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A Study of Multimodal Motherese: The Role of Temporal Synchrony between Verbal Labels and Gestures

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This study examined European American and Hispanic American mothers' multimodal communication to their infants ($N = 24$). The infants were from three age groups representing three levels of lexical-mapping development: prelexical (5 to 8 months), early-lexical (9 to 17 months), and advanced-lexical (21 to 30 months). Mothers taught their infants four target (novel) words by using distinct objects during a semistructured play episode. Recent research suggests that young infants rely on temporal synchrony to learn syllable–object relations, but later, the role of synchrony diminishes. Thus, mothers' target and nontarget naming were coded for synchrony and other communication styles. The results indicated that mothers used target words more often than nontarget words in synchrony with object motion and sometimes touch. Thus, "multimodal motherese" likely highlights target word-referent relations for infants. Further, mothers tailored their communication to infants' level of lexical-mapping development. Mothers of prelexical infants used target words in synchrony with object motion more often than mothers of early- and advanced-lexical infants. Mothers' decreasing use of synchrony across age parallels infants' decreasing reliance on synchrony, suggesting a dynamical and reciprocal environment–organismic relation.

INTRODUCTION

Like most events, communication is multisensory: It involves visual information such as facial motions, expressions and gestures, and tactile information such as touch as well as the auditory information contained in the speech stream (Jouanjean-L'Antoune, 1997; see Meltzoff & Kuhl, 1994, for a review). During communication, some of this multimodal information is coordinated and redundant across the senses; often the same information is seen and heard. For example, audible and visible speech are temporally synchronous and share a common rhythm, tempo, and intensity pattern. Visible gestures appear to be coordinated with audible speech (words) in a similar manner. In the present study, maternal multimodal communication to infants was investigated to see if it is coordinated and redundant across the senses.

Several studies have shown that young infants easily perceive redundant information in audible and visible speech. For example, 4-month-old infants showed a visual preference for bimodally presented vowels when redundancy between the mouth shape and the vowel sound was present (Kuhl & Meltzoff, 1988). Five-month-olds preferred intensity shifts that were redundant across modalities, such as a gradually opening mouth corresponding with a steady increase in the amplitude of a speech sound (Mackain, Studdert-Kennedy, Spieker, & Stern, 1983). Furthermore, 5-month-olds detected changes in language membership (English and Spanish) following bimodal habituation to a video film of a person reciting a passage in one of two languages when redundant information was present (synchronous face and voice) but not when the auditory information was removed (Bahrick & Pickens, 1988). Finally, infants of 3 to 4 months imitated mouth movements only when the visual and auditory components of a vowel were temporally coordinated (Legerstee, 1990). These findings suggest that redundant information such as temporal synchrony (the coincidence between visually given motions and vocalizations), intensity shifts, rhythm, and tempo common to auditory and visual speech is perceived across the senses during ongoing communication and recruits infants' attention. However, the redundancy between words and gesture has received little empirical investigation. Infants may also use this redundancy to learn the basics of communication such as the connection between facial and vocal expressions or words and referents.

Redundant information is present not only in bimodal communication but also in bimodal nonspeech events. Redundancy recruits infants' attention and facilitates the detection of intersensory relations (Bahrick & Pickens, 1994; Gibson, 1991). For example, 5-month-old infants detected a change in the rhythm of a hammer striking a surface when it was presented bimodally with auditory-visual synchrony. They failed to detect the rhythm change when it was presented unimodally (visually or acoustically), or bimodally

without synchrony (Bahrick & Lickliter, 2000). Thus, redundant information highlights the intersensory relations in bimodal events and enables perception of unified events across modalities.

In addition to redundant information, bimodal communication contains information that bears an arbitrary relation across the senses, such as a spoken word and a visible object or action. Lexical meaning is universally conveyed in the arbitrary but conventional relations between spoken words and referents. Research suggests that redundant information, such as synchrony, facilitates the detection of arbitrary syllable–object relations or mapping of syllables onto objects by preverbal infants (Gogate, 1999; Gogate & Bahrick, 1998, in press). In two recent studies, 7-month-old infants were found to require temporal synchrony between vocalic syllables (/a/ and /i/) and the motions of objects to learn and remember the arbitrary syllable–object relations. Infants did not learn or remember the arbitrary relations between the syllables and objects in the absence of temporal synchrony (Gogate & Bahrick, 1998, in press). In a further study, 8-month-old infants were found to require temporal synchrony to detect the arbitrary relations between two minimal pairs, /tah/ and /gah/, and objects (Gogate, 1999).

Further, recent experiments suggest that the conditions that foster learning of arbitrary syllable–object relations change with development as the child's ability to detect word–object relations improves. At first, prelexical infants require temporal synchrony between a vocalization and a moving object to detect the arbitrary relation between the vocalization and the referent (Gogate, 1999; Gogate & Bahrick, 1998, in press). Later, when infants are older and become more adept at learning word-referent relations on their own (early-lexical), they appear to rely less on temporal synchrony between a word and a referent but may still rely on object motion (14-month-olds; Werker, Cohen, Lloyd, Casasola, & Stager, 1998). Still later, older infants who are lexically advanced require neither temporal synchrony nor object motion to detect word–referent relations (15 and 24 months; Fernald, Pinto, Swingley, Weinberg, & McRoberts, 1998). Taken together, these findings suggest that infants' success in word–referent mapping shifts with development as infants become more perceptually and lexically competent.

With respect to maternal multimodal communication, several descriptive studies suggest that maternal communication to infants typically contains redundant information across the senses. For example, mothers name novel objects only in the presence of the objects for 10- to 21-month-olds (Masur, 1997). These episodes enable infants to attend to words that refer to objects and actions in the immediate context (Nelson, 1978; Snow, 1986). Further, Zukow (1991) concluded that Mexican and American mothers "educate" their infant's attention to word–referent relations by naming an object and simultaneously using gestures such as pointing or showing the object to the infant or touching the infant (Zukow, 1991). Consistent with these findings, Messer (1978) reported that 73%–95% of all maternal verbal references to toys were simultaneous with manipulations of the toys for 11- to 24-month-old infants. He concluded that mothers "synchronize" their verbal references and nonverbal gestures for infants during the first 2 years. On the basis of these observations and our research on infants' detection of syllable–object relations discussed earlier, we hypothesized that early communication to infants is multimodal and characterized by redundant information across the senses. We call this "multimodal motherese." The redundancy in multimodal motherese includes the temporal characteristics and intensity shifts common to the face and voice during speech, as well as the temporally synchronous auditory, visual, and tactile components such as naming, showing an object, and touching the infant concurrently.

Research also suggests that mothers adapt their verbal communication to infants in a manner that facilitates language learning. A number of studies have investigated the acoustic properties of infant-directed speech or unimodal "motherese." They show that when speaking to infants, adults use a greater degree of prosodic variation, a raised pitch, a slower tempo, and greater variation in intonation contours (Fernald & Simon, 1984; McRoberts & Best, 1997). Fernald (1992) has suggested that these exaggerated acoustic patterns, similar to rocking and nursing, have evolved to elicit and sustain infants' attention to speech as well as highlight the important parts of the speech stream. We expect that multimodal motherese serves a similar function. Further, the results of some observational studies are consistent with the view that mothers (and other adults) adapt their verbal and gestural communication in a manner that would facilitate lexical learning in infants. For example, when adults named objects and actions on which infants were focused, rather than those outside their focus, infants learned words rapidly (Akhtar, Dunham, & Dunham, 1991; Olsen-Fulero, 1982; Tamis-Lemonda & Bornstein, 1989). However, other studies have reported that mothers often name objects and actions outside infants' immediate attentional focus (Collis, 1977; Harris, Jones, & Grant, 1983). This finding is consistent with the view that mothers' communica-

tion is directed by and directs their infants' behavior and illustrates reciprocal adaptations in mother–infant communication (Studdert-Kennedy, 1991).

It has been proposed that adults integrate information across multiple modalities to facilitate word comprehension for preverbal infants (Bates, 1993; Sullivan & Horowitz, 1983; Zukow-Goldring, 1997). However, no studies to date have systematically investigated the nature of multimodal information that mothers and other caregivers might use to convey word–referent relations to infants. One possible reason for the lack of systematic investigation is that, until recently, maternal communication and lexical development have not been studied from an ecological viewpoint (Dent, 1990; Zukow-Goldring, 1997). According to the ecological view (E. J. Gibson, 1969; J. J. Gibson, 1979/1986), development should be studied within its natural context because the infant's language environment is designed to facilitate the detection of the link between linguistic events (words) and the world. Infants rely on their developing perceptual abilities to detect this link that mothers (caregivers) provide. In the current study, we asked how the linguistic environment might facilitate infants' learning of word–referent relations. Further, we hypothesized, in keeping with the dynamic systems view (Kelso, 1997; Lickliter, in press; Thelen & Smith, 1994), that infants learn word–referent relations as a result of a reciprocal relation between their intersensory perceptual abilities and maternal communication. Thus, given that infants require redundant information in multimodal communication and that their intersensory perceptual abilities vary with age, we asked whether multimodal maternal communication to infants contained redundant information and whether mothers used different kinds of information to highlight novel word–referent relations for infants of different ages.

The present study was designed with the primary goal of assessing and describing the nature of "multimodal motherese" and the changes that occur in maternal communication with infants' lexical development. Specifically, the development of lexical mapping was assumed to vary with infants' age. However, we did not employ a measure of lexical mapping in the present study. We compared maternal communication to infants of three ages, which typically represent different levels of lexical-mapping development: (1) prelexical infants (5–8 months), who may not yet detect novel word–referent relations on their own and do not produce words with a consistent meaning (Halliday, 1975); (2) early-lexical infants (9–17 months), who typically detect novel word–referent relations and are adding words to their vocabularies at a steady rate (Fenson et al., 1994; Waxman & Markow, 1995, p. 260); and (3) advanced-lexical infants (21–30 months), who typically detect novel word–referent relations on their own, as reflected in their vocabulary growth spurt (see Fenson et al., 1994).

Our first hypothesis was that if "multimodal motherese" is coordinated and functions to highlight word–referent relations for infants, then verbal labels and gestures should be temporally synchronous. That is, mothers should name referents in synchrony with the movements of objects. Our second hypothesis was that mothers' multimodal communication would shift with infants' age as the ability to detect word–referent relations changed. We had several more specific predictions. Because the youngest infants required temporal synchrony to learn the relations between objects and verbal labels (Gogate, 1999; Gogate & Bahrick, 1998), mothers were expected to use synchrony more often for young (5- to 8-month-old) infants to convey that a word and a referent belong together. Conversely, mothers were expected to use temporal synchrony less often for older (9- to 17- or 21- to 30-month-old) infants because they can detect word–referent relations on their own (see Balaban & Waxman, 1997; Fenson et al., 1994; Halliday, 1975). Mothers may name referents without the use of temporal synchrony or object motion more often once infants (21 to 30 months) become adept at detecting word–referent relations. Further, we predicted that if maternal communication were designed to facilitate learning of word–referent relations, then it would be temporally synchronous and tailored to infants' age to a greater extent when mothers explicitly taught infants our new target words rather than when they used other nontarget words.

METHOD

Participants

Twenty-four healthy, 5- to 30-month-old infants, 8 males and 16 females, and their mothers participated. Six additional dyads were excluded from the final sample because the infants became excessively fussy during the session ($N = 3$) or the mothers interchanged the target verbs and nouns during naming ($N = 3$). In the final sample, there were 8 infants from one of three age groups, 5 to 8 months, 9 to 17 months, and 21 to 30 months. These age groups represented three levels of lexical-mapping development: prelexical, early-lexical, and advanced-lexical, respectively. The mothers and infants resided in the southern suburbs of the Miami metropolitan area. Of these mothers, 12 spoke English to their infants, 11 spoke Spanish, and 1 spoke French. All mothers had at least 12 years of education.

Procedure

The mothers and infants were seen during a half-hour visit to the infant development laboratory. First, the experimenter introduced four labels, two nouns and two verbs, to the mother. They were *chi*, and *gow*, the names for two brightly colored puppets, and *pru* and *flo*, the names for two actions. *Pru* represented a leaping action, and *flo* a shaking action. The mothers were asked to teach each verb to their child by using a different object, *pru* with a stuffed toy bear wearing a white baseball suit with red stripes, and *flo* with a stuffed blue toy shark (Figure 1). The experimenter stood behind the infant, who was seated in a stroller, and demonstrated the actions to the mother without presenting synchrony between the actions and the words. Therefore, although infants may have heard the words, they did not see the objects until the mothers presented them during the session. Mothers were asked to teach the names for the objects and the actions by using any means that they normally used to communicate with their infants. Next, the infants were seated in an infant seat placed on a large table, and the mothers sat cross-legged on the table facing their infants and approximately 15 cm away. The older subjects (21- to 30-month-olds) sat on the table facing their mothers.

A camera (Panasonic, digital 5100) was positioned in front of the table so that the mother, the infant, and the camera formed three points of a right-angled triangle with the camera at the 90° base. Positioned to the infant's left and to the mother's right, the camera was focused on the mother and her infant as they played. A large mirror was placed in front of the camera on the far end of the table and against a wall to the right of the infant and to the left of the mother. The mirror captured most interactions between mothers and infants that were hidden from direct view of the

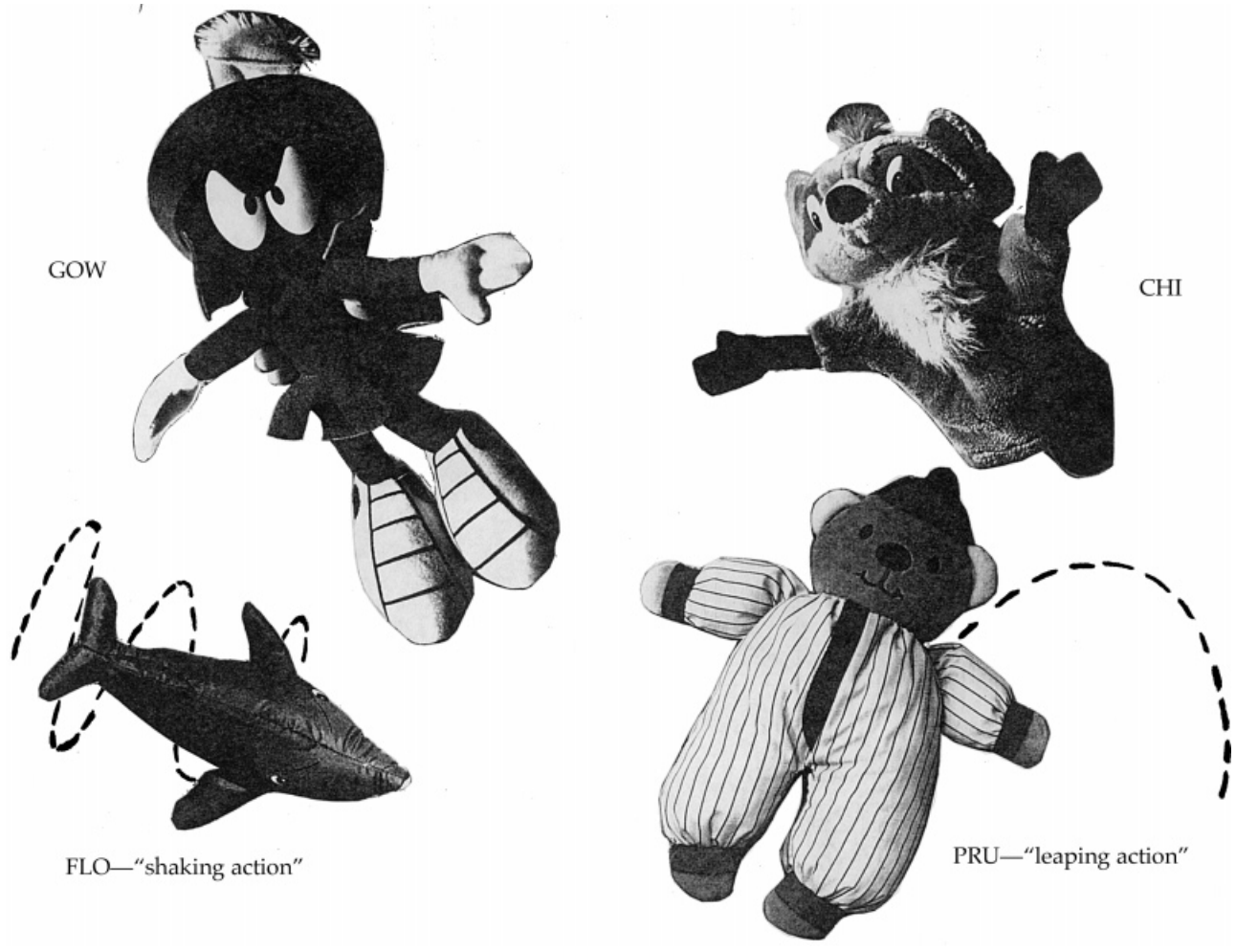

Figure 1 The objects and actions mothers named for their infants.

camera by either participant. For the first 5 min, mothers engaged their infants in free-play with a set of toys. These toys remained on the table during the remainder of the session. For the next 5 min, the mother taught the four target words to her infant during a semistructured play episode. The experimenter quietly entered the room once every 1 min and 15 s from behind the infant and placed each object one at a time on the large table within reach of the mother. This served as a cue for the mother to pick up each object and introduce the appropriate target word (noun or verb). The order in which mothers taught each target word was counterbalanced across the 24 dyads. Twelve infants, 4 from each age group, received the nouns first, and 12 infants, 4 from each age group, received the verbs first. Further, the order of the nouns (*chi* or *gow* first) and that of the verbs (*pru* or *flo* first) were counterbalanced across infants. The episodes were video recorded.

Coding and Scoring of the Data

The 5-min, semistructured play episodes were coded for occurrences of the target nouns and verbs and all other (nontarget) nouns and verbs that referred to concrete objects and actions that were demonstrated during the play episodes. The nontarget words were mainly references to the objects that the mothers used (e.g., *teddy* or *fishy*) to display the target actions and were references to the actions that the mothers performed using the target objects. For instance, if a mother said, "Look, the fishy is *floing*," the word *fishy* was included as a nontarget noun and was compared with mothers' use of the target nouns *chi* and *gow*. Similarly, if a mother said "Chi's clapping," then the word *clapping* was an instance of a nontarget verb. These instances of nontarget verb use were compared with mothers' use of the target verbs *pru* and *flo*. In addition, the nontarget words included references to other objects from the set of toys used during the initial free-play period that were still strewn across the table. The nontarget nouns most often used by the mothers were *bear*, *mama*, *fish*, *kiss*, *hands*, *doggie*, and *baby*. The nontarget verbs most often used by mothers were *give*, *take*, *see*, *look*, and *get*. No proper nouns other than instances where the mothers used the target names as proper nouns were included. The main reason for coding nontarget words was to compare multimodal properties of words and gestures when mothers specifically taught the names of objects or actions (target words) versus when no specific teaching took place (nontarget words).

A trained observer identified four types of maternal bimodal communication activities involving single words and accompanying gestures: (1) naming an object or action synchronous with object motion—moving synchronous, ms; (2) naming asynchronous with object motion—moving asynchronous, ma; (3) naming an object or action without object motion—static object, so; and (4) naming (an object or action) when the infant holds and manipulates an object—infant holds object, iho. (Note that our use of the term "temporal synchrony" differs from temporal contiguity, which has also been known to play a role in associative word learning. Temporal contiguity merely entails that a static object be present when a word is spoken. However, temporal synchrony entails object motion and a more precise alignment between an utterance and object motion; see the following discussion.) Bimodal communications were coded under the first type (ms) when mothers uttered a single word in temporal synchrony with a moving object. In 73% of the temporally synchronous occurrences, other types of intersensory redundancy were present between word and referent, such as shared rhythm and tempo (a match in the number and spacing of elements across words and object motions). These instances of intersensory redundancy were similar to the experimental stimuli of the Gogate (1999) and Gogate and Bahrick (1998) studies.

The temporal properties of the bimodally synchronous (1) and asynchronous (2) single-word occurrences were further analyzed so that we could better describe them. Randomly selected synchronous and asynchronous occurrences were measured for the temporal discrepancy between auditory and visual segments. The analysis of five synchronous and five asynchronous occurrences randomly selected from each of 9 participants showed a significant difference between these communication types. For the synchronous occurrences, all words occurred during an object's motion with only a small discrepancy between the onset of a word and object motion ($M = .06$ s, $SD = .09$) and between the offset of a word and object motion ($M = .09$ s, $SD = .12$). (Note that for young infants, the temporal alignment between sounds and motions need not be as precise as it must be for adults to judge them as synchronous; Lewkowicz, 1992.) For the asynchronous occurrences, the words typically preceded or followed an object's motion with a much greater discrepancy between a word and object motion ($M = .44$ s, $SD = .15$ for the onset, and $M = .51$ s, $SD = .14$ for the offset).

In addition to synchrony between single words and their referents (ms), mothers sometimes used an entire phrase or a clause that included a target or a nontarget word in temporal synchrony with an object's motion (gs). These instances of global syn-

chrony were analyzed separately from the four other types of bimodal communication because they did not specifically address the issue of mothers' communication of target versus nontarget words. Furthermore, because mothers rarely named static objects while pointing to them, these instances were merged with the static object category (so). In general, during naming, mothers sometimes used the target verbs *pru* and *flo* (with corresponding action referents) in the present progressive or present continuous, for example, "See how the bear is pru-ing" or "See how the bear pru-s." In part because mothers were given the objects and action referents to name, only two instances of target words were unimodal (in the absence of referents). During these instances, one mother hid the object behind her and showing her empty hands asked her infant "Where is *chi*?" These two instances were excluded from the analysis of multimodal communication types.

A trained observer identified and coded all target and nontarget word tokens for each dyad into the five bimodal communication types. A second trained observer identified and coded a portion of these data into the same five types, independent of the first observer. A small number of target word tokens (72 out of 2,013, $M = .035$, $SD = .035$) and nontarget word tokens (154 out of 2,279, $M = .06$, $SD = .06$) were not coded because mothers named the objects or actions out of the camera's view.

For each dyad, the total number of occurrences of each bimodal communication type (ms, ma, so, iho, and gs) and their mean frequencies were calculated across nouns and verbs. The proportions of total target-word tokens (PTTW) were derived by dividing the number of target-word tokens for each bimodal communication type by the total number of target-word tokens summed across all types (ms, ma, so, iho, gs, and uncoded occurrences). Because some mothers spoke more than others, the proportions gave each dyad equal weight. Interobserver reliability was obtained by comparing the PTTWs of the first observer for the five bimodal communication types to the PTTWs of the second observer. The match between the two observers' PTTWs, classified into the five types, averaged across 9 mothers' communications (38%, 3 dyads randomly selected from each age group) was .84 ($SD = .12$). The mean Pearson product moment correlation coefficient (r) between the two observers' PTTWs across 9 dyads was .90 ($SD = .13$). The match and correlation between the two observers' proportions of nontarget (other) word tokens (PTOW) were calculated in a similar manner. The total number of nontarget word tokens for each type (ms, ma, so, iho, and gs) was divided by the total nontarget word tokens across all bimodal types (ms, ma, so, iho, gs, and uncoded occurrences) for each of the 24 mother–infant dyads. The PTOWs of the first observer under these types were then compared with the PTOWs of the second observer. The match between the two observers' PTOWs classified into the five communication types averaged across 6 of the same mothers' communications (25%, 2 dyads randomly chosen from each age group) was .93 ($SD = .03$). The mean Pearson product moment correlation (r) between the two observers' PTOWs averaged across the 6 mothers was .98 ($SD = .01$).

Mothers sometimes communicated to infants by using three different modalities. They touched the infant with an object in coordination with naming and object motion. For instance, one mother of an 8-month-old named the shaking action as *flo* four times in a series and simultaneously shook the toy shark from side to side in full view of the infant and against the infant's leg. Mothers also sometimes named objects entirely synchronous with objects looming toward the infant and touched their infants such that the offset of naming and object motion coincided with touch. These instances of synchronous maternal trimodal (auditory-visual-tactile synchrony, or avt) communication of target and nontarget word tokens were identified and analyzed separately. The proportions of avt target and nontarget word tokens were calculated by dividing the number of avt occurrences by the total number of target and nontarget words spoken for each dyad, respectively. These proportions were calculated for the first and second observers. The mean Pearson product moment correlation between two observers' avt proportions, calculated for 6 of the same mothers used to obtain reliability for the bimodal tokens, was .97 ($SD = .07$) for the target words and .99 ($SD = .03$) for the nontarget words.

RESULTS

Maternal Bimodal (Auditory-Visual) Communication

Maternal bimodal communication of target words and infants' age. Do mothers tailor their communication of target words to match their infants' ability to detect word–referent relations? If maternal multimodal communication facilitates infants' learning of novel word–referent relations, then we should expect mothers to use more naming in synchrony with object motion for younger infants when synchrony is most important for learning. Conversely, we should expect mothers to use more naming in the presence of still objects later during development once infants can relate words and referents on their own. Thus, we

would expect an interaction between maternal communication type and infants' age.

To address this question, we analyzed the PTTWs for the four bimodal communication types (ms, ma, so, and iho). (Because the proportions of uncoded and globally synchronous occurrences were not considered in these analyses, the total proportions of these four bimodal communications did not violate the assumptions of the analysis of variance.) We performed repeated measures analysis of variance on the PTTWs as a function of infants' age (3) and maternal communication type (4) by using a general linear models procedure. The analysis revealed no significant main effect of age, $F(2, 21) = 1.16$, $p > .1$, but a significant effect of communication type, $F(3, 63) = 82.14$, $p < .001$. The mean PTTWs and standard deviations as a function of infants' age and bimodal communication types are given in Figure 2. A post hoc analysis of communication types (Scheffe's multiple comparison, two-tailed $p < .05$) revealed that infants of all ages received temporally synchronous maternal communication (ms) more often than other types. Thus, when mothers specifically teach words to infants, "multimodal motherese" is primarily characterized by temporally synchronous verbal labels and gestures.

More importantly, the analysis revealed a significant interaction between infants' age and maternal communication type, $F(6, 63) = 8.76$, $p < .001$, which supports our hypothesis that mothers' bimodal communication is tailored to infants' ability to detect word–referent relations. Post hoc analyses of the interaction (Scheffe's multiple comparison, two-tailed $p < .05$) showed that mothers of the three groups of infants differed significantly in the types of bimodal communication they used to teach target words. First, consistent with our prediction, mothers of the 5- to 8-month-olds used a significantly greater proportion of temporally synchronous occurrences than mothers of the older infants (9–17 months and 21–30 months, $p < .05$; Figure 2). Thus, mothers named target words in synchrony with object motion for young infants, who are typically unable to detect the relations on their own, more often than for older infants. This may serve to highlight spoken word–referent relations. This result provides empirical support for Zukow's (1991) descriptive findings. Second, the occurrences of naming asynchronous with object motion (ma) were too few and variant to produce any meaningful differences between ages ($p > .05$). However, the means were in the expected direction with mothers of the older infants using more instances of asynchrony than the mothers of younger infants (Figure 2). Third, according to prediction, mothers of the 21- to 30-month-olds named objects and actions holding a static object (so) significantly more often than mothers of the two younger groups (5–8 months and 9–17 months; $p < .05$). Mothers may name objects and actions with a static object more often for older infants because these infants may have other means for gleaning word–referent relations and may not re-

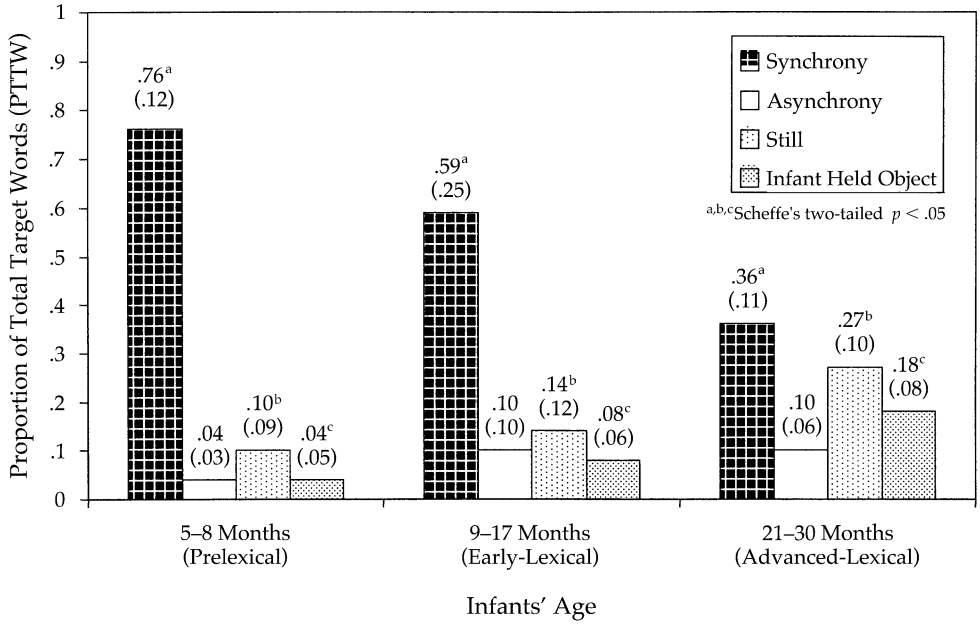

Figure 2 The mean proportion of total target word occurrences (PTTW and *SD*) in mothers' bimodal communication in the context of objects moving in temporal synchrony, asynchrony, remaining still, or being held by the infant.

quire the same degree of maternal guidance for detecting these relations as the young infants. Complementing this finding, mothers of the 21- to 30-month-olds often participated in joint communication that was partially regulated by the infant. These mothers, relative to those of younger infants (9–17 months and 5–8 months), named objects or actions more often while infants actively explored the objects or imitated the actions (iho; $p < .05$; Figure 2).

Further, to assess the effects of ethnicity in mothers' target word communications, an analysis of variance of infants' age (3), communication type (4), and ethnicity (2; European American, $n = 12$, Hispanic American, $n = 11$) was performed by excluding the French mother from the sample. This analysis revealed no main effect of ethnicity, $F(1, 17) = .67$, $p > .1$, but a main effect of communication type and an interaction between age and communication type. These results indicate that European American and Hispanic American mothers did not differ in the proportions of different communication styles they used to teach target words to their infants.

In summary, the results support our hypothesis that mothers tailor their bimodal communications of novel target words to their infants' ability to detect word–referent relations. Mothers used temporal synchrony in bimodal communication more often with younger infants than with older infants when they taught the target words. This is consistent with the view that mothers guide prelexical infants' attention to word–referent relations. Furthermore, at an age when infants generally demonstrate the ability to detect word–referent relations on their own (9–17 and 21–30 months), the frequency of temporal coordination in mothers' bimodal communication decreases. Thus, mothers of advanced-lexical infants named objects and actions more often when the objects were static.

Maternal bimodal communication of nontarget words and infants' age. If maternal multimodal communication serves to assist infants' learning of word–referent relations, then we should expect little tailoring of nontarget words to the infant's level of lexical development because mothers were not teaching nontarget words. Thus, we should expect no interaction effect between maternal communication type and infants' age. To test this hypothesis, we analyzed the proportions of total nontarget words (PTOW) for the four communication types (ms, ma, so, and iho). The mean PTOWs and standard deviations (*SD*) as a function of infants' age and maternal bimodal communication type are given in Figure 3. A repeated measures analysis of variance of communication type (4) and age (3) on the PTOWs revealed a significant effect of communication type, $F(3, 63) = 42.06$, $p < .001$, no effect of age, and in support of our hypothesis, no interaction between infants' age and maternal communication type ($ps > .1$). These results show that the mothers did not tailor their nontarget word communication to their infant's lexical development. Post hoc *t* tests of communication type (Scheffe's multiple

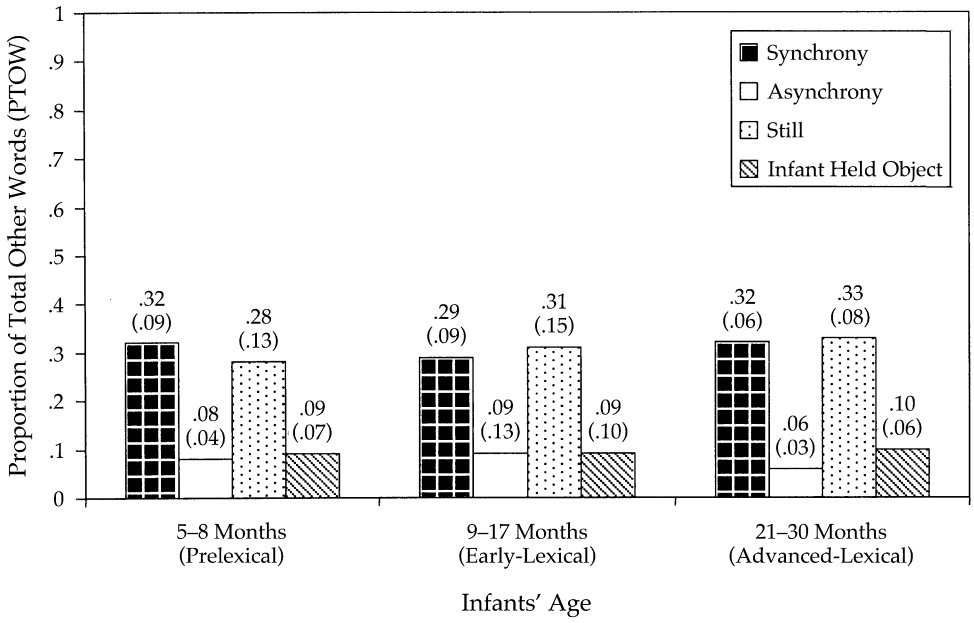

Figure 3 The mean proportion of total nontarget (other) word occurrences (PTOW and *SD*) in mothers' bimodal communication in the context of objects moving in temporal synchrony, asynchrony, remaining still, or being held by the infant.

comparison, two-tailed $p < .05$) revealed that maternal naming in temporal synchrony with object motion and naming in the presence of a static object were more frequent than either naming in temporal asynchrony with object motion or naming when the infant held an object (Figure 3). However, we found no significant difference between naming in temporal synchrony and naming in the presence of a static object ($p > .05$). Further, an analysis of the PTOW by ethnicity (Hispanic American versus European American), maternal communication type, and infants' age indicated no main effect of ethnicity or interactions between these factors ($ps > .1$).

Maternal bimodal target versus nontarget word communication and infants' age. If temporal synchrony serves to highlight word–referent relations for infants, then mothers should use synchrony more often when they specifically teach target words than when uttering nontarget words and this effect should be more pronounced in maternal communication with prelexical than advanced-lexical infants. Thus, a three-way interaction was predicted between word type (target versus nontarget), communication type, and infants' age.

The PTTWs (target words) and PTOWs (nontarget or other words) were, therefore, subject to a three-way analysis of variance of infants' age (3), maternal communication type (4), and word type (2). The analysis revealed the predicted three-way interaction between word type, bimodal communication type, and age, $F(6, 147) = 5.63$, $p < .001$. We conducted post hoc analyses (Scheffe's multiple comparison, two-tailed $p < .05$) to evaluate this interaction (see Table 1). Results indicated that mothers used a significantly greater proportion of target words (PTTW), but not nontarget words, in synchrony with object motion in

Table 1 The Number (Mean Frequency) and Mean Proportions (*SD*) of Mothers' Bimodal Communication to Infants across Age and Word Type

	Bimodal Communication Types			
	Moving-Synchronous Naming	Moving-Asynchronous Naming	Naming of a Still Object	Naming When the Infant Held an Object
Prelexical (5–8 months, $n = 8$)				
Target words				
Raw total (mean frequency)	618 (77.25)	31 (3.88)	76 (9.5)	37 (4.6)
Mean proportions (*SD*)	.76 (.12)[a]	.04 (.03)	.10 (.09)[a]	.04 (.05)[a]
Nontarget words				
Raw total (mean frequency)	168 (21)	34 (4.25)	143 (17.88)	50 (6.25)
Mean proportions (*SD*)	.32 (.09)	.08 (.04)	.28 (.13)	.09 (.07)
Early-lexical (9–17 months, $n = 8$)				
Target words				
Raw total (mean frequency)	360 (45.0)	55 (6.88)	98 (12.25)	47 (5.88)
Mean proportions (*SD*)	.59 (.25)[a]	.10 (.10)	.14 (.12)[a]	.08 (.06)[a]
Nontarget words				
Raw total (mean frequency)	161 (20.13)	63 (6.06)	198 (24.75)	55 (6.88)
Mean proportions (*SD*)	.29 (.09)	.09 (.13)	.31 (.15)	.09 (.10)
Advanced-lexical (21–30 months, $n = 8$)				
Target words				
Raw total (mean frequency)	231 (28.88)	46 (5.75)	124 (15.5)	107 (13.38)
Mean proportions (*SD*)	.36 (.11)[a]	.10 (.06)	.27 (.10)[a]	.18 (.08)[a]
Nontarget words				
Raw total (mean frequency)	361 (45.12)	62 (7.75)	399 (49.88)	106 (13.25)
Mean proportions (*SD*)	.32 (.06)	.06 (.03)	.33 (.08)	.10 (.06)
Total target words, 2,013[b]	1,209 (50.4)	132 (5.5)	298 (12.42)	191 (7.9)
	.57 (.23)[a]	.08 (.07)	.15 (.12)[a]	.10 (.09)
Total nontarget words, 2,279[c]	690 (28.75)	159 (6.62)	740 (30.80)	211 (8.79)
	.31 (.08)[a]	.08 (.08)	.30 (.11)[a]	.09 (.07)

[a] Scheffe's two-tailed $p < .05$ across infants' age, within communication type.
[b] Out of 2,013 target word tokens, 111 (.065) were globally synchronous and 72 (.035) were not codable.
[c] Out of 2,279 nontarget word tokens, 325 (.16) were globally synchronous and 154 (.06) were not codable.

communicating to prelexical infants than to early-lexical infants and also used a greater proportion of these target word communications to early-lexical infants than to advanced-lexical infants. During target word naming, mothers of early-lexical infants (9–17 months) also tended to name and point to a static object slightly more often than mothers of prelexical (5–8 months) and advanced-lexical (21–30 months) infants. This tendency parallels Murphy and Messer's (1977) finding that pointing is more salient to infants of this age. In contrast, no differences between communication types were found in the mean proportions of nontarget words (PTOW) across infants' age (two-tailed $p > .05$; Table 1). These findings support our hypothesis and establish that the mothers tailored their bimodal communication style to their infant's detection of word–referent relations when they explicitly taught target (novel) words to their infants but not when simply uttering nontarget words. On the basis of these findings we conclude that mothers used specific bimodal communication styles to systematically convey target word–referent relations. Mothers appear to use "multimodal motherese" to a greater extent for the purpose of highlighting novel word–referent relations to infants.

In addition, the analysis revealed a significant two-way interaction between communication type and age, $F(6, 147) = 7.67$, $p < .001$. Post hoc analyses (Scheffe's multiple comparison, two-tailed $p < .05$) revealed that mothers of prelexical infants used target and nontarget words in temporal synchrony with object motion more often ($M = .54$, $SD = .25$) than mothers of advanced-lexical infants ($M = .34$, $SD = .09$). Conversely, mothers of advanced-lexical infants used target and nontarget words in the presence of a static object more often ($M = .30$, $SD = .10$) than mothers of prelexical infants ($M = .19$, $SD = .12$). Further, mothers of advanced-lexical infants used target and nontarget words when the infants manipulated the objects more often ($M = .14$, $SD = .08$) than mothers of prelexical infants ($M = .07$, $SD = .06$). Thus, older infants increasingly regulate naming contexts by manipulating objects of interest.

Furthermore, the analysis revealed a significant interaction between word type and communication type, $F(3, 147) = 30.80$, $p < .001$. Post hoc analyses (Scheffe's multiple comparison, two-tailed $p < .05$) of the means revealed that mothers named objects and actions in synchrony with object motion more often for target words, $M = .57$, $SD = .23$, than nontarget words ($M = .31$, $SD = .08$). Conversely, the mothers named objects and actions while holding a static object more often for nontarget words, $M = .30$, $SD = .11$, than for target words, $M = .15$, $SD = .12$. These differences corroborate our prior results, which suggests that mothers use temporal synchrony to highlight novel word–referent relations for infants of all ages. We found no differences between target and nontarget words for naming asynchronous with object motion or naming when infants held objects ($p > .05$).

Finally, the analysis of variance revealed main effects of communication type, $F(3, 147) = 122.34$, $p < .001$, and word type, $F(1, 147) = 4.15$, $p < .05$, but no significant main effect of age, $p > .1$. Post hoc analyses (Scheffe's two-tailed $p < .05$) of communication type indicated that mothers used temporal synchrony more often than all other types across target and nontarget word types ($M = .44$, $SD = .22$). These findings demonstrate that maternal communication to infants of all ages is most often temporally coordinated regardless of word type.

Mothers' Bimodal Communication of Nouns and Verbs

Do mothers' bimodal communication styles differ across lexical categories (i.e., nouns versus verbs)? To address this question, we calculated the proportions of nouns and verbs in each bimodal communication type (ms, ma, so, iho, gs, and uncoded) over the total number of nouns and verbs, respectively, for each word type (target and nontarget) and dyad. We conducted two separate analyses of variance on these proportions to assess the effects of word type, maternal bimodal communication type, infants' age, and interactions.

Target versus nontarget nouns. A repeated measures analysis of variance of the proportion of total nouns by word type (2), age (3), and communication type (4) revealed a significant main effect of word type, $F(1, 21) = 9.72$, $p < .001$, communication type, $F(3, 63) = 24.92$, $p < .001$, but not age, $F(2, 21) = .45$, $p > .1$. Post hoc t tests (Scheffe's multiple comparison, $p < .05$) of communication type revealed that the mean proportions of the temporally synchronous (ms, $M = .40$, $SD = .23$) noun communications was greater than the means of other types across infants' age and word type (target and nontarget). The mean proportions and frequencies are given in Table 2.

More importantly, the analysis revealed a significant three-way interaction between word type, maternal communication type, and infants' age, $F(6, 63) = 3.56$, $p = .004$. Post hoc tests (Scheffe's multiple comparison, $p < .05$) showed that mothers of prelexical infants used target nouns in temporal synchrony with object motions more often ($M = .71$, $SD = .17$) than mothers of early- and advanced-lexical infants (9–17

Table 2 The Number (Mean Frequency) and Mean Proportions (*SD*) of Mothers' Bimodal Communication of Nouns to Infants across Age and Word Type

	Bimodal Communication Types			
	Moving-Synchronous Naming	Moving-Asynchronous Naming	Naming of a Still Object	Naming When the Infant Held an Object
Prelexical (5–8 months, $n = 8$)				
Target nouns				
Raw total (mean frequency)	317 (39.5)	26 (3.25)	60 (7.5)	15 (1.88)
Mean proportions (*SD*)	.71 (.17)[a]	.07 (.05)	.13 (.12)	.03 (.04)
Nontarget nouns				
Raw total (mean frequency)	47 (6.6)	10 (1.25)	39 (4.88)	13 (1.62)
Mean proportions (*SD*)	.34 (.13)	.08 (.08)	.29 (.18)	.08 (.10)
Early-lexical (9–17 months, $n = 8$)				
Target nouns				
Raw total (mean frequency)	126 (15.62)	28 (3.5)	94 (11.7)	41 (5.12)
Mean proportions (*SD*)	.43 (.20)[a]	.10 (.09)	.24 (.15)	.12 (.09)
Nontarget nouns				
Raw total (mean frequency)	39 (4.88)	19 (2.38)	25 (4.88)	18 (2.25)
Mean proportions (*SD*)	.25 (.25)	.22 (.29)	.22 (.23)	.09 (.15)
Advanced-lexical (21–30 months, $n = 8$)				
Target nouns				
Raw total (mean frequency)	90 (11.25)	24 (2.75)	71 (8.8)	32 (3.34)
Mean proportions (*SD*)	.34 (.20)[a]	.09 (.08)	.29 (.13)	.11 (.08)
Nontarget nouns				
Raw total (mean frequency)	98 (12.25)	19 (2.38)	121 (26.0)	38 (4.75)
Mean proportions (*SD*)	.30 (.11)	.04 (.03)	.38 (.12)	.10 (.07)
Total target nouns, 1,017[b]	529 (22.21)	76 (3.17)	225 (9.38)	88 (3.62)
	.51 (.24)[a]	.09 (.08)	.22 (.15)	.09 (.08)
Total nontarget nouns, 615[c]	184 (7.75)	48 (2.0)	185 (7.46)	69 (2.88)
	.29 (.17)	.12 (.18)	.29 (.19)	.09 (.11)

[a] Scheffe's two-tailed $p < .05$ across infants' age.
[b] Of the 1,017 target noun tokens, 34 (.04) were globally synchronous and 59 (.07) were not codable.
[c] Of the 615 nontarget verb tokens, 85 (.14) were globally synchronous and 28 (.05) were not codable.

months, $M = .43$, $SD = .20$; and 21–30 months, $M = .34$, $SD = .20$). In contrast, no differences were found in mothers' use of temporally synchronous nontarget nouns as a function of infants' age ($p > .1$). Further, mothers of advanced-lexical infants (21–30 months) used target nouns (but not nontarget nouns) when infants held an object significantly more often than mothers of prelexical and early-lexical infants (5–8 months, and 9–17 months; $p < .05$). The analysis also showed a significant interaction between word type and communication type, $F(3, 63) = 8.895$, $p < .001$. Post hoc t tests of the mean proportions (Scheffe's multiple comparisons, two-tailed $p < .05$) across communication types and word types revealed that mothers' use of target nouns in temporal synchrony was greater than all other communication types (see Table 2). These results parallel the overall results and suggest that when mothers specifically taught nouns to their infants, their bimodal communication matched infants' ability to detect word–object relations.

Target versus nontarget verbs. A repeated measures analysis of variance of the proportion of total verbs by infants' age (3), maternal communication type (4), and word type (2; target, nontarget) also showed a significant main effect of communication type, $F(3, 63) = 63.75$, $p < .001$, and word type, $F(1, 21) = 17.41$, $p < .001$, but no effect of age, $F(2, 21) = .24$, $p > .1$. Identical to the nouns, post hoc t tests (Scheffe's multiple comparison, two-tailed $p < .05$) of communication types revealed that mothers used verbs in temporal synchrony with actions (ms, $M = .47$, $SD = .29$) more often than all other communication types.

More importantly, the analysis revealed a significant three-way interaction between infants' age, maternal communication type, and word type, $F(6, 63) = 4.5$, $p < .001$. The mean proportions and frequencies

of target and nontarget verbs are given in Table 3. Post hoc *t* tests of the three-way interaction showed, interestingly, that mothers of early-lexical infants (9–17 months, $M = .72$, $SD = .41$), unlike the mothers of the advanced-lexical infants ($M = .40$, $SD = .10$) but similar to those of prelexical infants (5–8 months, $M = .82$, $SD = .17$), used target verbs most often in temporal synchrony with actions. Mothers' use of temporal synchrony to teach verbs may serve to facilitate infants' learning of verb–referent relations at that age (see Discussion). Furthermore, a paired-sample *t* test of mothers' temporally synchronous target verbs ($M = .72$, $SD = .38$) versus nouns ($M = .43$, $SD = .20$) for early-lexical infants (9–17 months) showed a significant difference between these lexical categories, $t(7) = 2.50$, $p < .05$. This developmental pattern also suggests greater highlighting of verbs than nouns for early-lexical infants.

The post hoc tests of the three-way interaction revealed further results similar to those of the nouns and verbs taken together. Mothers of advanced-lexical infants used target verbs more often with static objects (so) or when infants held an object (iho) than mothers of the prelexical and early-lexical infants (see Table 3). Similarly, mothers of advanced-lexical infants used target verbs when infants held objects (iho) more often than mothers of prelexical and early-lexical infants ($p < .05$). No such differences by age were observed in mothers' use of nontarget verbs for any of the communication types. These results, similar to the analysis of nouns, suggest that mothers tailored their bimodal communication of target but not nontarget verbs when they specifically taught them to their infants.

In summary, the separate analyses of nouns and verbs parallel the overall analysis of target and nontarget words. Mothers adapted both types of target

Table 3 The Number (Mean Frequency) and Mean Proportions (*SD*) of Mothers' Bimodal Communication of Verbs to Infants across Age and Word Type

	Bimodal Communication Types			
	Moving-Synchronous Naming	Moving-Asynchronous Naming	Naming of a Still Object	Naming When the Infant Held an Object
Prelexical (5–8 months, $n = 8$)				
Target verbs				
Raw total (mean frequency)	304 (38.0)	5 (.25)	16 (2.0)	22 (2.75)
Mean proportions (*SD*)	.82 (.19)[a]	.01 (.02)	.03 (.07)[a]	.06 (.08)[a]
Nontarget verbs				
Raw total (mean frequency)	114 (14.25)	24 (3.0)	104 (13.0)	37 (4.63)
Mean proportions (*SD*)	.30 (.10)	.07 (.05)	.23 (.11)	.09 (.08)
Early-lexical (9–17 months, $n = 8$)				
Target verbs				
Raw total (mean frequency)	236 (28.75)	26 (3.25)	4 (.5)	6 (.75)
Mean proportions (*SD*)	.72 (.38)[a]	.12 (.29)	.02 (.04)[a]	.03 (.06)[a]
Nontarget verbs				
Raw total (mean frequency)	122 (15.25)	44 (5.5)	159 (19.88)	37 (4.63)
Mean proportions (*SD*)	.25 (.12)	.11 (.11)	.34 (.12)	.08 (.09)
Advanced-lexical (21–30 months, $n = 8$)				
Target verbs				
Raw total (mean frequency)	140 (17.5)	22 (2.5)	53 (6.62)	75 (9.4)
Mean proportions (*SD*)	.40 (.10)[a]	.08 (.08)	.19 (.13)[a]	.21 (.13)[a]
Nontarget verbs				
Raw total (mean frequency)	262 (32.75)	43 (5.38)	278 (34.75)	68 (8.5)
Mean proportions (*SD*)	.31 (.08)	.06 (.04)	.32 (.09)	.09 (.05)
Total target verbs, 996[b]	680 (28.33)	53 (2.2)	73 (3.04)	103 (4.29)
	.63 (.31)[a]	.07 (.17)	.08 (.12)	.10 (.12)
Total nontarget verbs, 1,661[c]	498 (20.75)	111 (4.62)	541 (22.54)	142 (5.92)
	.29 (.10)[a]	.08 (.08)	.30 (.11)[a]	.08 (.07)

[a] Scheffe's two-tailed $p < .05$ across infants' age.
[b] Of the 996 target verb tokens, 73 (.09) were globally synchronous and 12 (.02) were not codable.
[c] Of the 1,661 nontarget verb tokens, 243 (.18) were globally synchronous and 126 (.06) were not codable.

words to infant's level of lexical development. Thus, their adaptive use of both lexical categories contributed to the synchrony effects for target versus nontarget word communications.

Trimodal Communication (Auditory-Visual-Tactile Synchrony; avt)

Of the total number of target word occurrences (2,013) across 24 mothers, 350 (17%) were synchronous with mothers' touching the infant with the object and visual object motion. Of the total number of nontarget word occurrences (2,279) across 24 mothers, only 117 (5%) were synchronous with mothers' touching the infant with the object and object motion.

Do mothers integrate auditory, visual, and tactile information during naming to highlight word–referent relations for their infants? If integration of information across multiple modalities serves to highlight word–referent relations, then their occurrence in maternal communication should be more frequent for target than nontarget words. Further, mothers should use avt more often during communication with younger infants relative to older infants because younger infants may require avt highlighting more than the older infants. To address these hypotheses, the proportion of mothers' naming in synchrony with object motion and touch (avt) was assessed for variation as a function of word type (target, nontarget) and infants' age. We submitted the avt to a two-way repeated measures analysis of variance, using word type (target, nontarget) as the within-subjects factor and age (3) as the between-subjects factor. The mean proportions of avt and standard deviations across age are given in Figure 4. The analysis revealed a significant main effect of word type, $F(1, 21) = 17.28$, $p < .001$. As predicted, mothers used avt more often for communicating target words ($M = .17$, $SD = .13$) than nontarget words ($M = .06$, $SD = .09$; Figure 4) to infants of all ages (Scheffe's two-tailed $p < .05$). Thus, mothers highlighted target word–referent relations by integrating auditory, visual, and tactile information for their infants.

In addition, the analysis revealed a significant main effect of age, $F(2, 21) = 5.27$, $p < .01$. Mothers of prelexical infants used more avt (5–8 months) compared with mothers of advanced-lexical infants (21–30 months) across target and nontarget word types (Scheffe's two-tailed $p < .05$; Figure 4). These results suggest that mothers' trimodal coordination also highlights word–referent relations for infants on the threshold of lexical development. However, the analysis revealed no interaction between word type and age because mothers' use of avt synchrony for nontarget words also decreased across age ($p > .1$).

In summary, the analyses of bimodal and trimodal

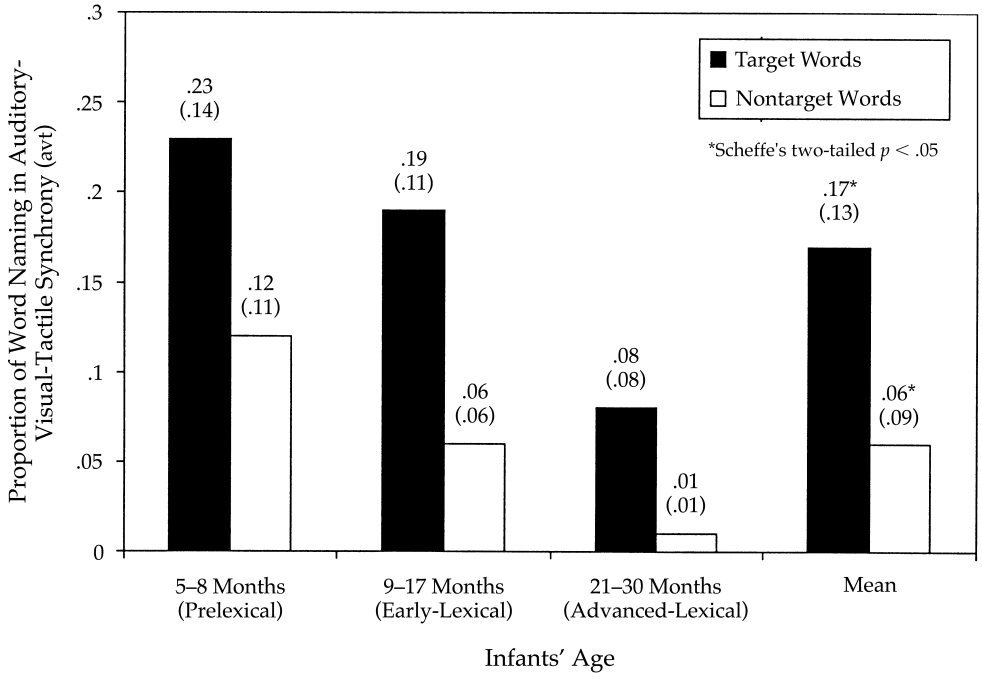

Figure 4 Proportion of target and nontarget word naming with auditory-visual-tactile synchrony (avt) in mothers' communication with infants.

communication together suggest that mothers highlighted target- but not nontarget word–referent relations for their infants by using multimodal coordination between words and object motion (and sometimes touch). There were more instances of all types of multimodal coordination for target words than for nontarget words, and multimodal coordination varied as a function of infants' level of lexical development. Therefore, we conclude that "motherese" is multimodal and primarily characterized by temporally coordinated verbal labels and gestures. Multimodal "motherese" serves to highlight novel word–referent relations and likely facilitates infants' ability to detect these arbitrary relations.

DISCUSSION

Under conditions of the present study where the mothers taught their infants labels for novel objects and actions, a dramatic 99.99% of their utterances were multimodal. Of those utterances 60% were temporally synchronous with object motion. Thus, European American and Hispanic American mothers typically use a great deal of intersensory redundancy in the form of temporal synchrony between verbal labels and gestures with infants. This result corroborates the findings of prior descriptive studies, which suggests that temporal coordination of spoken words and gestures is prevalent in British English (Messer, 1978), Mexican, and American (Zukow-Goldring, 1997) mothers' communication to their infants.

The results of this study also support the hypothesis that mothers use temporal synchrony to highlight novel word–referent relations for young infants. Mothers named objects or actions in temporal synchrony with the motions of objects when teaching novel (target) words more often than when using other (nontarget) words. This finding supports the view that synchrony serves to highlight novel word–referent relations for infants. Also consistent with this view, mothers used object motion and touch synchronous with target words more often than with nontarget words. In contrast, the mothers used more nontarget words than target words while holding static objects. "Multimodal motherese" is likely a natural, adaptive behavior that has evolved to transmit conventional word–referent relations to infants. Fernald (1992) proposed a similar view in reference to the acoustic properties of "unimodal" motherese.

Furthermore, mothers were found to tailor their bimodal (auditory-visual) and multimodal (auditory-visual-tactile) communication to their infant's lexical development when specifically teaching words. They named objects and actions in temporal synchrony with object motion more often for their prelexical (5–8 months) infants, who were most likely to benefit from maternal guidance to the word–referent relations. Experimental findings have shown that 7-month-olds learn the relations between /a/ and /i/ and two objects (Gogate & Bahrick, 1998) and 8-month-olds learn the relations between the minimal pairs /tah/ and /gah/ and two objects (Gogate, 1999) only when temporal synchrony is provided. Thus, synchrony likely facilitates the learning of word–object relations at this age. In the present study, mothers used temporal synchrony less often for advanced-lexical infants, who typically detect word–referent relations on their own (21–30 months). These mothers were also more likely than the mothers of younger infants (5–8 months) to name objects and actions when the children held the objects and manipulated them. These findings demonstrate that mothers tailored their communication to their infants' ability to detect word–referent relations. Apparently, as infants' lexical development (indexed here by age) increases, maternal multimodal naming decreases.

What purpose does synchronous auditory, visual, and tactile information serve in maternal communication and how might temporal synchrony facilitate word learning in young infants? As discussed earlier, presenting information across multiple modalities simultaneously serves to highlight the relations between the two patterns of stimulation (Bahrick & Lickliter, 2000; Bahrick & Pickens, 1994). The redundancy between a heard speech pattern and a seen moving object or touch can capture infants' attention and highlight the arbitrary relation (Gogate, 1999; Gogate & Bahrick, 1998). Thus, temporal synchrony can facilitate infants' detection of word–referent relations.

This study in conjunction with others suggests a bidirectional relationship between maternal multimodal communication styles and infants' perception of word–referent relations. Mothers use more temporal synchrony at a time when infants rely on synchrony most for detecting word–referent relations (Gogate, 1999; Gogate & Bahrick, 1998; in press). Similarly, the decrease in maternal use of temporal synchrony, observed in the present study, appears to be well timed with infants' (at 14 months) increased ability to detect word–referent relations without temporal synchrony on the basis of object motion alone (Werker et al., 1998). In addition, mothers' naming of objects or actions with static objects seems well adapted to older infants' ability to glean word–referent relations on their own without temporal synchrony or object motion in video presentations (Fernald et al., 1998). Together, these findings suggest that "multimodal motherese" is adapted to the infants' level of lexical development.

Research has also revealed other bases for lexical learning. During live object presentations, infants as young as 12 months (Hollich, Hirsh-Pasek, & Golinkoff, in press) and older infants of 18 to 20 months (Baldwin et al., 1996) can also rely on the speaker's gaze to a static object to detect word–referent relations. By 24 months, children can rely on the speaker's surprise at seeing a mismatched word and referent to establish the correct link between the word and another referent (Tomasello & Barton, 1994). Further, at about the same time, infants begin to coregulate the naming contexts with their caregivers. In the present study, for advanced-lexical infants (21–30 months), naming was not entirely regulated by the mother but appeared to be partially regulated by the infant. Mothers sometimes named objects and actions when infants actively held and manipulated the objects. Another study reported similar behavior when mothers named objects to 2-year-olds (Masur, 1997). Once infants are able to detect word–referent relations on their own, infant-regulated maternal naming may in part promote the child's rapid lexical development (Akhtar et al., 1991; Tamis-Lemonda & Bornstein, 1989). This pattern fits well with Rogoff's (1990) observations that mothers, at first, regulate their infants' learning, and later, with infants' increasing competence, both mothers and infants coregulate infants' learning. More importantly, the match between maternal communication styles and infants' changing requirements for these styles in detecting word–referent relations supports the ecological and dynamic systems views of development (Gibson, 1979; Thelen & Smith, 1994). This match underscores the reciprocity between changing organismic-environmental systems for word–referent mapping, a prerequisite for word comprehension (see review by Gogate, Walker-Andrews, & Bahrick, in press).

Yet another example of reciprocity in maternal multimodal communication and infants' detection of word–referent relations was mothers' more frequent use of temporal synchrony with target verbs than with nouns to the early-lexical infants (9–17 months). The continued greater use of temporal synchrony when specifically teaching verb–referent relations seems well adapted to infants' verb learning ability. Verbs are typically fewer in infants' early vocabularies and are used far less productively than nouns even by 2-year-olds (see Golinkoff, Mervis, & Hirsh-Pasek, 1994; Nelson, Hampson, & Shaw, 1993; Tomasello, Akhtar, Dodson, & Rekau, 1997). In keeping with this developmental pattern, mothers highlighted verbs with temporal synchrony more often than nouns for early-lexical infants. Some researchers have offered the suggestion that infants' slower ability to detect verb–referent relations may result in part from the low perceptual salience of verbs, which often refer to fleeting events, versus that of nouns, which refer to tangible objects (Goldfield, 1993). Apparently, mothers continue to highlight verbs longer than nouns in their bimodal communication to infants because infants require such highlighting. These findings support Studdert-Kennedy's (1991) claim that maternal language is as adapted to the infant as the infant is to maternal language.

Note, however, that maternal adaptation of communication styles to infants' level of lexical development does not imply any awareness of this adaptation. The adaptations are likely the result of an ongoing self-organization of one system to the changes of the other (see Gogate et al., in press). For example, mothers are not aware of their use of intersensory redundancy. They are "simply trying to communicate with their infants" (Snow, 1986; p. 72). Their use of intersensory redundancy may be, in part, a by-product of their attempts to gain their infants' attention. The infant may, in turn, attend to the communication that is most salient (temporally synchronous communication).

The present study is the first to systematically quantify maternal multimodal communication and has shown how maternal communication likely complements the infant's changing ability to perceive word–referent relations. We have shown that maternal multimodal communication can provide infants with rich opportunities for detecting word–referent relations by means of developmentally appropriate multimodal naming contexts. Further investigations could examine the extent of the match between the timing of infants' lexical competence and mothers' adaptive multimodal communication by measuring infants' level of lexical competence within age and assessing the changes in the mother's use of synchrony in multimodal communication to her infant. The degree of this alignment might well be a critical factor determining infants' success in word comprehension. Furthermore, cross-cultural studies are required to address how cultures vary in their adaptive use of temporal synchrony and other communication styles.

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