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Deng, Sophia
Sloutsky, Vladimir

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The Role of Linguistic Labels in Infants' Categorization:
An Eye Tracking Study

Wei (Sophia) Deng (deng.69@osu.edu)
Department of Psychology and Center for Cognitive Science
The Ohio State University
209C Ohio Stadium East, 1961 Tuttle Park Place
Columbus, OH 43210 USA

Vladimir M. Sloutsky (sloutsky.1@osu.edu)
Department of Psychology and Center for Cognitive Science
The Ohio State University
208C Ohio Stadium East, 1961 Tuttle Park Place
Columbus, OH 43210 USA

Abstract

How do words affect categorization? According to one theoretical account, even early in development, labels are category markers and are different from other features. According to another theory, early in development, labels are part of the input and are no more than other features. The current study addressed this issue by examining the effects of labels on category learning in 8- to 12- month infants. Infants were familiarized with exemplars from one category in either label-defined or motion-defined condition and then tested with prototypes from learned category and novel category. Eye tracking results indicated that infants exhibited better category learning in the motion-defined than in the label-defined condition. These results provide little evidence for the idea that labels are category markers that facilitate category learning.

Keywords: Cognitive Development, Categorization, Attention, Label, Psychology, Human Experimentation.

Introduction

The ability to form categories is an important component of human cognition (see Murphy, 2002, for a review). It has been well established that this ability appears early in development, with young infants capable of forming categories at an early age (Eimas & Quinn, 1994; Oakes, Madole, & Cohen, 1991), and a substantial body of experimental evidence suggest that linguistic labels affect this process (Balaban & Waxman, 1997; Waxman & Markow, 1995; Fulkerson, Waxman, & Seymour, 2006; Waxman & Booth 2003; Robinson & Sloutsky, 2007). However, the mechanisms underlying the role of labels remain unclear, which has generated considerable debate. Some have argued that words denoting categories have the special status of category markers and, as such, they facilitate category learning at the earliest stages of word learning. At the same time, others have argued that early in development words are akin to other features, but they may become category markers in the course of development.

According to the former theory, early in development, young infants have general assumptions that words but not other kinds of auditory inputs are category markers which denote categories and "infants embark on the task of word learning equipped with a broad, universally shared expectation, linking words to commonalities among objects" (Waxman, 2003). According to this view, linguistic labels refer to category information and facilitate infants' category learning. There is much evidence consistent with this view. First, some researchers have demonstrated that labels may facilitate infants' categorization above and beyond other kinds of auditory input (Balaban & Waxman, 1997; Fulkerson & Haaf, 2003; Fulkerson et al., 2006; Ferry, Hespos, & Waxman, 2010). Second, facilitative effects of linguistic labels were demonstrated for basic-level as well as superordinate or global categories (Balaban & Waxman, 1997; Waxman & Markow, 1995; Waxman & Booth, 2003). Finally, effects of labels have been shown to affect infants' performance on a variety of cognitive tasks, such as inductive inference (Graham, Kilbreath, Welder, 2004; Welder & Graham, 2001) and object individuation (Xu, 2002; Xu, Cote, & Baker, 2005).

There are challenges, however, to the idea that linguistic labels are category markers that facilitate categorization early in development. There are theoretical proposals arguing that, at least early in development, labels are features of items (similar to color or shape) rather than category markers (Sloutsky & Lo, 1999; Sloutsky & Fisher, 2004; Sloutsky, Lo, & Fisher, 2001) and the contribution of linguistic labels is driven by attentional rather than conceptual factors (Napolitano & Sloutsky, 2004; Sloutsky & Napolitano 2003). There is also evidence that auditory input overshadows (or attenuates processing of) corresponding visual input (Lewkowicz, 1988a, 1988b; Napolitano & Sloutsky, 2004; Robinson et al., 2005; Robinson & Sloutsky, 2004a, 2004b; Sloutsky & Napolitano, 2003). Furthermore, many of the studies examining the effects of labels on infants' category learning compared the effects of labels with those of unfamiliar sounds, but not with a silent condition. When a salient baseline was introduced (e.g., Robinson & Sloutsky, 2007), labels did not facilitate infants' category learning above the

silent baseline (see also Robinson & Sloutsky, 2008, for similar findings on individuation tasks).

There is also recent evidence by Deng and Sloutsky (2012) who demonstrated that labels function the same way as other features for young children, but they may become category markers in the course of development. In particular, Deng and Sloutsky used a variant of Yamauchi & Markman's (1998, 2000) paradigm and pitted category label against a highly salient visual feature. They found that unlike many adults who relied on category label, children relied on the salient feature.

If labels are not category markers for preschoolers, how they can be category markers attracting attention to within-category commonalities for infants (e.g., Balaban & Waxman, 1997; Ferry, Hespos, & Waxman, 2010; Waxman & Markow, 1995)? Although there is evidence that labels do little above and beyond a silent condition (Robinson & Sloutsky, 2007), none of the studies claiming that labels are category markers compared effects of labels with those of highly salient visual features. How do labels affect (a) patterns of attention and (b) the outcome of category learning? And how do these effects differ from those of highly salient visual features? The goal of this research is to answer these questions by using a combination of eye tracking and a more traditional novelty preference paradigm.

Overview of Current Study

The goal of the study reported here was to examine the role of labels in category learning in infancy. The experiment consisted of two between-subjects conditions: label-defined condition and motion-defined condition. In both conditions, infants were familiarized with the exemplars from one category and then tested with the prototype of this category and that of the contrast category. Infants saw the same testing stimuli in both conditions and neither label nor motion was provided during testing. Eye gaze data were collected from infants while being trained and tested in both conditions. If labels are category markers and are able to direct attention to the category-relevant information, then infants should learn better when labels are provided. This should not be the case, however, if labels are part of input rather than category markers.

Method

Participants

Thirty-eight infants (16 boys and 22 girls) ranging in age from 8 to 12 months (M = 10 months, 14 days; SD = 1 month, 27 days) participated in this experiment. Data provided by 2 infants were excluded from analyses due to fussiness and 6 infants were excluded for not looking at a single test trial.

Apparatus

A Tobii T60 eye-tracker with the sampling rate of 60 Hz (i.e., 60 gaze data points per second for each eye) was used
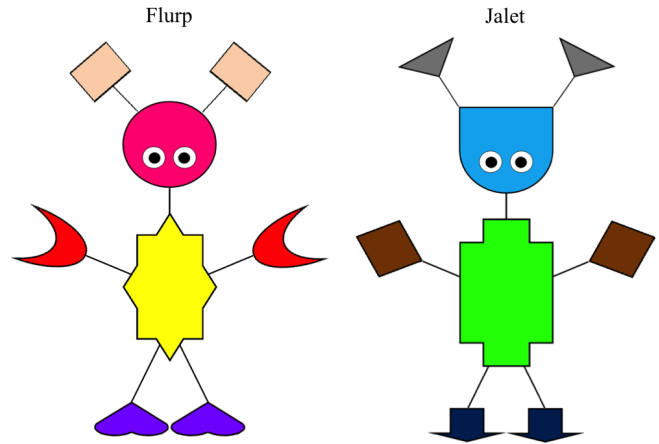

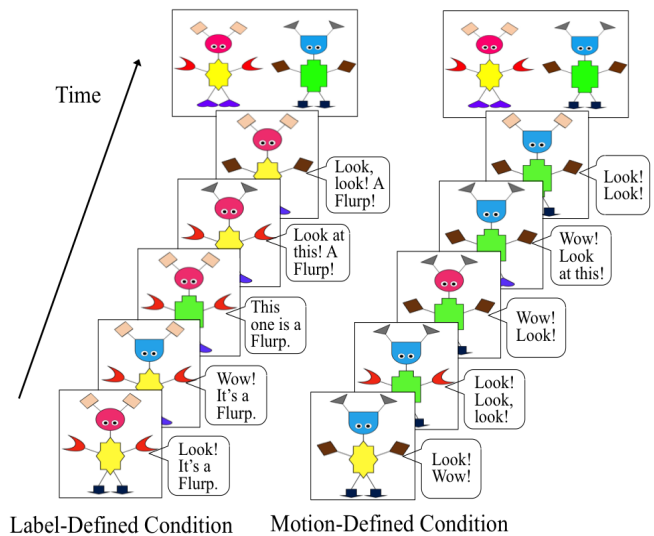Figure 1. Prototypes of stimuli from Categories A and B.

Figure 2. Example Stimuli.

to collect eye gaze data. The eye-tracker is integrated into a 17-inch computer monitor and located on a table inside a booth enclosed by black curtains. A trained experimenter monitored the experiment using Tobii Studio gaze analysis software installed on a 19-inch Dell OptiPlex 755 computer outside the booth. A video stream displaying participants' activities was projected onto a 9-inch black and white Sony SSM-930 CE television for experimenter's online monitoring. Two Dell speakers were located behind a black curtain on each side of the eye-tracker.

Materials and Design

The materials were colorful drawings of artificial creatures and novel labels "flurp" and "jalet". The items had five features varying in color and shape and two categories were formed by different feature values (see Figure 1). As shown in Table 1, the two categories have a family-resemblance structure, which was derived from two prototypes (A0 and B0) by modifying the values of one of five features – head, antenna, hands, body, or feet. For example, to produce the

Table 1. Category structure used in learning.

Category A							Category B						
Stimuli	Head	Body	Hands	Feet	Antenna	Label/ Motion	Stimuli	Head	Body	Hands	Feet	Antenna	Label/ Motion
A1	1	1	1	1	0	1	B1	0	0	0	0	1	0
A2	1	1	1	0	1	1	B2	0	0	0	1	0	0
A3	1	1	0	1	1	1	B3	0	0	1	0	0	0
A4	1	0	1	1	1	1	B4	0	1	0	0	0	0
A5	0	1	1	1	1	1	B5	1	0	0	0	0	0
A0	1	1	1	1	1	1	B0	0	0	0	0	0	0

Note. The value 1 = any of five dimensions identical to "Flurp" (see Figure 1). The value 0 = any of five dimensions identical to "Jalet" (see Figure 1). A0 and B0 are prototypes of each category.

stimulus A1, the value of the antenna was changed from 1 to 0 so that it had four features consistent with the prototype A0 and one feature consistent with the prototype B0. See Figure 2 for example of stimuli.

There were two between-subjects conditions (label-defined vs. motion-defined). In the label-defined condition, the value of label did not vary across the exemplars; whereas in the motion-defined condition, a pattern of motion did not vary across the exemplars. In particular, one of the features (the feet) was animated to be highly salient using Macromedia Flash MX software and all the members of a given category had feet with the same pattern of motion. For "flurps", the feet were purple, heart-shaped, and stretched up and down; whereas, for "jalets", the feet were dark blue, arrows-shape, and moved sideways.

Procedure

Infants were seated on parents' laps approximately 60 cm away from the eye-tracker. Parents were instructed not to interact with infants and not to point or label any of the stimuli. Prior to the experiment, infants completed a 5-point calibration sequence. The calibration points consisted of dynamic kitten images appearing in different locations on the screen, with "bounce" sound. After successful calibration, a colorful picture of a baby playing with several different toys was presented on the screen to keep infants' attention.

When infants and parents were ready to begin, an experimenter started the experiment by pressing the space bar. The picture of baby disappeared and infants were presented 20 familiarization trials and 4 test trials. The trials were mixed and pseudo-randomly assigned into 4 blocks, with 5 familiarization trials followed by 1 test trial in each block. On each familiarization trial, infants saw a creature produced from the structure of one category shown in Table 1 with a white background lasting for 8000 msec and heard a phrase starting at the onset of each trial. In label-defined condition, a labeling phrase (e.g., "Look! This is a Flurp") was presented in each trial and lasted for approximately 2800 msec. However, in motion-defined condition, the phrase was not labeled (e.g., "Look at this one!"). The feet of the creature moved after the phrase and the motion lasted for 3000 msec. The onset of motion in motion-defined condition was approximately the same as that of label in

label-defined condition. After familiarization, infants were tested with preference trial (in each block). Each test trial consisted of the prototype of the category that infants were trained with in familiarization and the prototype of the contrast category, and presented without either label or motion for 8000 msec. A dynamic bouncing ball was presented as an attention-engager between trials within each block. A short cartoon video was presented between blocks in order to let infants have a rest. All gaze data were recorded by the computer using Tobii Studio gaze analysis software.

Results

Analyses presented below primarily focused on the percentage looking to the prototype of novel category at test and on the patterns of attention during familiarization phase and testing phase. Gaze data were exported from the computer using Tobii Studio gaze analysis software. Scenes were created for every trial (both familiarization and test) and eighteen areas of interest (AOIs) for fixations were defined: one rectangle surrounding the creatures on familiarization trials, two rectangles surrounding two prototypes respectively on test trials, and fifteen ellipses surrounding each feature of the creatures on both familiarization and test trials. These data were used to calculate (1) novelty preference score based on the proportion of looking time to the prototype of novel category as compared to the total looking time to both of the prototypes at test; and (2) patterns of attention based on the proportion of looking time to different features on both familiarization and test trials.

Novelty Preference Scores

To examine how labels or patterns of motion affected infants' categorization, a novelty preference score was calculated for each test trial: accumulated looking time to the prototype from novel category divided by the overall looking time for both stimuli. The main results are presented in Figure 3. The data were submitted to a 4 (block: 1 vs. 2 vs.3 vs.4) by 2 (condition: label-defined vs. motion-defined) mixed ANOVA, with block as a within-subjects factor and condition as a between-subjects factor. There was a significant main effect of condition, $F(1, 28) = 11.51$ $MSE = 0.24$, $p < .01$, $\eta_p^2 = 0.291$, with infants looking substantially
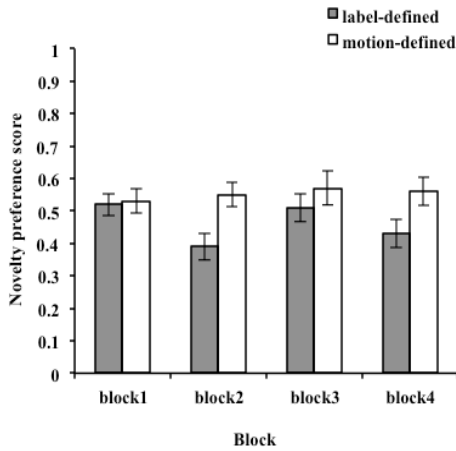
Figure 3. Infants' novelty preference score at test in 4 blocks for label-defined and motion-defined conditions.
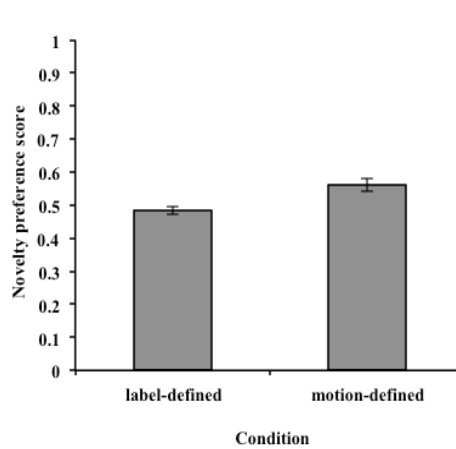

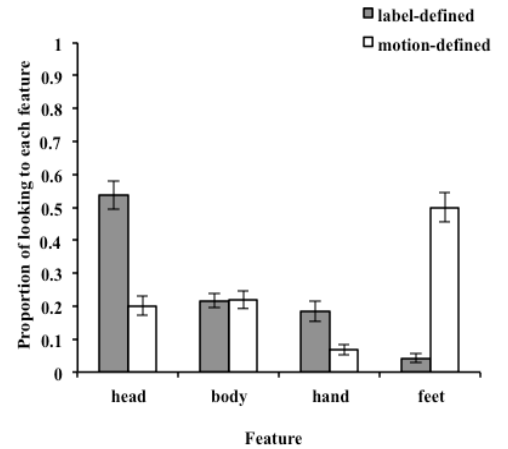Figure. 4. Infants' novelty preference score averaged across four blocks at test.

Figure 5. Infants' proportion of accumulated looking time to each feature averaged across 4 blocks at familiarization.
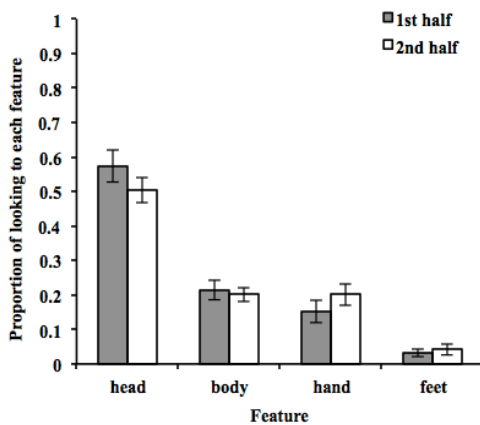

Figure 6. Infants' proportion of looking time to each feature in 1st and 2nd half familiarization trial in label-defined condition.
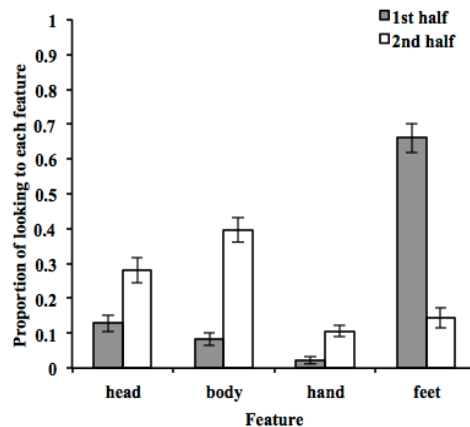

Figure 7. Infants' proportion of looking time to each feature in 1st and 2nd half familiarization trial in motion-defined condition.
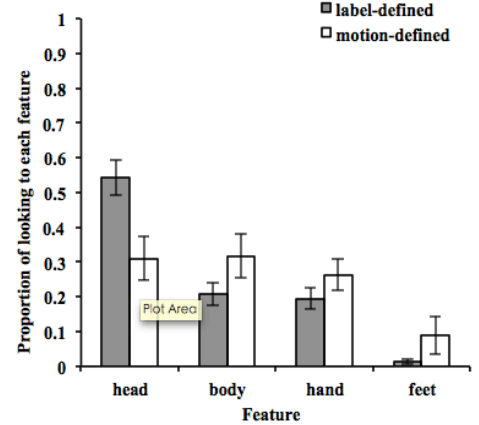

Figure 8. Infants' proportion of accumulated looking time to each feature averaged across 4 blocks at test.

longer to the novel category in motion-defined condition compared to the label-defined condition. However, neither the main effect of block ($p = .45$) nor the interaction between block and condition ($p = .34$) was found. Therefore, data were collapsed across blocks for each condition and the results are presented in Figure 4. As shown in Figure 4, infants looked significantly longer to the novel category in motion-defined condition than in label-defined condition, independent sample $t(28) = 3.71$, $p < .01$, $d = 1.44$. In addition, infants' novelty preference score was significantly higher than chance in motion-defined condition

one-sample $t(11) = 3.27$, $p < .01$, $d = 0.94$; whereas in label-defined condition, infants' looking to the novel category was not different from chance, $p = .19$.

Patterns of Attention

To determine if moving feet served as an engager and pushed infants' attention to other features, we compared the accumulated looking time to the stimuli on familiarization trials in two conditions. The gaze data (accumulated looking time) were submitted to a 4 (block: 1 vs. 2 vs. 3 vs. 4) by 2 (condition: label-defined vs. motion-defined) mixed

ANOVA, with block as a within-subjects factor and condition as a between-subjects factor. Results revealed a main effect of block, $F(3, 84) = 12.87$, $MSE = 0.00$, $p < .01$, $\eta_p^2 = 0.315$, with infants' accumulated looking time decreasing through blocks. However, infants' accumulated looking time did not differ between label-defined and motion-defined conditions, $p = .44$.

Because the comparable accumulated looking during familiarization trials resulted in different outcomes of category learning in two conditions, we deemed it necessary to examine how attention was distributed among different features of the stimuli at both familiarization and test. The proportion of looking time to different features on both familiarization (averaged across five trials within each block) and test trials (averaged across old and new prototypes) were calculated and the data were submitted to two separate 4 (feature: head[1] vs. body vs. hands vs. feet) by 4 (block: 1 vs. 2 vs. 3 vs. 4) by 2 (condition: label-defined vs. motion-defined) mixed ANOVAs, with feature and block as within-subjects factors and condition as a between-subjects factor. For familiarization trials, because there was no main effect of block ($p = .16$), these data were collapsed across four blocks. As shown in Figure 5, there was an interaction between feature and condition, $F(3, 84) = 44.74$, $MSE = 0.80$, $p < .01$, $\eta_p^2 = 0.615$. Infants' accumulated more looking to the head in label-defined condition compared to motion-defined condition, independent sample $t(27.7) = 6.46$, $p < .01$, $d = 2.25$; whereas they looked significantly longer at the feet, independent sample $t(13.4) = 9.9$, $p < .01$, $d = 4.45$, and the hands, independent sample $t(25.2) = 3.40$, $p < .01$, $d = 1.14$, in motion-defined condition than in label-defined condition. Infants accumulated comparable looking to body in both conditions, $p = .91$. Since the label and the moving feet were not presented for the entire 8-second trial in training, we further examined infants' pattern of attention by comparing their accumulated looking to each feature in the first half of the trial to that in the second half of the trial. Data were submitted to two 4 (feature: head vs. body vs. hands vs. feet) by 2 (time course: 1st half vs. 2nd half) repeated measures ANOVAs for the label-defined and motion-defined conditions respectively. As shown in Figure 6, in the label-defined condition, there was a main effect of feature, $F(3, 51) = 43.25$, $MSE = 1.63$, $p < .01$, $\eta_p^2 = 0.718$, and an interaction between feature and time course, $F(3, 51) = 5.74$, $MSE = 0.02$, $p < .01$, $\eta_p^2 = 0.253$. Infants looked significantly longer at the head in both of the 1st and 2nd half of the familiarization trial, Bonferroni $ps < .01$, but shorter at the feet, $ps < .05$. In the motion-defined condition, as shown in Figure 7, there was a main effect of feature, $F(3, 33) = 42.63$, $MSE = 0.46$, $p < .01$, $\eta_p^2 = 0.795$, and an interaction between feature and time course, $F(3, 33) = 57.67$, $MSE = 0.79$, $p < .01$, $\eta_p^2 = 0.840$. In contrast to infants who biased to the head in the label-defined condition, infants' looking was more widely distributed in the motion-defined condition: they looked longer at the moving feet during the first 4-second familiarization trial,

Bonferroni $ps < .01$, but they looked longer at the body and head during the latter half of familiarization trial (looking time: body > head > feet > hand; only for the last pair, Bonferroni $p < .01$).

Similar analyses were conducted to examine the patterns of attention on test trials (recall that neither labels nor motion was presented during these trials). Since there was no main effect of block ($p = .42$), the data were collapsed across blocks and results are presented in Figure 8. Similar to familiarization, there was an interaction between feature and condition, $F(3, 84) = 4.94$, $MSE = 0.18$, $p < .01$, $\eta_p^2 = 0.150$. Infants looked longer at the head in label-defined condition compared to motion-defined condition, independent sample $t(28) = 2.87$, $p < .01$, $d = 1.11$. However, there was little evidence that infants in motion-defined condition just focused on feet to categorize; their looking instead was more widely distributed across the features, $ps > .24$.

Discussion

In the study reported here, we investigated the role of labels in infants' categorization by comparing effects of labels with those of highly salient visual features. By using a combination of eye tracking and a more traditional novelty preference paradigm, we examined the patterns of attention and the outcome of category learning.

The current study reveals several important findings. First, infants exhibited better category learning when they saw a salient visual feature (i.e., moving feet) compared to when they heard a label. Second, although infants accumulated comparable looking during learning in motion-defined condition compared label-defined condition, their attention was more distributed among different features when there was a salient visual feature whereas they spent most of their time looking at the head when they heard a label. Third, there was little evidence of labels facilitating category learning in infants.

Many studies have examined the role of labels in infants' categorization and there is little agreement on the role of labels being category markers or features. However, none of the studies examining the effects of labels on categorization in infancy demonstrated that these effects are greater than those of highly salient features. By comparing the outcome of category learning and examining the patterns of attention in label-defined and motion-defined conditions, the current study has provided new evidence as to how labels may affect category learning in infancy. The results indicate that a pattern of motion has a greater facilitative effect on category learning than the label.

The current study raises an interesting question about the role of labels in infants' categorization by comparing the effects of label to those of a salient feature and the results suggest the labels may start out as features rather than category markers. Future research will examine whether labels merely fail to facilitate category learning or they actually hinder infants' category learning in infancy.

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[1] Antenna are combined with head as one level of feature.

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