INFANCY, *11*(2), 191–202

BRIEF REPORTS

The Influence of Mouthing on Infant Vocalization

Mary K. Fagan
Department of Psychological Sciences
University of Missouri–Columbia

Jana M. Iverson
Department of Psychology
University of Pittsburgh

Although vocalization and mouthing are behaviors frequently performed by infants, little is known about the characteristics of vocalizations that occur with objects, hands, or fingers in infants' mouths. The purpose of this research was to investigate characteristics of vocalizations associated with mouthing in 6- to 9-month-old infants during play with a primary caregiver. Results suggest that mouthing may influence the phonetic characteristics of vocalizations by introducing vocal tract closure and variation in consonant production.

Mouthing, defined as contact of an object with the mouth, lips, or tongue (Rochat, 1989; Ruff, Saltarelli, Capozzoli, & Dubiner, 1992), is a common behavior during infancy (Belsky & Most, 1981; Fenson, Kagan, Kearsley, & Zelazo, 1976; Kopp, 1976). In a study of 7.5– to 21-month-old infants (Belsky & Most, 1981), all 40 infants displayed mouthing behavior during play with toys between 7.5 and 13.5 months. In addition to its prominence across infants, mouthing is a regularly occurring behavior both in terms of number of occurrences and duration of episodes (Kopp, 1976; Ruff, 1984; Whyte, McDonald, Baillargeon, & Newell, 1994).

Correspondence should be addressed to Mary K. Fagan, Indiana University, School of Medicine, Riley Research Wing 044, 699 West Drive, Indianapolis, IN 46202. E-mail: mkfagan@indiana.edu

Studies of mouthing have not typically examined vocalizations associated with episodes of mouthing. Moreover, studies of mouthing often focus on the mouthing of objects, less frequently investigating contact of the hands and fingers with infants' mouths. Elbers (1982), however, noted that between ages 6 and 12 months her son vocalized with the back of one hand against his mouth and while holding his fingers in his mouth. She interpreted both activities as variants in bringing about vocal tract closure and constriction. In an additional study of 4 infants between 6 and 11 months, Ejiri and Masataka (2001) documented both the frequent occurrence of mouthing and co-occurrences of mouthing and vocalization; however, they did not describe the characteristics of co-occurring vocalizations. Descriptions of vocalizations that co-occur with mouthing may be important for three reasons: Mouthing is an exploratory behavior that may extend to encompass exploration of co-occurring vocalizations; the peak period of mouthing behavior in infancy coincides with and may contribute to advances in consonant production; and mouthing, which appears to contribute to the development of multimodal object perception, may also contribute to the development of multimodal speech perception.

Mouthing and Exploration

Studies documenting the exploratory nature of object-related mouthing have consistently shown that infants use mouthing as a means to explore object characteristics and discover what they afford for action (Fenson et al., 1976; Rochat, 1989; Ruff et al., 1992). Moreover, infants vary their approach to exploration to maximize the information they obtain (e.g., scratching objects to obtain information about their affordance for noise; Rochat, 1989) and exploit affordances differentially (e.g., fingering textured objects and mouthing patterned objects). The exploratory nature of mouthing is further evident in infants' response to novelty. Among 5-month-old infants, for example, mouthing was closely followed by looks to confirm object properties. Mouthing followed by looks declined as objects became more familiar but recovered with the introduction of small changes in object texture or shape (Ruff et al., 1992). Thus, object-related mouthing serves important exploratory functions and contributes to infants' ability to maximize and exploit sensory information.

Whether the exploratory function of mouthing extends to co-occurring vocalizations has not been assessed. If, for example, infants explore object affordances for bringing about vocal tract closure, as suggested by Elbers (1982), vocalizations that co-occur with mouthing may be more likely to contain supraglottal consonants (consonants characterized by oral constriction or closure, e.g., [d]), as opposed to glottal consonants (consonants characterized only by laryngeal constriction or closure; i.e., [h]),[1] than vocalizations that do not.

[1]Glottal consonants are among the consonants most frequently produced by infants across languages (see Locke, 1983; Vihman, 1996).

Mouthing Peak and Consonant Production

The 6- to 9-month period is an important time of change in mouthing behavior. Object mouthing emerges early in infancy and increases between 15 and 20 weeks as reaching becomes productive (Rochat, 1989; Spencer, Vereijken, Diedrich, & Thelen, 2000). Mouthing peaks between 6 and 9 months and declines between 9.5 and 15.5 months, replaced by other forms of object exploration and manipulation (Belsky & Most, 1981; McCall, 1974; Palmer, 1989; Rochat, 1989; Ruff, 1984; Ruff et al., 1992; Whyte et al., 1994; Zelazo & Kearsley, 1980).

The 6- to 9-month period is also an important time of change in consonant production. Infants' first consonant-like sounds emerge between 2 and 4 months with the onset of cooing (see Locke, 1983; Vihman, 1996). Between 6 and 9 months, during the peak period of mouthing, consonant variation increases (Holmgren, Lindblom, Aurelius, Jalling, & Zetterstrom, 1986) and consonant–vowel repetition begins (e.g., Fagan, 2005; Koopmans-van Beinum, Clement, & van den Dikkenberg-Pot, 2001). Holmgren et al. (1986), for example, found an abrupt change in consonant production at 30 weeks when glottal attributes of vocalizations decreased and supraglottal consonants increased. During this period of speech development when infants produce new consonants, they also begin to form associations between articulatory maneuvers and auditory correlates of consonant production (Kuhl & Meltzoff, 1984). Despite the simultaneous timing of peaks in mouthing behavior and increased consonant production, little is known about the relation between mouthing and consonant exploration.

Evidence suggests, however, that infants do explore nonspeech sounds during object manipulation and during mouthing, selectively responding to object affordances in favor of sound production. For example, 9.5– and 10-month-old infants manipulated objects capable of producing sound more often than silent objects (McCall, 1974), and 6- to 12-month-old infants shook a sounding bell more often than a bell without a clapper (Palmer, 1989). This preference for sound production extends to support surfaces and influences mouthing behavior: When presented with wood or foam-covered table surfaces and a bell without a clapper, 6- to 9-month-old infants tended to shake the bell in the foam-table condition and bang the bell against the table in the wood-table condition; in the foam-table condition, infants spent more time mouthing objects than they did in the wood-table condition (Palmer, 1989).

Thus, infants appreciated the affordances of objects and support surfaces for producing sound and chose behaviors that maximized sound production whenever possible. In light of these findings, infants may also appreciate the potential for mouthing to influence vocalization. If, for example, infants explore object affordances for influencing sounds during mouthing, vocalizations produced during mouthing may be characterized by greater variation in consonant production than are nonmouthing vocalizations.

Multimodal Perception

Cross-modal knowledge of object properties has been demonstrated throughout the first year. For example, 1-month-old infants demonstrated visual recognition of orally explored object shapes (Meltzoff & Borton, 1979) and properties (Gibson & Walker, 1984). Multimodal exploration increases between 3 and 5 months as infants bring objects into view for visual inspection and to the mouth for oral contact. Repeated inspections appear to facilitate cross-modal comparisons as infants relate what they experience in both modalities (Rochat, 1989). Moreover, the availability of multimodal feedback influenced exploration tendencies (Gibson & Walker, 1984). For example, infants explored objects with their hands in a darkened room, but engaged in more frequent and varied object manipulation when the lighting permitted both manual and visual feedback.

In a similar way, the availability of multimodal feedback may encourage exploration of vocalizations during mouthing. Ruff et al. (1992) suggested that turning objects in the mouth provides infants with information about object size and shape. This information about objects is likely to be dependent at least in part on proprioceptive information about the openness and shape of the mouth and the contour of the tongue and lips as they accommodate and explore objects. Vocalizations that occur during mouthing may benefit both from proprioceptive feedback regarding oral postures associated with object mouthing and from auditory feedback about the consonant sounds associated with these oral postures. Moreover, research has shown that infants anticipate the size and shape of objects, changing the shape and orientation of the hands and mouth to accommodate grasping and mouthing (Ruff, 1984; Witherington, 2005). Thus, mouthing-related changes in the shape of the mouth, along with exploratory movements of the tongue and lips, may generate novel and varied articulatory postures and contribute to the development of multimodal links between oral gestures and auditory consequences.

In summary, mouthing may contribute not only to the discovery of object properties but also to the discovery of consonant properties. This study was designed to examine vocalizations that occurred during the mouthing of objects, hands, or fingers and to assess potential relations between mouthing and consonant production.

METHOD

Participants

Participants included 40 infants, 10 at each of four ages (6, 7, 8, and 9 months), with equal numbers of boys and girls at each age. This age range allowed observation of vocalization and mouthing during a time when both behaviors frequently occur and during the peak period of mouthing in infancy. All infants were from monolingual, English-speaking households and were developing within typical expectations (as determined by parent report and a brief developmental questionnaire). There was no evidence or parent report of hearing loss.

Procedure

Infants were videotaped in their homes for 20 min while playing with a primary caregiver. Observations consisted of (a) toys of various sizes and shapes presented in fixed order for 3 min each (a rattle, plastic keys on a ring, and a dome-shaped toy containing moving balls), (b) 3 to 5 min looking through a picture book, (c) 5 min of floor play with graduated stacking rings and toys containing noisemakers, and (d) 3 to 5 min of free play with a variety of the infants' own toys.

Coding

Infant vocalizations (excluding laughter, crying, squeals, and vegetative noises) were identified from videotapes and phonetically transcribed using broad phonetic transcription and International Phonetic Alphabet notation.[2] Vocalization boundaries were determined by an audible or visible breath or a silence of 1 sec or longer (Lynch et al., 1995). Vocalizations containing at least one consonant and vowel (CV; e.g., [da]) were identified, and consonants were further categorized as glottal (e.g., [h]) or supraglottal (e.g., [k], [d], [b], etc.). A supraglottal consonant inventory was compiled for each child from the subset of vocalizations containing at least one CV. All vocalizations were coded for co-occurrence with mouthing of objects, hands, or fingers.

Reliability

Intercoder reliability was assessed in four ways. Trained coders independently identified occurrences of vocalization (10% of the videotapes, n = 663 vocalizations), noted the presence of mouthing during vocalization (50% of the videotapes, n = 1,740 vocalizations), and transcribed and categorized vocalizations according

[2]Infant vocalizations are difficult to transcribe as they often differ in timing and precision from adult forms (e.g., quasi-vowels; Nathani & Oller, 2001; Oller, 2000). During the second half of the first year, vocalizations (including those in this study) are generally more well formed (Oller, 2000), although still difficult to transcribe. Because consonants in early infant vocalizations generally do not carry linguistic meaning, in this article the terms *consonant* and *vowel* refer to consonant-like and vowel-like productions.

to whether they contained at least one CV (20% of the videotapes, $n = 511$ vocalizations). Finally, consonant inventories were compiled for vocalizations containing at least one supraglottal CV (20% of the videotapes, $n = 108$ vocalizations). Mean percentage agreement was 90% for the occurrence of vocalization, 96% for the presence of mouthing during vocalization, 89% for the presence of a CV, and 82% for specific supraglottal consonants within consonant inventories.

RESULTS

Analyses focused on frequency of vocalization, number of vocalizations that co-occurred with mouthing, and the relative frequency and diversity of supraglottal consonants in mouthing versus nonmouthing vocalizations. Multivariate analysis of variance indicated no significant interactions (Age × Gender) or main effects of age or gender on number of vocalizations, number of vocalizations with mouthing, or number of CV vocalizations. (Table 1 lists frequency data for these variables by age group.) Therefore, subsequent analyses were performed with data collapsed across age and gender.

Vocalizations With Mouthing

All infants vocalized regularly during the observation period ($M = 85.3$, $SD = 44.5$, range = 21–202). Of all vocalizations, 28% co-occurred with mouthing ($SD = 17\%$, range = 0–65%). The mean number of vocalization–mouthing co-occurrences was 23.2 ($SD = 16.5$, range = 0–59). Only 1 infant, a 9-month-old boy, did not vocalize during mouthing.

Of vocalizations that co-occurred with mouthing, most occurred during the mouthing of objects ($M = 94\%$, $SD = 15$, range = 26–100%) rather than hands and fingers ($M = 6\%$, $SD = 15$, range = 0–74%). For 2 infants, however, vocalization during mouthing of hands and fingers was exceptionally frequent—74% of all vocalizations with mouthing for 1 infant (a 6-month-old girl) and 41% for the other (a 7-month-old girl). Thus, when objects are available, as they were in this study, 6– to 9-month-old infants appear to prefer vocalizing while mouthing objects. Because vocalization during mouthing of the hands and fingers was relatively infrequent ($M = 1.6$, $SD = 4.6$, range = 0–25) when compared with objects ($M = 21.6$, $SD = 16.2$, range = 0–57), separate analyses for hands and fingers were not conducted. Subsequent analyses were performed on data from all vocalizations that co-occurred with mouthing (i.e., vocalization during mouthing of objects, hands and fingers).

Regarding the relation between overall frequency of vocalization and frequency of vocalization with mouthing, total number of vocalizations was significantly correlated with number of mouthing vocalizations, $r = .66$, $p < .01$,

TABLE 1
Vocalizations, Vocalization-Mouthing Co-occurrences, CV Vocalizations, and CV Vocalizations With Mouthing by Age Group

	Vocalizations			*Co-occurrences*			*CV Vocalizations*			*CV Vocalizations With Mouthing*		
Age in Months	*M*	*SD*	*Range*	*M*	*SD*	*Range*	*M*	*SD*	*Range*	*M*	*SD*	*Range*
6	92.1	32.9	54–133	28.3	16.5	2–48	24.7	11.2	7–41	8.2	6.6	1–17
7	71.9	31.2	38–126	22.9	13.9	9–45	27.8	15.8	10–58	9.7	7.3	0–22
8	80.9	54.3	21–202	19.2	17.7	1–59	26.5	27.3	4–89	7.8	9.5	0–23
9	96.4	56.2	27–192	22.4	18.8	0–55	44.5	29.4	9–106	10.6	9.0	0–29

Note. CV = consonant and vowel.

two-tailed. Thus, infants who vocalized frequently also vocalized frequently during mouthing. Vocalization during mouthing, therefore, was neither a behavior that was characteristic only of younger babies (absent a main effect of age) nor of quieter babies, but of actively vocalizing babies between 6 and 9 months.

Consonant Production

All infants produced vocalizations containing at least one CV: all but 1 in the absence of mouthing and all but 4 in the presence of mouthing.[3] Additionally, all infants produced supraglottal consonants: all but 1 in the absence of mouthing and all but 4 in the presence of mouthing. Supraglottal consonants produced across all ages in both mouthing and nonmouthing vocalizations included [k, g, ŋ, j, t, d, n, l, w, b, m, and f]. Additionally, one or two 8- or 9-month-old infants produced rare instances of the following supraglottal consonants in nonmouthing vocalizations: [ʒ, p, v, r, and θ].

The proportion of CV vocalizations that occurred with mouthing (i.e., number of CV mouthing vocalizations / total mouthing vocalizations; $M = .37$, $SD = .20$) was similar to the proportion of CV vocalizations that did not occur with mouthing ($M = .33$, $SD = .16$), $t(38) = 1.4$, $p < .16$. However, CV vocalizations that co-occurred with mouthing were significantly more likely to contain a supraglottal consonant (i.e., supraglottal CV mouthing vocalizations / total CV mouthing vocalizations; $M = .58$, $SD = .33$) than were CV vocalizations that did not ($M = .46$, $SD = .26$), $t(34) = 2.3$, $p < .05$, $d = .40$.[4] In other words, CV vocalizations produced during mouthing were more likely to contain a consonant formed by the tongue or lips than were nonmouthing CV vocalizations.[5]

Variety in supraglottal consonant production was assessed by comparing type/token ratios of supraglottal consonants to supraglottal CV vocalizations (i.e., number of unique supraglottal consonants / number of supraglottal CV vocalizations) calculated for mouthing versus nonmouthing vocalizations, with larger values reflecting greater variation in consonant production. A paired-samples *t* test indicated a significantly larger ratio of supraglottal consonants to supraglottal CV vocalizations for mouthing vocalizations ($M = .79$, $SD = .46$) than for nonmouthing

---

[3]A relatively small proportion of vocalizations contained CV repetitions ($M = .04$, $SD = .07$).

[4]Infants produced sizeable proportions of mouthing and nonmouthing CV vocalizations with glottal consonants, .42 and .54, respectively (e.g., [hæ]). Thus, production of supraglottal consonants did not appear to be the result of infants' inability to produce glottal consonants in either condition (i.e., mouthing or nonmouthing vocalizations).

[5]Supraglottal CV vocalizations produced during mouthing were more likely to contain labial consonants (i.e., bilabial, labial-dental, and [w], $M = .58$, $SD = .37$) than lingual consonants (i.e., alveolar, palatal, and velar; $M = .41$, $SD = .37$), although the proportions were not statistically different, $t(31) = 1.35$, $p = .19$.

vocalizations (*M* = .55, *SD* = .36), $t(29) = 2.51$, $p < .05$, $d = .58$. Thus, mouthing appears to influence both the likelihood that supraglottal consonants will be produced and the variety with which they occur.

To further investigate the relation between mouthing vocalizations and consonant production, number of vocalization–mouthing co-occurrences was compared with number of unique supraglottal consonants for each infant. Number of co-occurrences was significantly correlated with inventory size, $r = .40$, $p < .05$, two-tailed. Together these findings suggest a possible relation between consonant production and vocal exploration during mouthing.

DISCUSSION

Co-occurrences of vocalization and mouthing were regularly observed among 6- to 9-month-old infants. For infants in this age range, vocalization during the mouthing of objects occurred more frequently than did vocalization during mouthing of the hands and fingers. CV vocalizations that co-occurred with mouthing were more likely to contain supraglottal consonants and variety in supraglottal consonant production than were vocalizations that did not. Supraglottal consonants produced in both conditions were representative of those typically produced by infants in this age range across a variety of languages. Infants typically produce stops, nasals, and glides, in addition to glottal consonants, during the second half of the first year, whereas most other sounds (e.g., fricatives and affricates) are relatively infrequent (see Locke, 1983; Vihman, 1996, for a review).

Given evidence of greater supraglottal consonant variety in mouthing vocalizations, similarities among consonant inventories for mouthing and nonmouthing vocalizations may suggest infants' tendency to vary routinely produced features of consonant articulation (i.e., place, manner, and voicing) during mouthing rather than to explore novel combinations. In fact, rare instances of later developing consonants in nonmouthing vocalizations (i.e., [θ and *r*]) may suggest that some characteristics of consonant articulation are difficult to produce while mouthing.

These results suggest that mouthing may influence consonant features of co-occurring vocalizations by bringing about vocal tract closure, as suggested by Elbers (1982), and by affecting change in articulatory postures in association with object position, shape, and movement. Moreover, the availability of multimodal feedback in mouthing vocalizations may encourage consonant exploration. Thus, mouthing may influence infant vocalizations not only by introducing changes in oral closure and articulatory postures but also by enhancing multimodal feedback.

Exploration

Exploration is guided by the search for information, including information about novelty and sound production (McCall, 1974; Piaget, 1952; Rochat, 1989; Ruff, 1986). Thus, when object mouthing is accompanied by vocalization, infants may engage in two types of exploratory behavior—exploration of objects and of vocalizations—both motivated by the search for information. Encountering novel information increases infants' chances of learning (Bradley-Johnson, Friedrich, & Wyrembelski, 1981; Rochat, 1989; Ruff, 1984) and contributes to cognitive and perceptual development (Bradley-Johnson et al., 1981; Ruff, 1984). Through exploration, therefore, infants play an active role in developmental change (Spencer et al., 2000).

Interactions between exploration and development are reflected in evidence of reduced mouthing in infants at risk for developmental delay. For example, infants with Down syndrome spent less time mouthing novel objects than did typically developing infants (Bradley-Johnson et al., 1981), duration of mouthing episodes was shorter among preterm infants than full-term infants (Kopp, 1976), and newborn infants of depressed mothers spent 50% less time orally exploring objects than did infants of nondepressed mothers (Hernandez-Reif, Field, del Pino, & Diego, 2000).

Multimodal Feedback

Infants' multimodal exploration of objects (Rochat, 1989) and interest in contingent sounds (McCall, 1974) suggest that infants may also engage in multimodal exploration of vocalizations. In the same way that infants explore interactions between sound-making affordances of objects and table surfaces (Palmer, 1989), they may explore interactions between sound-making affordances of objects and vocalizations. Because actions on objects reveal something about what infants perceive (Palmer, 1989), frequent co-occurrences of mouthing and vocalization may indicate interest in the effects of mouthing on vocalization. In fact, the most salient characteristic of activities that engage infants' attention may be the potential to provide perceptual consequences (McCall, 1974).

Multimodal aspects of the perception–action loop, especially proprioceptive feedback, warrant increased attention (Thelen, 1989). Multimodal aspects of vocalizations that co-occur with mouthing may contribute to the development of consonant information. Infants demonstrate cross-modal sensitivity to adults' vowel vocalizations at 4.5 months, looking longer to films of talkers articulating vowels that matched auditorily presented stimuli than to films that did not (Kuhl & Meltzoff, 1982, 1984; Patterson & Werker, 1999). At around the same age, infants also begin to imitate vowels they hear (Kuhl & Meltzoff, 1996). That infants recognize that sounds correspond to movements suggests that speech information is intermodally represented (Kuhl & Meltzoff, 1984). Additional research is needed to test possible relations between mouthing and cross-modal sensitivity to consonant perception and imitation.

In summary, these findings lend further support to the idea that mouthing is an effective mechanism of exploration for 6- to 9-month-old infants and suggest that it may play a role in infants' exploration of their own vocalizations. Although infants likely explore vocalizations produced both with and without mouthing, mouthing may uniquely influence co-occurring vocalizations in a way that facilitates consonant exploration. The information that infants gather during exploration of mouthing vocalizations may thus contribute to speech development as well as to perceptual and cognitive development.

ACKNOWLEDGMENTS

Mary Fagan is now at Indiana University.

Portions of this work were presented at the biennial meeting of the International Society on Infant Studies, Chicago, May 2004. This research was supported in part by grants from the University of Missouri Research Board and from the National Institutes of Health (R01 HD41607) to Jana Iverson. We thank Karin Clauss, Shanna Irvin, Jeanine Jesberg, Ashley Paluska, and Tracy Warnecke for assistance with data collection and reliability.

REFERENCES

Belsky, J., & Most, R. J. (1981). From exploration to play: A cross-sectional study of infant free play behavior. *Developmental Psychology, 17,* 630–639.

Bradley-Johnson, S., Friedrich, D. D., & Wyrembelski, A. R. (1981). Exploratory behavior in Down's syndrome and normal infants. *Applied Research in Mental Retardation, 2,* 213–228.

Ejiri, K., & Masataka, N. (2001). Co-occurrence of preverbal vocal behavior and motor action in early infancy. *Developmental Science, 4,* 40–48.

Elbers, L. (1982). Operating principles in repetitive babbling: A cognitive continuity approach. *Cognition, 12,* 45–63.

Fagan, M. K. (2005). *Trends in mean length of utterance before words and grammar.* Unpublished doctoral dissertation, University of Missouri, Columbia, MO.

Fenson, L., Kagan, J., Kearsley, R. B., & Zelazo, P. R. (1976). The developmental progression of manipulative play in the first two years. *Child Development, 47,* 232–236.

Gibson, E. J., & Walker, A. S. (1984). Development of knowledge of visual-tactual affordances of substance. *Child Development, 55,* 453–460.

Hernandez-Reif, M., Field, T., del Pino, N., & Diego, M. (2000). Less exploring by mouth in newborns of depressed mothers. *Infant Mental Health Journal, 21,* 204–210.

Holmgren, K., Lindblom, B., Aurelius, G., Jalling, B., & Zetterstrom, R. (1986). On the phonetics of infant vocalization. In B. Lindblom & R. Zetterstrom (Eds.), *Precursors of early speech* (pp. 51–63). New York: Stockton Press.

Koopmans-van Beinum, F. J., Clement, C. J., & van den Dikkenberg-Pot, I. (2001). Babbling and the lack of auditory speech perception: A matter of coordination? *Developmental Science, 4,* 61–70.

Kopp, C. B. (1976). Action-schemes of 8-month-old infants. *Developmental Psychology, 12,* 361–362.

Kuhl, P. K., & Meltzoff, A. N. (1982). The bimodal perception of speech in infancy. *Science, 218,* 1138–1141.

Kuhl, P. K., & Meltzoff, A. N. (1984). The intermodal representation of speech in infants. *Infant Behavior and Development, 7,* 361–381.

Kuhl, P. K., & Meltzoff, A. N. (1996). Infant vocalizations in response to speech: Vocal imitation and developmental change. *Journal of the Acoustic Society of America, 100,* 2425–2438.

Locke, J. L. (1983). *Phonological acquisition and change*. New York: Academic.

Lynch, M. P., Oller, D. K., Steffens, M. L., Levine, S. L., Basinger, D. L., & Umbel, V. M. (1995). Development of speech-like vocalizations in infants with Down syndrome. *American Journal of Mental Retardation, 100,* 68–86.

McCall, R. B. (1974). Exploratory manipulation and play in the human infant. *Monographs of the Society for Research in Child Development, 39*(2, Serial No. 155).

Meltzoff, A. N., & Borton, R. W. (1979). Intermodal matching by human neonates. *Nature, 282,* 403–404.

Nathani, S., & Oller, D. K. (2001). Beyond ba-ba and gu-gu: Challenges and strategies in coding infant vocalizations. *Behavior Research Methods, Instruments, & Computers, 33,* 321–330.

Oller, D. K. (2000). *The emergence of the speech capacity*. Mahwah, NJ: Lawrence Erlbaum Associates, Inc.

Palmer, C. F. (1989). The discriminating nature of infants' exploratory actions. *Developmental Psychology, 25,* 885–893.

Patterson, M. L., & Werker, J. F. (1999). Matching phonetic information in lips and voice is robust in 4.5-month-old infants. *Infant Behavior and Development, 22,* 237–247.

Piaget, J. (1952). *The origins of intelligence in children* (M. Cook, Trans.). New York: International Universities Press.

Rochat, P. (1989). Object manipulation and exploration in 2- to 5-month-old infants. *Developmental Psychology, 25,* 871–884.

Ruff, H. A. (1984). Infants' manipulative exploration of objects: Effects of age and object characteristics. *Developmental Psychology, 20,* 9–20.

Ruff, H. A. (1986). Components of attention during infants' manipulative exploration. *Child Development, 57,* 105–114.

Ruff, H. A., Saltarelli, L. M., Capozzoli, M., & Dubiner, K. (1992). The differentiation of activity in infants' exploration of objects. *Developmental Psychology, 28,* 851–861.

Spencer, J. P., Vereijken, B., Diedrich, F. J., & Thelen, E. (2000). Posture and the emergence of manual skills. *Developmental Science, 3,* 216–233.

Thelen, E. (1989). The (re)discovery of motor development: Learning new things from an old field. *Developmental Psychology, 25,* 946–949.

Vihman, M. M. (1996). *Phonological development: The origins of language in the child*. Cambridge, MA: Blackwell.

Whyte, V. A., McDonald, P. V., Baillargeon, R., & Newell, K. M. (1994). Mouthing and grasping of objects by young infants. *Ecological Psychology, 6,* 205–219.

Witherington, D. C. (2005). The development of prospective grasping control between 5 and 7 months: A longitudinal study. *Infancy, 7,* 143–161.

Zelazo, P. R., & Kearsley, R. B. (1980). The emergence of functional play in infants: Evidence for a major cognitive transition. *Journal of Applied Developmental Psychology, 1,* 95–117.