigating the time-course underlying infants' mapping of novel words to meaning.

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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, and 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, in this endeavor, infants most readily identify nouns and link them to objects and categories thereof. This early noun-category link then provides the foundation for the acquisition of other links between grammatical forms and meanings (Dixon, 1982; Gentner, 1982; L. 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 (compare, e.g., a hard mattress vs. a hard test), and because verbs derive meaning from the relations among nouns (compare, e.g., A chases B vs B chases A), predicates (both adjectives and verbs) are interpreted in conjunction with the nouns with which they appear (e.g., Dixon, 1982).

There is now considerable empirical support for this theoretical perspective. After an initial period during which infants expect open class words (independent of their grammatical form) to map onto a broad range of commonalities among objects (Waxman & Booth, 2003), infants first carve out a specific expectation for the meaning of nouns. By 14 months, they distinguish count nouns from other grammatical forms and map them specifically to categories (and not properties) of objects (Booth & Waxman, 2003; Waxman, 1999b; Waxman & Booth, 2001), but their mappings for words from other grammatical categories remain quite general (Booth & Waxman, 2003; Echols & Marti, 2004; Waxman & Booth, 2001). Indeed, the earliest empirical evidence that infants single out adjectives and map them specifically to properties (and not categories) of objects comes from infants at 21 months of age (Waxman & Markow, 1998). Young word learners' ability to map verbs to actions and relations among objects also appears to follow this more protracted developmental course.

This developmental decalage has been documented in several labs (e.g. Childers & Tomasello, 2006; Gasser & Smith, 1998; Gentner, 1982; Hall & Moore, 1997; Imai, Haryu, & Okada, 2005; Smith, Jones, & Landau, 1992; Waxman & Booth, 2001; Waxman, Lidz, Braun, & Lavin, under review). To take a recent example, consider Booth and Waxman (see Waxman & Booth, 2001) in which an experimenter introduced 14-month-old infants to toy objects from the same object category and embodying the same property (e.g., four purple horses). She labeled these with either a novel noun ("These are blickets") or a novel adjective ("These are blickish"). After a brief contrast phase in which infants were shown an object that was neither 'a blicket' or 'blickish,' the experimenter presented infants with two test objects. The category-match test object was from the same category as the familiarization objects, but embodied a different property (e.g., a green horse); the property-match test object was from a contrasting category, but embodied the now-familiar property (e.g., a purple chair). When asked to "find another blicket", infants in the noun condition strongly favored the category-match. In contrast, when asked to "find another blickish one," infants in the adjective condition showed no preference for either the category- or property-match (also see Waxman, 1999; Waxman & Booth, 2001). However, there were hints, evident in some analyses, and for some of stimuli, that 14-month-olds might have begun to establish a link between adjectives and object properties.

The current experiment was designed to address two inter-related goals. First, to clarify the trajectory underlying the acquisition of adjectives, we gathered additional evidence regarding whether 14-month-olds, who clearly expect count nouns to map onto categories, might also expect adjectives to map specifically onto 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). We began with the consideration that although the absence of an interacting adult might make the task less engaging for infants, an automated procedure also offers several potential advantages (see Hollich et al., 2000; Tincoff & Jusczyk, 1999; Werker, Cohen, Lloyd, Casasola, & Stager, 1998).

First, it offers greater experimental control over the presentation of both linguistic and visual stimuli. In the interactive task, the experimenter spoke directly to the infant while presenting the objects. Although her comments were carefully scripted, and although she made every effort to control the timing, emphasis and pitch contours of her speech, it was inevitable that minor variations occurred. If she inadvertently emphasized nouns, this may have rendered the novel nouns more salient than the novel adjectives, and may have contributed to the apparent decalage between successful mapping of novel nouns and adjectives. Similarly, although the protocol called for precise timing in the presentation and retrieval of the referent objects, some infants were more willing to relinquish toys than were others. Inevitably, then, there was some variation in the duration of each infant's exposure.

Second, an automated version might be less demanding for infants. Although both the interactive and automated versions include the same number of trials and mentions of each novel word, the automated version is only three minutes long, as compared to 10 to15 min for the interactive task (depending upon the predilections of the participant). In addition to reducing demands on attention in this way, the automated task also requires from infants a less demanding response. In the interactive task, after choosing actively between the two test objects, infants were asked to place their choice in the experimenter's hand. In the automated version, we rely only on infants' looking time as the dependent measure.

Third, the automated methodology permits us to develop a more precise analysis of the time-course underlying infants' responses to words presented in continuous speech. This topic has received considerable attention in recent years, but until now, the evidence has come exclusively from infants' responses to familiar words. Typically in these studies infants view two simultaneous images (e.g., a dog and a baby) as an audio-taped voice asks, for example, 'Find the baby!' Infants' eye movements provide insights into when they orient toward the image that matches the spoken word. In general, infants between 15 and 18 months initiate a visual response to a highly familiar word within 300 msec after the word has been uttered (Fernald, Pinto, Swingley, Weinberg, & McRoberts, 1998). By 18 to 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). Questions remain regarding the time-course underlying infants' response to newly-learned words as well as how infants deploy their visual attention in more challenging experimental settings. The word-learning task that we present here presents particularly distinct processing challenges. To succeed in this task, infants must recognize that the novel word presented at test is the same word they heard during familiarization. They must then map it to one of two alternatives, each of which shares some salient commonality (i.e., same category or same property) with the familiarization images.

Finally, the automated procedure provides an ideal platform for discovering whether and how infants' expectations in word-learning are shaped by features of their ambient language. There is evidence for cross-linguistic variation in preschool-aged children's extensions of novel adjectives, suggesting that their expectations are shaped by linguistic features of their native language (Waxman, Senghas & Benvesniste, 1997; Waxman & Guasti, 2008). However, all of the relevant evidence comes from interactive tasks involving infants raised in mono-lingual English environments. To identify how the ambient language shapes infants' expectations, it will be necessary to consider infants acquiring languages other than English, and such an undertaking will require not only a cross-linguistic but also a cross-cultural approach. Because adults' styles of interacting with infants vary considerably across cultures (Kidwell & Zimmerman, 2006; Ochs & Sheiffelin, 1995; Scheiffelin & Ochs, 1986) it is important to develop an experimental task that taps into infants' expectations in word-learning, but does not depend upon their direct interaction with an adult. With an automated task, it is possible to accommodate infants from a wide variety of linguistic communities (by changing the audiotaped instructions from English to any other language) without introducing cultural variations in adult-infant styles of interaction and without sacrificing precise experimental control.

In the current experiment, we developed an automated task, patterned closely after the interactive tasks featured in previous work (Booth & Waxman, 2003; Waxman & Booth, 2001). We first ask whether 14- and 18-month-old infants' performance in this automated procedure would converge with that observed in the more interactive tasks. If so, then infants at both ages should map novel nouns specifically to categories. At issue then will be the developmental status of the adjective-property link. If the 'hints' of a precocious ability to map adjectives specifically to object properties are robust, then they should be evident at both 14- and 18-months in the more precisely-controlled conditions of the current investigation. If these ‘hints’ were spurious, then 14-month-olds should map adjectives broadly to both categories and properties of objects. Evidence from 18-month-olds will reveal whether a more specific expectation linking adjectives to object properties emerges over this age range. By focusing our analyses on visual responses as they unfold, we expect to provide a first benchmark in delineating 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 to 14.47 months) and forty-eight infants (24 females) with a mean age of 18.01 months (range = 17.5 to 18.65 mos) were recruited from Evanston, IL and its surrounding communities. All were acquiring English as their native language and were primarily from Caucasian middle- to upper-middle-class families. Macarthur-Bates Communicative Development Inventory (MBCDI, Fenson et al., 1993) scores at 14- and 18-months were 14.02 words (ranging from 0 to 84) and 101.62 words (ranging = 5 to 321), respectively. An additional 12 14-month-olds and 10 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. See Table 1

Visual stimuli. We created 44 digital pictures (organized into 4 sets of 11 pictures each). Each set included eight familiarization images: four from the same basic-level category (e.g., four purple horses, varying in size, posture, and details) and four 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 novel color (e.g., a blue 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 adopted an infant-directed speech register to produce the linguistic stimuli. Her utterances were recorded in a sound-attenuated booth, edited to control timing, duration, peaks, etc., and then synchronized with the visual stimuli. Auditory stimuli varied as a function of condition (see below).

Procedure

Participants were welcomed into a playroom where caretakers completed the MBCDI. An experimenter then escorted the infant and caretaker into an adjoining testing room. The infant was seated 1.8 m directly in front of a 155 cm screen. The caretaker, seated behind the infant, was instructed not to talk or to influence the infant's attention in any way. The experimenter then moved behind a screen to control presentation of the stimuli. Visual stimuli were presented on a screen. Auditory stimuli were projected from a speaker hidden directly above the infant. Infants' looking behavior was recorded with a video camera centered above the screen. Sessions lasted approximately 3 min.

Each infant completed the entire procedure four times (see Table 1), each time with a different set of stimuli. Each trial included three distinct phases (familiarization, contrast, and test). See Figure 1. On two trials, the familiarization images were from the same basic-level category (e.g., four purple horses); on the remaining two trials, they were from the same superordinate-level category (e.g., four purple animals). Trial order was counterbalanced; half of the infants in each condition began with a basic-level trial.

To capture infants' attention at the beginning of each trial, infants saw an image of a smiling infant, centered on the screen for 4 s, accompanied by a soundtrack of an infant giggling. Infants were randomly assigned to a Noun, Adjective or No Word (control) condition. All infants saw exactly the same videos; what varied was the audio stimulus. We describe the procedure using the script from the noun condition as an example. See Figure 2 for full details.

Familiarization phase. (24 s) Four distinct 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 in the noun condition 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 precisely the same fashion.

Contrast Phase. (8.5 s) Two distinct two images were presented, one at a time, centered on the screen. The first image depicted an object that differed from the familiarization items in both category membership and in color (e.g., an orange carrot). The accompanying audio track projected a distinctly disappointed tone ("Uh oh! This one is not a *blicket*".) The second image was selected randomly from those presented during familiarization (e.g., a purple dog). The accompanying audio projected a cheerful tone (e.g., "Yay, this one is a *blicket*."). Each image was presented for 4.25s.

We introduced the contrast phase here, and in the original interactive task, to indicate that the novel words could not be generalized broadly to any and all objects. By (unhappily) introducing a contrast object and then (cheerfully) re-introducing a target object, our hope was to demonstrate that some objects are good instances of the intended category, but that others are not. Importantly, because the contrast object was drawn from a different object category (e.g., it was not an animal) than the target, and embodied a different object property (e.g., it was not a purple thing), the object itself could not bias infants' construal of the relation among the familiarization objects.

Test Phase. (8 s) Two distinct images were presented simultaneously, one on either side of the screen. The category test object was a member of 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 test question directed infants toward one of the test objects (e.g., "Look at these! Find the *blicket*!"). After the test question, the images remained visible in silence for 4 s. This constituted the response period.[1]

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. For each frame of the 4-second response period (30 frames per s), coders identified whether the infant's eyes were oriented to the left image, right image, 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 3 displays infants' visual attention in each condition in each frame (.033 s) of the response period.[2] In order to identify when performance among the conditions diverged reliably, we calculated, for each infant and trial, the proportion of attention devoted to the category test image (dividing their attention to the category test image by their attention to both test images, combined) for each one-second window within this period. Table 2 presents the relevant means for each age and condition. We submitted these proportions to a series of ANOVAs, one for each 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, setting a conservative alpha level of .01 to compensate for multiple comparisons. In the first two windows of the response period, there were no main effects or interactions. In the third window (frames 60-90), there was a significant main effect for condition, $F(2, 85) = 4.96$, $p < .01$, but no effects involving age or level. The significant condition effect dissipated in the final 1-second window, where there were again no main effects or interactions.

A closer look at the third window reveals that, as predicted, infants devoted more attention to the category test image in the Noun condition ($M = .72$, $se = .04$) than in either the adjective ($M = .53$, $se = .04$; $t(62) = 3.74$, $p < .001$, $d = .93$) or no word ($M = .53$, $se = .05$; $t(62) = 2.85$, $p < .01$, $d = .73$) conditions. There was no difference between these latter two conditions. Finally, non-parametric analyses of individual infants' response patterns converged well with this analysis based on group means. See Table 3. In the noun condition, infants overwhelmingly favored the category-match. This distribution differed significantly from that in both the adjective (X^2 (1, N = 64) = 19.32, $p < .001$) and no word conditions (X^2(1, N = 64) = 19.32, p <.002). There was no difference between the latter two conditions, where infants' responses were distributed more evenly[3]

Discussion

This work offers insights into infants' emerging abilities to distinguish among grammatical forms, and map each form appropriately to meaning. First, infants' performance on this automated version of the word-learning task converges well with the most robust findings from the interactive procedure.[4] Both tasks reveal that by 14 months, infants map count nouns specifically to object categories. Second, infants across both ages tested in the automated procedure showed no evidence of mapping adjectives specifically to object properties. This suggests that the unstable ‘hints’ of this ability observed in 14-month-olds in the interactive procedure were likely spurious. These findings lend strength to the view that infants’ expectation for a specific link between nouns and object categories emerges prior to their expectation for a specific link between adjectives and object properties. Moreover, the absence of an age effect reveals that this gap between the acquisition of specific links for nouns and adjectives is considerable, persisting for more than four months’ time.

Of course, it is possible that under more supportive learning conditions, infants might link adjectives successfully to object properties (e.g., if adjectives are presented in a wider range of syntactic frames (L. R. Gleitman & Gillette, 1999), or if baseline preferences are eliminated). However, even if such conditions could be found, we suspect that this link would still best be described as fragile, especially in comparison to the early and robust link between nouns and object categories. The currently available evidence suggests that a link between adjectives and properties does not emerge in robust form until sometime between 18 and 21 months of age (Waxman & Markow, 1998). A goal for future work will be to pinpoint more precisely the acquisition of this adjective-property link.

In addition, the current work offers another type of contribution. The carefully-calibrated automated procedure introduced here sets the stage for advancing research in two directions. First, it represents an initial step in identifying the time-course underlying infants’ efforts to map novel words to meaning. Previous investigations have described infants’ responses to familiar words and familiar objects in a relatively simple forced-choice task (Fernald et al., 1998; Fernald et al., 2001; Swingley et al., 1999). In the paradigm presented here, however, the task was quite different and quite challenging. Infants were first familiarized to a novel word and then asked to extend that word beyond the objects on which it had been introduced. To succeed in this task, infants had to a) recognize that the novel word presented at test was the one they had heard previously during familiarization, b) identify the grammatical form of the novel word, and c) map the word to one of two alternatives, both of which bore a relation (either a category- or property-based) to the familiarization objects The time-course underlying infants' responses to novel words in this complex task was clear; a full 2 s. of processing was required before infants revealed a differential response across conditions. This evidence serves as a starting point for identifying the timing of the component cognitive processes required for mapping novel words to meaning. Age-related changes in these patterns will be of particular interest as investigations proceed.

Second, the automated procedure provides a platform for examining how the links between grammatical form and meaning are shaped by the structure of the ambient language in which an infant is immersed. 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 class; in others, like Bantu languages, there are only a handful of words that can be classified as adjectives (Dixon, 1982; Baker, 2002; Waxman, et al., 1997). This being the case, it stands to reason that the link between adjectives and their meaning must be tuned by the characteristics of the ambient language. The current method provides an opportunity for examining this tuning process in a range of language communities.

In sum, the evidence presented here 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 the noun-category link provides a foundation for the more protracted discovery of link between other grammatical forms and their meaning. Specifically, it supports the proposal that the acquisition of adjectives must build on knowledge of nouns because the former regularly derive their meaning from the nouns that they modify (e.g., red hair vs. red fire engine) (Bolinger, 1967; Dixon, 1982; Klibanoff & Waxman, 2000; 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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Footnotes

[1] 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).

[2] Notice that infants in all conditions showed an initial preference for the familiar-category test object, all *ts*(31) > 2.10 , *p*s < .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.

[3] There was no correlation in any condition between productive vocabulary and performance.

[4] Effect sizes in the automated version were comparable to those of the interactive task, providing additional support for its viability.

Table 1

Complete List of Stimuli

Set	**Familiarization**		**Contrast**	**Test**
	Basic Level	*Superordinate Level*		
1	4 purple horses	4 purple animals: dog, lion duck, frog	orange carrot	green horse vs. purple chair
2	4 green apples	4 green fruits: grapes, pear lemon, banana	brown hat	red apple vs. green cup
3	4 red birds	4 red animals: cat, duck fish, elephant	yellow boot	blue bird vs. red hammer
4	4 blue cars	4 blue vehicles: motorcycle, plane helicopter, bus	orange	red car vs. blue butterfly

Table 2.

Mean proportion of attention (and standard error) devoted to the familiar category test image for each condition, age and response window

Condition	Second 1	Second 2	Second 3	Second 4
		14 months		
Noun	.59 (.05)	.58 (.06)	.66 (.05)	.56 (.07)
Adjective	.59 (.05)	.54 (.06)	.51 (.04)	.54 (.05)
No Word	.69 (.04)	.56 (.08)	.48 (.06)	.60 (.07)
		18 months		
Noun	.59 (.04)	.68 (.05)	.78 (.05)	.66 (.05)
Adjective	.61 (.04)	.62 (.06)	.56 (.06)	.57 (.07)
No Word	.60 (.06)	.58 (.07)	.59 (.09)	.63 (.07)

Table 3.

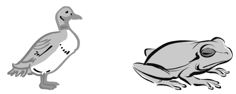
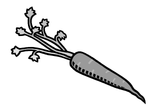
Number of infants in each condition devoting more than 55% of their attention to either test image during the third second of the response period.

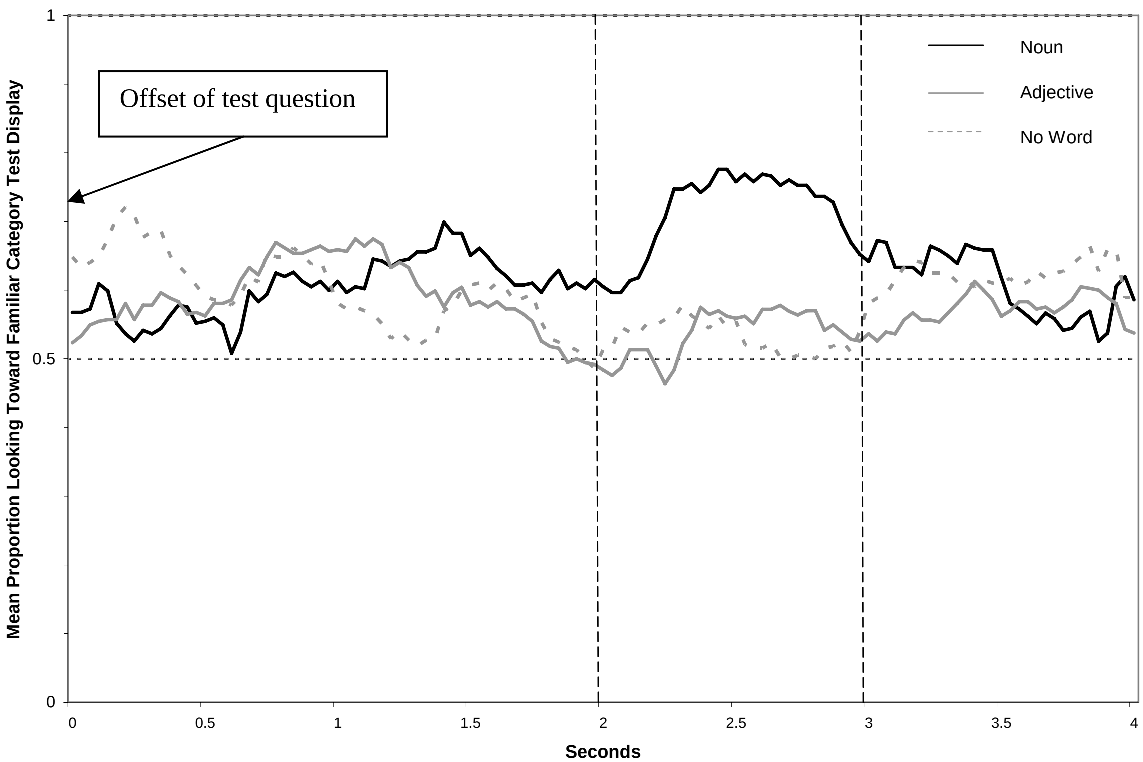
Condition	Category-match	No preference	Property-match
Noun	28	0	4
Adjective	12	9	11
No Word	15	4	13

Figure Captions

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

Figure 2. Average distribution of attention across each frame of the response period for each condition. 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.

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!



Offset of test question
Noun
Adjective
No Word
Mean Proportion Looking Toward Familiar Category Test Display
Seconds
1
0.5
0
0
0.5
1
1.5
2
2.5
3
3.5
4