Developmental Science 7:1 (2004), pp 42–47

REPORT

Auditory–oral matching behavior in newborns

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Abstract

Twenty-five newborn infants were tested for auditory–oral matching behavior when presented with the consonant sound /m/ and the vowel sound /a/ – a precursor behavior to vocal imitation. Auditory–oral matching behavior by the infant was operationally defined as showing the mouth movement appropriate for producing the model sound just heard (mouth opening for /a/ and mouth clutching for /m/), even when the infant produced no sound herself. With this new dependent measure, the current study is the first to show matching behavior to consonant sounds in newborns: infants showed significantly more instances of mouth opening after /a/ models than after /m/ models, and more instances of mouth clutching after /m/ models than after /a/ models. The results are discussed in the context of theories of active intermodal mapping and innate releasing mechanisms.

Introduction

The question whether young infants are capable of imitating other people's actions has been long debated among infancy researchers (e.g. Field, Woodson, Greenberg & Cohen, 1982; Fontaine, 1984; Heimann, 1998; Kuhl & Meltzoff, 1982, 1996; Kugiumutzakis, 1999; Meltzoff & Moore, 1977, 1983a; Uzgiris, 1981). Interest in this question is due to the status of imitation as one of the milestones in social-cognitive development: early imitation reveals primitive forms of infants' understanding of self and other persons, of equivalence relations between own and others' actions. Early imitation has been proposed as one of the driving forces in the development of intersubjectivity and an understanding of mental states (Meltzoff & Moore, 1998). Moreover, the capacity for imitation, especially for vocal imitation, is considered as a prerequisite for language acquisition (Rodgon & Kurdek, 1977).

Many studies have revealed imitative responses to certain kinds of adult behaviors in very young infants. In a study by Meltzoff and Moore (1977) infants younger than 1 month imitated three facial gestures: lip protrusion, mouth opening and tongue protrusion, as well as sequential finger movements. Another study (Meltzoff & Moore, 1983a) showed that even newborns from 42 minutes to 71 hours successfully imitated mouth opening and tongue protrusion. This finding was confirmed and extended by Kugiumutzakis (1999) who found imitation of mouth opening, tongue protrusion and blinking even in 45-minute-old newborns. Newborn infants also imitate facial expressions such as happiness, sadness and surprise (Field *et al.*, 1982). Overall, it seems that imitation of some facial behaviors by young infants is robust soon after birth.

However, there are at least two ways to interpret these findings. On a lean account of these data, the matching responses shown by young infants are not imitations in the proper sense, but rather behaviors triggered by an innate releasing mechanism (IRM; Lorenz & Tinbergen, 1938/1970; Tinbergen, 1951). According to this construal, facial behaviors like tongue protrusion are triggered in certain specific situations, for example in situations where an object is approaching the infant. The data on neonatal matching behaviors to facial gestures do then not show something about imitative abilities, but rather about specific releasing mechanisms. Support for this position comes, for example, from Jacobson (1979; see also Anisfeld, 1991; Jones, 1996) who found that moving a felt-tip pen or a small ball toward the face of 6-week-olds could elicit their tongue protrusion responses in a similar way as tongue protrusion models provided by an adult.

The second, rich interpretation of the data argues that the infant matching behavior is proper imitation.

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According to this construal, an innate releasing mechanism theory is unable to account for the wide range of adult behaviors to which young infants show matching behavior (e.g. Meltzoff & Moore, 1983a, 1983b, 1989). The reason for the failure of the IRM theory is that separate releasing mechanisms would have to be posited for each type of matching behavior, and that this would amount to a very unparsimonious and implausible explanation. As an alternative, Meltzoff and Moore (1983a, 1983b, 1989) propose an active intermodal mapping (AIM) account: newborns are able to coordinate and integrate information from different sensory modalities, and understand the equivalence between body transformations they see and body transformations of their own felt proprioceptively.

Imitation of vocal sounds presents an interesting test case for these two competing positions: if young infants can be shown to imitate sounds in a differential and systematic way, this would speak against a simple releasing mechanism explanation, because it is implausible to assume a releasing mechanism for each sound pattern. Furthermore, vocal imitation is interesting due to its prominent role in language development.

Studies with older infants have found that there is a significant positive relationship between vocal imitation and vocabulary development (Rodgon & Kurdek, 1977) and that early imitators are better at language acquisition than late imitators (Nelson, 1973). In studies with young infants some evidence was found for early vocal imitation. Three-month-old infants could be shown to mimic the vowels /a/, /i/ and /u/ (Kuhl & Meltzoff, 1982, 1996). One study presented young infants also with consonants (Kugiumutzakis, 1999) and found that 2 months after birth, infants could imitate the vowel sound /a/, the consonant sound /m/ and the vowel-consonant combination sound /ang/, whereas newborns only imitated /a/, but not /m/ and /ang/. The data on vocal imitation in young infants are interpreted by Kuhl and Meltzoff (1996) along the lines of the rich AIM interpretation: they posit an internalized auditory-articulatory 'map' that specifies the relations between mouth movements and sounds. This 'map' leads infants to recognize the relationship between their own articulatory movements and the sounds they hear.

In the present work we wanted to replicate and extend the findings on neonatal imitation of adult vocal behaviors by presenting newborns with adult vowel and consonant sound models. Existing studies on vocal imitation in young infants have convergingly demonstrated imitation of vowel sounds only, but it remains less clear whether and when infants imitate consonant sounds. For example, the studies by Kuhl and Meltzoff (1982, 1996) did not provide consonant sounds as stimuli at all. The study by Kugiumutzakis (1999) failed to show that newborns could imitate consonant sounds. These negative findings, however, might be false negatives due to methodological artifacts: the criterion for an imitative response by the infant in this study was that the infant had to emit vocalization that clearly contained the sounds /a/, /m/ or /ang/, respectively. However, in preliminary observations, we found that infants did not systematically emit clear sounds unless associated with crying or feeding. Accordingly, Kugiumutzakis' criteria might have been too demanding for newborns. Performance factors, above all an immature articulatory system in newborns, may be responsible for negative results with this methodology. In the present study, therefore, we did not take infants' vocalization as dependent measure. Rather we scored infants' mouth movements as a reaction to a consonant and a vowel sound and analyzed the production of auditory–oral matching behavior – an important precursor to vocal imitation. Auditory–oral matching behavior was operationally defined as performance of a mouth movement appropriate for producing the adult model sound.

Method

Participants

Twenty-five infants took part in the study (15 males and 10 females, age range = 24 hours to 7 days, mean age = 3 days). All infants were healthy, without diagnosed health problems, and had at least 36 weeks gestation. They all had a 1 and 5 minute Apgar score of 7 or higher. The testing room was quiet. All infants were tested on average 1 hour after feeding. Six additional infants were tested, but they were excluded from future analysis because of upset status ($n = 3$), or experimenter error ($n = 3$). Infants were all in an active state during testing and they responded at least once during each condition.

Procedure

A female experimenter (E) sat on a chair, and held the newborn in an almost upright position with one hand supporting his/her head, another holding his/her torso. The infant's face was about 30 cm from the experimenter's face. A digital video camera (JVC, model GR-DVL 109) was placed behind the experimenter. Another experimenter adapted the zoom to make sure the infant's face was clearly captured. During testing, E evaluated the infant's alertness status. All infants were alert during the experiment, even if they closed their eyes, all performed movements and responded at least once per condition.

Table 1 *Process of the experiment*

/a/ (4 sec.)	Interval (1 sec.)	Repeat 4 times, which forms a trial (20 sec.)	Repeat the trial 8 times	/m/ (4 sec.)	Interval (1 sec.)	Repeat 4 times, which forms a trial (20 sec.)	Repeat the trial 8 times

Figure 1a *Mouth opening.*

Figure 1b *Mouth clutching.*

Each infant was presented with two sounds: /a/ and /m/. Each sound was presented in a soft and stable way, and lasted 4 seconds. The interval between sounds was 1 second. The experimenter made /a/ or /m/ successively for 4 times, which formed one trial. Each trial was 20 seconds long. The interval between trials was 25 seconds. If the infants were upset, or yawned, or sneezed, the time between trials was longer since the experimenter waited until the infants had calmed down. Twelve of 19 infants received the stimuli with the order /m/ – /a/; the remainder ($n = 7$) received the reverse order. Each infant was presented with 8 trials for each condition. Nine infants received additional trials because during the experiment they were upset or tired. The trials in which the infant was not in the appropriate status were excluded from future analysis. In the final analysis, each infant had 8 trials for each condition. The process of the experiment is shown in Table 1.

Response measures and coding

All videotapes of the infant's face were coded by an experimenter, blind to the hypotheses. We coded the infant's mouth movements in response to the vocal model only, with the sound off, and irrespective of the sounds the infant emitted. We counted as auditory–oral matching responses mouth movements by the infant that were appropriate to produce the model sound. That is, mouth opening was counted as matching behavior to /a/, and mouth clutching was counted as matching behavior to /m/.

A behavioral event was coded as a mouth opening when the infant's lips opened from their resting position and then went back to the resting position (see Figure 1a). An instance of mouth clutching was scored when the infant closed her mouth tightly and then released it into the loose resting position; or when the infant moved her lips back and forth once (see Figure 1b).

Mouth movements that occurred periodically as part of yawning, sneezing and sucking were not included. Following Kugiumutzakis (1999), responses were only coded immediately during the 4 seconds of presentation of the model. The response period was marked and established by a digitized counter on the VCR. The number of mouth openings and mouth clutchings in each trial was determined, and then the sum of mouth openings and mouth clutchings was computed for each infant over the 8 trials of each condition.

A second coder, unaware of the hypotheses and blind as to the conditions of the study, coded a random sample of 26% of the tapes for reliability. Pearson correlations were used to assess the reliability. The r's for the interobserver assessments were as follows: frequency of mouth opening to /a/, .994; frequency of mouth opening to /m/, .974; frequency of mouth clutching to /m/, .980; frequency of mouth clutching to /a/, .942.

Results

Since 12 infants received the /m/ stimuli first and 7 infants the /a/ stimuli first, we checked for order effects. Mann-Whitney tests revealed that there were no differences between these two groups with respect to their matching responses (over 8 trials) both to /m/ and to /a/ ($ps > .30$). During the experiment, some infants opened their eyes ($n = 6$), others kept their eyes closed ($n = 13$). Infants generally kept their eyes open or closed for all trials. In the event that the infant changed the state of the eyes during testing, he/she was categorized according to the overall state (eyes open or closed) during testing. Reliability on the infants who had eyes opened or closed was performed on a random 36% of infants and was 100%.

Table 2 shows the mean numbers of mouth opening and mouth clutching (summed over 8 trials per condition) as a function of condition and of whether the eyes were open or closed. In both subgroups infants showed significantly more often mouth opening after /a/ models than after /m/ models, and significantly more often mouth clutching after /m/ than after /a/ models, as revealed by Wilcoxon Signed Rank Tests (see the corresponding *z*- and *p*-values in Table 2). Furthermore, Mann-Whitney U-tests revealed that there was no difference in matching responses between the infants with open eyes and those with closed eyes ($ps > .25$ both for matching responses to /a/ and to /m/). Therefore in further analyses the data of these two groups of infants were collapsed.

Figure 2 shows – for the whole sample – the mean frequencies of infants' mouth opening and mouth clutching on the 8 /m/ and the 8 /a/ trials. Wilcoxon Signed Rank Tests revealed that infants showed significantly more often mouth opening after /a/ models than after /m/ models ($z = -3.67$, $p < .001$), and significantly more often mouth clutching after /m/ than after /a/ models ($z = -3.25$, $p < .001$).

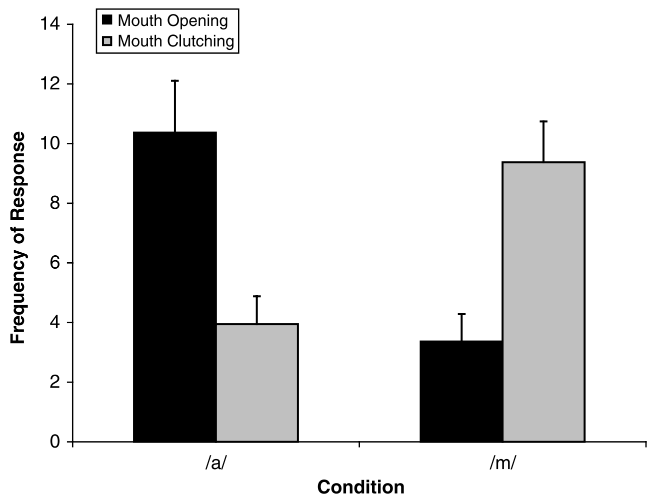

Figure 2 *Mean frequencies of mouth opening and mouth clutching responses (summed over 8 trials) as a function of model condition.*

We also examined the response patterns of the infants individually. Each individual infant could produce a greater frequency of mouth openings to /a/ condition (+), to /m/ condition (–), or same to both conditions (0). Similarly, each infant could produce a greater frequency of mouth clutching to /m/ condition (+), to /a/ condition (–), or same to both conditions (0). The numbers of infants producing one of the possible combinations of these response patterns are shown in Table 3. A one-sample χ^2 test revealed that the frequency distributions differed from chance, exact $\chi^2 = 78.20$, df = 8, $p < .0001$.

Then we checked the number of infants falling into two most extreme cells (++ vs. ––). The infants in the (++) cell consistently gave matched response to both conditions; the infants in the (––) cell consistently gave mismatched response to both conditions. Under the null hypothesis, the probability that infants fall into one or the other of these two response types is equal. The result

Table 2 *Mean number of responses (summed over 8 trials per condition) as a function of condition and corresponding z-scores in infants with eyes open and eyes closed*

	Eyes open ($n = 6$)			Eyes closed ($n = 13$)		
Response	mean	*z*-score	*p* value	mean	*z*-score	*p* value
Mouth opening to /a/	12.33	–2.207	.027	9.46	–2.977	.003
Mouth opening to /m/	7.5			1.46		
Mouth clutching to /m/	7.17	–2.023	.043	10.38	–2.489	.013
Mouth clutching to /a/	1.5			5.08		

Table 3 *Number of infants displaying each of the possible response patterns for the frequency measure*

Response pattern	++	+0	0+	+−	−+	0−	−0	00	−−	Total
N	14	1	0	2	2	0	0	0	0	19

Note: The response patterns are shown as ordered pairs describing the two infant responses: mouth openings, and mouth clutching; '+' means infant responded more often to the matching stimulus than to the mismatching stimulus; '–' means infant responded more often to the mismatching stimulus than to the matching stimulus; '0' means infant responded equally often to both stimuli.

indicates that there were 14 infants in the (++) cell and no infants in the (−−) cell (see Table 3).

Discussion

The results of the present study show that newborns can perform an important precursor behavior to vocal imitation under certain laboratory conditions. The newborns produced significantly more mouth openings to /a/ condition than to /m/ condition and more mouth clutching to /m/ condition than to /a/ condition. That is, newborn infants showed the corresponding mouth movements to both vowel and consonant vocal models. These data confirm and extend the findings by Kuhl and Meltzoff (1982) that 3–4-month-old infants can imitate vowel sounds.

The present findings extend the results reported by Kugimutzakis (1999). In that study it was found that newborns clearly imitated /a/, but not /m/ and /ang/. Kugiumutzakis suggested that performance factors might have played a role in the negative findings regarding /m/ and /ang/: it might have been too difficult for newborns to emit consonant and vowel-consonant sounds. The emission of the sounds /m/ and /ang/ requires neuromuscular control of the front part of the mouth, and the newborn's vocal system may not yet be mature enough to do this. Therefore, in the present study we used a procedure and coding system that differed from Kugiumutzakis' in some specific ways: Kugiumutzakis decided to stop the modeling once the infant started reproducing the model or emitted other scored responses. In this way, infants were provided with different numbers of trials. The procedure was stricter in our study. Each infant received the same number of trials. Moreover, we used a fundamentally different coding system: instead of infants' vocalization of the model sound, we coded the mouth movements appropriate for producing the model sound. With this revised methodology we found that even newborns could show matching behavior to both vowel and consonant sounds.

The present data provide new evidence in favor of the AIM interpretation of early matching behavior. If the production of matching sounds to a model was mediated by an IRM, there should be several processes for different sounds. However, the patterns of matching behavior after each of the two models are systematic and very similar in proportion. It would thus seem rather implausible to posit two different releasing mechanisms that happen to elicit similar proportions of matching behavior. Rather it is more plausible and parsimonious to account for the findings in terms of a unified underlying intermodal mapping.

The findings of the present study also fit nicely with other work on neonatal and early infant imitation. Meltzoff and Moore (1977) reported that 2- to 3-week-olds imitated three oral gestures, and one manual gesture. Another experiment (Meltzoff & Moore, 1983a) demonstrated that newborns imitated two facial acts. Field *et al.* (1982) showed that newborns with an average age of 36 hours could discriminate and imitated three facial expressions (happy, sad, surprised). Overall, these studies and the present data provide converging evidence for an AIM construal of early imitation.

Another interesting finding of this study is that there was no difference in the performance of matching mouth movements between infants who closed their eyes during the model and those who had their eyes open. In other words, it did not matter whether the infants saw the adult's mouth shape or not during the model. This is even more convincing evidence in favor of an AIM explanation (see also Meltzoff & Moore, 1997) because it suggests that newborns can map perceived sounds onto corresponding mouth movements, even if they have not seen these mouth movements in others. It is thus likely that infants possess some kind of auditory-articulatory 'map' (Kuhl & Meltzoff, 1996) from birth. The current research suggests that newborn infants are able to match oral behaviors. Such ability is a likely precursor to more mature forms of vocal imitation and language production in general. Future longitudinal studies are needed to investigate the potential link between auditory–oral matching behaviors and developing imitation capacities.

Acknowledgements

We would like to thank Kerstin Traeger, Jennifer Speares, Felizitas Schmaus, Kristin Liebal and Julian Heister for help with participant recruitment, data collection and coding. Thank you to the staff of the Universitäts Frauenklinik in Leipzig for their support and for help with participant recruitment. We are grateful also to the families who participated in the study.

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Received: 5 September 2002
Accepted: 24 January 2003