Categorization in 3- and 4-Month-Old Infants: An Advantage of Words Over Tones

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Neonates prefer human speech to other nonlinguistic auditory stimuli. However, it remains an open question whether there are any conceptual consequences of words on object categorization in infants younger than 6 months. The current study examined the influence of words and tones on object categorization in forty-six 3- to 4-month-old infants. Infants were familiarized to different exemplars of a category accompanied by either a labeling phrase or a tone sequence. In test, infants viewed novel category and new within-category exemplars. Infants who heard labeling phrases provided evidence of categorization at test while infants who heard tone sequences did not, suggesting that infants as young as 3 months of age treat words and tones differently vis-à-vis object categorization.

Questions concerning the relation between linguistic and conceptual organization hold a central position in the cognitive sciences. Most of the research investigating the dawning of this relation has focused on early word learning and has documented that by roughly children's first birthdays, words support the formation of object categories (e.g., Balaban & Waxman, 1997; Fulkerson & Haaf, 2003; Namy, 2001; Waxman & Booth, 2003; Waxman & Braun, 2005; Woodward & Hoyne, 1999). More recent work has identified a link between words and object categories in infants as young as 6 months (Fulkerson & Waxman, 2007). Our goal was to consider this phenomenon in infants at 3 and 4 months.

Background

Waxman and Markow (1995) showed that for infants as young as 12 months of age, providing the same name for a set of distinct objects (e.g., four different animals) highlights commonalities among them and supports the formation of an object category (e.g., animal). For half of the infants in their task, the objects (e.g., the four animals) were introduced in conjunction with a novel noun (e.g., "See the *fauna*?"); for others, the very same objects were introduced with a general orienting phrase containing no novel word (e.g., "See here?"). At test, infants viewed two objects: a new member of the now-familiar object category (e.g., another animal) and a member of a novel object category (e.g., a vehicle), and heard, "See what I have?" Infants in the word condition showed a reliable preference for the novel object (e.g., a vehicle); those in the no word control condition revealed no preference. These outcomes document an early link between words and object categories in infants just beginning to build a lexicon.

Additional evidence documents the specificity of this phenomenon within the 1st year of life. At 13–14 months, infants distinguish between *kinds* of novel words, mapping novel words presented as nouns (but not adjectives) specifically to object categories (Booth & Waxman, 2009; Waxman & Booth, 2001). But younger infants' expectations about words are less precise. At 11 months, they do not distinguish between kinds of words (nouns and adjectives) in categorization tasks (Waxman & Booth, 2003). Nonetheless, their expectations are not so general as to include novel words under any circumstance: If the *same* novel word is applied to a set of distinct objects, 12-month-olds successfully

form an object category, but if a *different* word is applied to each, they do not (Waxman & Braun, 2005). This indicates that by 12 months, infants successfully cull novel words from the ongoing speech stream, detect whether the same or different words have been applied to a set of objects, and expect that objects named by the same word (but not those named by different words) are members of a shared category.

Importantly, although other kinds of auditory stimuli, including tones and melodic sequences, are engaging to infants, these stimuli do not promote object categorization even when they are consistently applied. Fulkerson and Waxman (2007) compared the influence of novel words and tone sequences on object categorization in infants at 6 and 12 months. Infants viewed pictures of exemplars from the same category (e.g., dinosaurs), presented sequentially. Infants in the word condition heard a naming phrase as they viewed each picture (e.g., ''Look at the toma! Do you see the toma?''); those in the tone condition heard a sequence of pure tones, matched precisely to the word condition for timing, duration, and volume. At test, all infants viewed pictures of a new exemplar from the familiar object category (e.g., a new dinosaur) and an exemplar from a novel category (e.g., a fish), presented side by side. Infants in the word condition revealed a reliable preference for the member of the novel category, indicating that they successfully formed the object category. Infants in the tone condition failed to reveal reliable preferences, suggesting that they had not formed an object category. Thus, by 6 months of age, words facilitate object categorization in a way that well-matched tone sequences do not.

It is important to point out that the claim is not that object categorization depends entirely on the presentation of words. Clearly, there are many circumstances in which humans, and even nonhuman animals, categorize successfully even in the absence of a novel word (e.g., Hespos & Spelke, 2004; Mareschal & Quinn, 2001; Plunkett, Hu, & Cohen, 2008; Quinn, 2002; Santos, Sulkowski, Spaepen, & Hauser, 2002). The claim is more measured and more precise: Even before infants produce words on their own, naming a set of objects with a consistently applied word promotes the formation of object categories, highlighting commonalities among objects in a way that other well-matched auditory stimuli (e.g., tone sequences) do not (Brown, 1957; Waxman & Markow, 1995). Interpreted in this light, the claim is that words support the ubiquitous process of categorization and are

especially effective in highlighting commonalities among objects that may otherwise have gone undetected (Fulkerson & Waxman, 2007; Gelman & Kalish, 2006; Plunkett et al., 2008; Waxman & Markow, 1995).

In the current study, we sought to examine the precursors to this phenomenon in infants at 3 and 4 months of age. We focused our efforts here because although 3- and 4-month-old infants share with older infants an interest in human speech, it is not until roughly 6 months of age that they begin to parse individual words (especially their own names) from the stream of fluent speech (Bortfeld, Morgan, Golinkoff, & Rathbun, 2005; Jusczyk & Aslin, 1995). Apparently, then, infants' treatment of words may differ importantly from 3 to 6 months. Although infants prefer human speech to many types of nonlinguistic auditory stimuli even at birth (Ramus, Hauser, Miller, Morris, & Mehler, 2000; Vouloumanos & Werker, 2007), whether this early preference has any consequences on categorization behaviors in infants younger than 6 months remains very much an open question.

Our goal was to examine object categorization under two different auditory conditions, one involving human speech (the word condition) and the other serving as a nonlanguage control (the tone condition). This design permitted us to discover whether words and tones exert the same influence on infants' categorization, or whether words enjoy a privileged status vis-à-vis categorization as early as 3 or 4 months of age.

Method

Participants

Participants included 46 healthy, full-term infants divided into two age groups. There were twenty-four 4-month-olds (9 males, 15 females) with an average age of 4 months 5 days (range = 3 months 23 days to 4 months 21 days) and twenty-two 3-month-olds (13 males, 9 females) with an average age of 3 months 7 days (range = 2 months 19 days to 3 months 21 days). Half of the infants within each age group were randomly assigned to the word condition and the others to the tone condition. All infants in the language condition were from families where English was the predominant language spoken in the home. An additional 13 infants were tested but excluded due to parental or sibling interference (2), fussiness (10), or falling asleep during the study (1). An additional 17 infants, who looked at the stage for less than half of

the familiarization period, were included in separate analyses (5 were 3-month-old infants and 12 were 4-month-old infants). Other studies have shown that the amount of exposure infants receive during the familiarization period can affect whether infants will show a novelty or a familiarity preference during test trials (e.g., Theissen, Hill, & Saffron, 2005). We suspected that the low exposure to the familiarization stimuli may have impacted their ability to form a category and separate post hoc analyses were conducted to examine that possibility.

Participant families were recruited from a commercial mailing list from the surrounding area and contacted by mail and telephone. They were given a t-shirt or a book as a gift but were not otherwise compensated for their participation. The participants were predominantly from White, middle-class families. The ethnicity of the sample was 80% non-Hispanic. The racial make-up was 75% White, 5% Asian, 3% Black/African American, 9% multiracial, and 8% chose not to answer.

Stimuli

The stimuli were identical to the stimuli used in Fulkerson and Waxman (2007).

Visual stimuli. Twenty slides of line-drawn dinosaurs and fish were produced to form two familiarization sets of eight stimuli each and two sets of two test stimuli each (see Figure 1). Stimuli were outlined in black and filled in with a solid color. Within each familiarization set, stimuli varied in color; within each test set, stimuli were matched in color.

Auditory stimuli. Two sets of naming phrases (''Look at the *toma/modi*. Do you see the *toma/modi*?'') were spoken by a female in the infant-directed speech register and recorded for presentation. Two sequences of pure tones (400 and 800 Hz), matched to the naming phrases in duration (2.2 s), pause length, and volume (82 dB) were created.

Apparatus

Infants sat on a parent's lap in a small room in front of a wooden puppet stage measuring 243.5 cm high, 128 cm wide, and 61 cm deep. The infants faced an opening in the front of the stage (93 cm above the floor, 61 cm high, and 106 cm wide). Visual stimuli were projected onto a white screen via a slide projector from behind the stage. A white projection screen was on the stage behind

a sheet of black foam core. There were two 18 × 18 cm windows cut into the cardboard. There was 11 cm of separation between the two windows, which were centered approximately 75 cm from the infants' eye level. Auditory stimuli were presented through a central speaker hidden 56 cm below of the screen. Infants were videotaped through a 3-cm hole in the stage located 12 cm below the projection screens.

Procedure

The novelty-preference task included a familiarization phase and a test phase (see Figure 1). All infants saw the same visual stimuli materials (either dinosaurs or fish). What differed was the accompanying audio: Infants were randomly assigned to either the word or the tone condition. Parents were instructed not to influence their infant's attention in any way and to close their eyes during test trials.

Familiarization phase. Infants were presented with a sequence of eight different exemplars from a single category (either dinosaurs or fish). The category used was counterbalanced across both word and tone conditions. In the word condition, infants heard a naming phrase as they viewed the stimuli; in the tone condition, infants heard a sequence of pure tones. In both conditions, the auditory stimulus was introduced once at the onset of the visual stimulus and again 10 s after the onset of the visual stimulus. The trials were a fixed duration of 20 s, and the order of presentation was randomized across participants. The position of the image alternated sides from trial to trial. The following factors were counterbalanced across participants: left/right position of the first image, use of toma/modi or 400/800 Hz, and familiarization to a picture of a dinosaur or a fish.

Test phase. All infants saw the same two test stimuli: a new exemplar from the familiar category and an exemplar from a novel category. These were presented side by side in silence. The test phase began with the infants' first visual fixation to one of the stimuli and lasted until the infant had accumulated 10 s of looking to the test stimuli. The left–right positioning of the test stimuli was counterbalanced across infants.

Coding. Trained observers, blind to the condition assignment, coded infants' visual fixations online. Later, off-line frame-by-frame coding to determine left and right looks was conducted using ELAN (2007). Thirty-three percent of infants in each age and condition were recoded by an
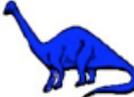
Trial	Word	Tone	Left Screen	Right Screen
Familiarization 1	Look at the Toma! Do you see the Toma?	----- -- --- ----- -- --- --- ----		
Familiarization 2	Look at the Toma! Do you see the Toma?	----- -- --- ----- -- --- --- ----		
Familiarization 3	Look at the Toma! Do you see the Toma?	----- -- --- ----- -- --- --- ----		
Familiarization 4	Look at the Toma! Do you see the Toma?	----- -- --- ----- -- --- --- ----		
Familiarization 5	Look at the Toma! Do you see the Toma?	----- -- --- ----- -- --- --- ----		
Familiarization 6	Look at the Toma! Do you see the Toma?	----- -- --- ----- -- --- --- ----		
Familiarization 7	Look at the Toma! Do you see the Toma?	----- -- --- ----- -- --- --- ----		
Familiarization 8	Look at the Toma! Do you see the Toma?	----- -- --- ----- -- --- --- ----		
Test				

Figure 1. A representation of the procedure and stimuli for both the word and tone conditions.
Note. In familiarization trials, infants saw eight different line drawings of dinosaurs (or fish). Each dinosaur was accompanied by either a voice saying ''Look at the *toma*! Do you see the *toma*?'' (word condition) or a series of pure tones (tone condition). During test trials, infants saw a dinosaur and a fish and coders measured how long each infant looked at each image.

independent observer. Reliability between observers was 91% during familiarization and 90% during test.

To measure categorization, a preference score was calculated for each infant by dividing their looking time to the novel-category exemplar at test by their total looking time (10 s). Chance performance was .50. Six 3-month-olds (three in each condition) looked exclusively to one test stimulus. Because we were uncertain whether these infants noticed the other test stimulus, we presented a second test trial and used their performance on this trial to calculate a preference score. We obtain the same results (see below) whether we include these

preference scores for these infants or exclude their data entirely.

Preliminary analyses revealed no significant effect of sex, the specific word or tone used during visual stimuli, or left or right position of the test stimuli; the data were therefore collapsed across these variables in subsequent analyses.

Results

The results, depicted in Figure 2, reveal that words and tones have distinct effects on object categorization. Importantly, infants hearing words and tones accumulated comparable looking durations during familiarization, yet only those hearing words revealed evidence of categorization at test.

An analysis of performance during familiarization revealed no differences in infants' looking times in the word condition ($M = 114.51$, $SD = 20.85$) and tone condition ($M = 118.28$, $SD = 22.28$). A univariate analysis of variance (ANOVA) with total looking time during familiarization as a dependent variable and age (3 or 4 months) and conditions (word or tone) as between-subject variables confirmed that there were no significant main effects, $Fs(1, 42) < 1$, or interaction, $F(1, 42) = 2.94$, $p = .09$. This suggests that the words and tone sequences presented in this experiment were equally engaging to our young participants. Impor-

Figure 2. Box plots for mean looking times during test trials for each condition. (a) Preference score for 3-month-olds in the word and tone conditions. (b) Preference score for the 4-month-olds in the word and tone conditions.
Note. Preference score is the looking time to the novel-category exemplar divided by the total looking time. The diamonds represent the mean, the central line in the box is the median, and the upper and lower portions of the box represent the first and third quartiles on either side of the mean. The dotted line represents a chance score.

tantly however, differences between these conditions did emerge at test.

An Age (3 or 4 months) × Condition (word or tone) ANOVA using infants' preference scores at test as a dependent variable revealed no main effects, but it did reveal a significant Age × Condition interaction, $F(1, 42) = 6.08$, $p = .018$, $\eta^2 = .126$. Further analyses revealed that 3- and 4-month-old infants performed comparably in the tone condition, $F(1, 22) = 0.08$, $p = .78$; at neither age did performance with tones differ from the chance level: 3-month-olds ($M = 0.56$, $SD = 0.24$), $t(11) = .84$, $p = .42$, and 4-month-olds ($M = 0.53$, $SD = 0.22$), $t(11) = .50$, $p = .63$. In contrast, infants' performance in the word condition varied reliably as a function of age, $F(1, 20) = 12.40$, $p = .002$, $\eta^2 = .38$: Three-month-olds showed a reliable preference for the familiar test object ($M = 0.36$, $SD = 0.14$), $t(9) = -3.14$, $p = .01$, and 4-month-olds showed a reliable preference for the novel ($M = 0.64$, $SD = 0.22$), $t(11) = 2.27$, $p = .04$.

An examination of individual infants' performance echoed this pattern of results. We tabulated the number of infants at each age and in each condition demonstrating either a novelty or a familiarity preference and compared these to the number expected by the binomial distribution. In the word condition, nine of the ten 3-month-old infants showed a familiarity preference, and ten of the twelve 4-month-old infants showed a novelty preference (both p values < .05). In the tone condition, five of the twelve 3-month-old infants showed a familiarity preference, and seven of the twelve 4-month-old infants (both p values > .7) showed a novelty preference.

These results reveal that by 3–4 months of age, presenting infants with words influences object categorization in a way that presenting them with tones does not. Moreover, this influence is expressed as a familiarity preference at 3 months but as a novelty preference at 4 months. To better understand this shift from familiarity to novelty preferences, we examined the correlation between performance in this task and age (in days). For infants in the word condition, there was a strong positive correlation between age and performance, $r(22) = .61$, $p = .003$ (see Figure 3). For those in the tone condition, there was no corresponding correlation, $r(24) = -.18$, $p = .41$.

This developmental shift from familiarity to novelty preference, although unanticipated in the context of the current experiment, is not unprecedented in the infant categorization literature. Both novelty and familiarity preferences are indices of categorization. Roder, Bushnell, and Sasseville
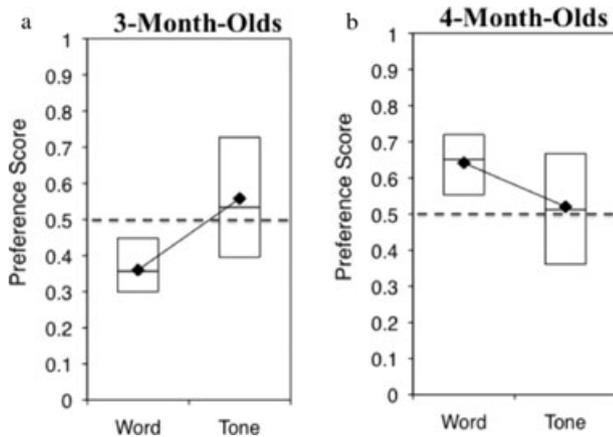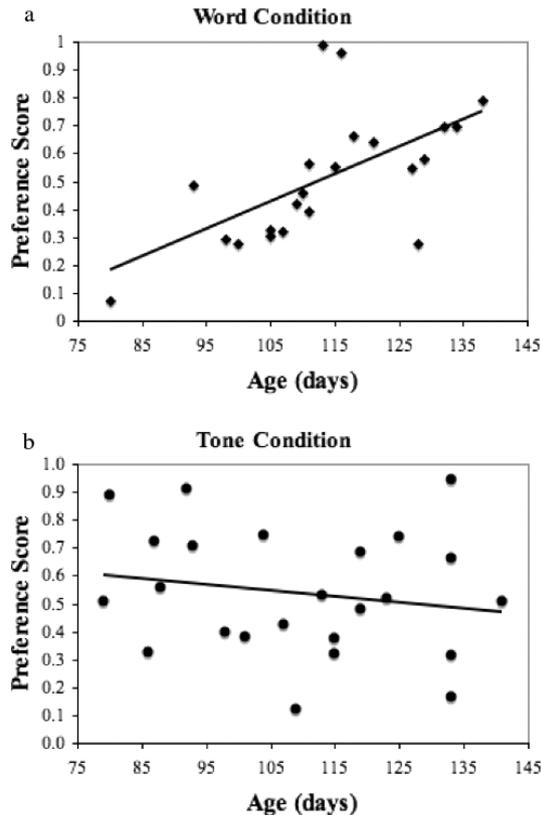
Figure 3. Scatter plot depicting the correlation between each infant's age (in days) and their preference scores. (a) Word condition. (b) Tone condition.
Note. The lines represent the best fit of the correlation between age and preference score within each condition.

(2000) found that this shift in preference was due to the amount of exposure infants had accumulated; infants first demonstrated a reliable familiarity preference prior to expressing a novelty preference. Interpreted in this light, the current results suggest that for 3-month-olds in the word condition, the process of categorization is indeed underway (after all, their performance differed significantly from chance) but that they may require more exposure before they shift from a familiarity to a novelty preference (Roder et al., 2000; Rose, Gottfried, Melloy-Carminar, & Bridger, 1982; Wagner & Sakovits, 1986). If this interpretation is correct, then perhaps 4-month-olds in the word condition who happen to accrue little looking time during familiarization materials should reveal a familiarity preference as well.

To test this possibility, we conducted a post hoc analysis on the twelve 4-month-old infants (five in the word condition, seven in the tone condition) who had been eliminated from the previous analyses because they accrued too little exposure to the familiarization images (recall that for the previous analyses, we excluded infants who looked for less than 50% of the familiarization trials). Performance in the tone condition was unaffected by exposure. These tone condition infants, like those in the main analyses, did not differ significantly from chance, ($M = 0.42$, $SD = 0.22$), $t(6) = -.99$, $p = .36$. In contrast, 4-month-olds in the word condition showed a significant familiarity preference ($M = 0.35$, $SD = 0.07$), $t(4) = -3.72$, $p = .008$. This is consistent with our interpretation of the shift from a familiarity to a novelty preference at 3 and 4 months, respectively: For the stimuli presented here, infants' expression of a familiarity versus novelty preference at test is related to their exposure during familiarization.

Discussion

The results demonstrate that words influence object categorization at 3 and 4 months, and do so in a way that is distinct from the influence of carefully matched tones. This study makes two primary contributions. First, it offers the earliest evidence to date for a link between words and object categories. While previous studies have demonstrated this link in infants as young as 6 months (Fulkerson & Waxman, 2007), the current findings offer insight into the origins of this ability in 3- and 4-month-old infants. Second, these results indicate that even at this early developmental moment, words exert an influence on object categorization that is distinct from that of tones (Balaban & Waxman, 1997; Fulkerson & Haaf, 2003; Fulkerson & Waxman, 2007; Waxman & Booth, 2003; Waxman & Braun, 2005; Waxman & Markow, 1995; Woodward & Hoyne, 1999; Xu, 1999, 2002).

This finding, intriguing in and of itself, also calls into question the claim that the facilitative effect of words can be accounted for entirely by appealing to matters of paired associations. In the current experiment, the tones as well as the words were correlated perfectly with the visually presented objects. If the categorization effect could be attributed to nothing more than an association between auditory and visual stimuli (e.g., Robinson & Sloutsky, 2007), then infants should have performed comparably, whether they heard words or tones. The fact that they did not serves as evidence that words exert an influence that cannot be accounted for entirely by association, even in infants as young as 3 months of age.

The current results also make important contact with evidence of infants' categorization behaviors.

The classic behavioral index of category formation in infants rests on their treatment of novel versus familiar test stimuli. Previous evidence concerning the link between words and object categorization in infants at 6, 9, and 12 months of age has consistently revealed a preference for the novel test stimuli (Balaban & Waxman, 1997; Fulkerson & Waxman, 2007). In the experiment reported here, 4-month-olds display this novelty preference, but 3-month-olds reveal a familiarity preference. As we have pointed out, familiarity and novelty preferences are both indices of object categorization (Aslin, 2007; Roder et al., 2000). For example, Roder et al. (2000) demonstrated that infants tend to exhibit a familiarity preference early in processing followed by a novelty preference in subsequent trials. The mechanism underlying the expression of novelty versus familiarity preferences is not well understood, but several hypotheses have been advanced. For example, some have argued that familiarity preferences are the result of incomplete encoding (Hunter & Ames, 1988; Roder et al., 2000; Rose et al., 1982; Wagner & Sakovits, 1986) or that subcomponents of fully encoded stimuli can trigger recognition responses for familiarity that are stronger than attention response to novelty (Kaplan & Werner, 1987). Others have suggested that factors including maturity, processing speed, and encoding efficiency are involved (Colombo, 2002; Johnson, Slemmer, & Amso, 2004). The absence of an independent assessment for these confounded cognitive processes makes it impossible to predict familiarity or novelty effects, although the consensus among infancy researchers is that both effects are behavioral indices of category formation. Future studies may pursue this issue by systematically varying exposure to the words, the visual stimuli, or to both over the course of familiarization.

The current findings also raise questions about the range of auditory stimuli that promote categorization at 3 and 4 months of age. We have documented that novel words (presented as nouns) promote categorization in a way that tones do not. In future work, it will be important to identify which auditory features, present in the word condition but absent in the tone condition, might underlie this effect. It will also be important to ascertain which other complex sounds (e.g., backward speech, filtered speech) also promote categorization in young infants and whether this facilitative effect is specific to human vocalizations.

It will also be important to understand better the mechanism underlying the facilitative effect of words on categorization at 3 and 4 months. As we

have pointed out, it is unlikely that infants in the current experiment parsed the novel words from the labeling phrases in which they were embedded; it is also unlikely that they somehow understood the meaning of the words and phrases we presented. Why, then, did words promote categorization over and above the effect of tone sequences? We speculate that in the context of hearing human speech, very young infants become engaged in attentional and behavioral processes that they might otherwise not engage in. An analogy may illustrate this point. Recent research has documented a dramatic influence of vocalizations on the behavior of Nile crocodile hatchlings and mothers. Under naturalistic conditions, the vocalizations made by hatchlings just before they hatch can be heard by mothers and by hatchlings in neighboring eggs in the nest. In an ingenious experiment, Vergne and Mathevon (2008) presented hatchlings and mothers with recordings of the vocalizations emitted by other hatchlings just before they had hatched. These recordings had very specific behavioral effects; they motivated hatchlings to tap on their shells and mothers to open their nests. Obviously, it is unlikely that these vocalizations exerted their effects because of the ''meaning'' they conveyed to mothers and other hatchlings. Instead, exposure to these vocalizations appears to have engendered a series of behaviors that happen to promote hatching and nesting. How does this analogy bear on infants' performance in the current experiment? We suspect that human speech, and perhaps especially infant-directed speech, engenders in young infants a kind of attention to the surrounding objects that promotes categorization. We proposed that over time, this general attentional effect will become more refined, as infants begin to cull individual words from fluent speech, to distinguish among individual words and kinds of words, and to map those words to meaning. A goal for future research will be to identify the processes underlying this developmental trajectory.

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