



# Imitation of "bye-bye" in very low-birth weight infants.

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Imitation is an important human behavior that facilitates learning and promotes the acquisition of social cognition. This ability is reportedly associated with social interactions and empathy.<sup>1</sup> Imitative behavior appears to emerge from the acquisition of different kinds of knowledge, and motor, cognitive and social skills. Therefore, the ability to imitate is important in the estimation of the developmental state of infants.

Recent studies have shown that the human ability to imitate is innate. Newborn infants can imitate simple behaviors such as tongue protrusion.<sup>2</sup> Abravanel and Sigafos have shown that newborn infants repeatedly match a human model's tongue protrusions in imitation experiments.<sup>3</sup> Imitation of the oral gestures of adults is especially dependent on an inbuilt knowledge.<sup>3,4</sup> It was reported that this ability is afforded by the human mirror system.<sup>1,5</sup> The mirror system matches the visual input from an observed action directly using a stored motor program for the same behavior. The imitation circuitry is composed of the posterior part of the superior temporal sulcus, the rostral part of the inferior parietal lobule, and the posterior part of the inferior frontal gyrus and adjacent ventral premotor cortex.<sup>6</sup>

The ability to imitate develops throughout infancy. 'Bye-bye' is a typical imitative behavior in infancy. Newborn infants cannot imitate the bye-bye gesture because it requires the development of the manual motor skill and visual system for complete corrective behavior. This behavior usually appears between 10 and 12 months of age, and the time of appearance of the bye-bye gesture has been used as a developmental milestone during infancy.<sup>7</sup>

It is well known that very low-birthweight (VLBW) infants exhibit great risk in the development of speech, motor skills, and visual-perceptual abilities. Human newborns have pre-wired mirror neuron systems that contribute to development during infancy.<sup>2</sup> Problems that occur in the neonatal period may affect the development of these systems. The human brain develops so rapidly during the late intrauterine and early postnatal periods that early exposure to the extrauterine environment can hinder the formation of the neural network.<sup>8</sup> In addition, Marín Gabriel et al. reported that both persistent low weight and small head circumference are correlated with retardation of various motor skills.<sup>9</sup> There is a possibility that the immature formation of the neural network leads to a delay in the imitation of others, such as bye-bye, but little is known about the development of imitation behaviors in VLBW infants.

The aims of this study were to clarify when VLBW infants begin to imitate bye-bye and how their hand motions develop as compared with full-term infants. The information obtained in this study might be useful to understand the development of imitation skills in VLBW infants.

## Methods

Five hundred and ninety-seven full-term infants with typical development (306 boys and 291 girls; age, 6–21 months; mean age,  $10.8 \pm 3.2$  months) and 95 VLBW infants (49 boys and 46 girls; corrected age, 6–21 months; mean age,  $13.0 \pm 4.0$  months) participated in this study. Full-term infants were followed at the Well-Baby Check-Ups, Kobe Palmore Hospital. Their gestational age was between 38 and 42 weeks, with a size that was appropriate for gestational age (birthweight, 2500–3500 g). None of them exhibited abnormalities in development at 2 years of age. VLBW infants who participated in the family support programs of Kobe University were enrolled in this study.

Infants were excluded if they had periventricular leukomalacia, or chromosomal abnormalities. We confirmed that none of the VLBW infants had mental, sensory or motor retardation through follow up until 2.5 years of age. They were born at gestational age 22–35 weeks (mean,  $28.7 \pm 2.8$  weeks) with a birthweight <1500 g (mean,  $1052 \pm 289$  g; range, 433–1498 g). Among the 95 VLBW infants included in the study, 33 infants were light for birth date, and there were nine twin pairs (Table 1).

Gestational age and birthweight were confirmed by medical records at the neonatal intensive care unit and the maternal and child health handbooks. None of the mothers had a history of being treated for behavior problems, or diagnosis of developmental disorders. We investigated the time at which the infants began to imitate bye-bye and how they moved their hands by direct observation and interview with the mothers. We also recorded bye-bye hand motions in 358 full-term infants (mean age,  $12.5 \pm 2.8$  months) and 61 VLBW infants (mean age,  $14.8 \pm 3.6$  months). We observed near the exit of the rooms in which the Well-Baby Check-Ups or family support programs were carried out. After completion of the check-ups or programs, the researchers stood at the same location and said good-bye to them orally with a hand motion of waving bye-bye several times. The behaviors of the infant responding to their motions were confirmed by direct observation and recording with an 8 mm video camera (Digital video camera FV-M1, Canon) for more than 5 min. Differences in categorical measures (the prevalence of bye-bye and of the first type of hand motions) between the two groups were analyzed using  $\chi^2$  test. The mean age of appearance of bye-bye in the two groups was compared using Mann–Whitney U-test. Statistical significance was set at  $P < 0.05$  for all tests. Statistical analysis was performed using IBM SPSS Statistics ver.19 (IBM Japan, Tokyo, Japan).

We provided all parents with a full account of the purposes and methods of this study and obtained their agreement to participate. The study was approved by the medical ethics committee of Kobe University Graduate School of Health Sciences.

Table 1 VLBW infant demographic details

	Boys (n = 49)	Girls (n = 46)	Total (n = 95)
	Mean $\pm$ SD or n (%)	Mean $\pm$ SD or n (%)	Mean $\pm$ SD or n (%)
Corrected age (months)	13.0 $\pm$ 4.2	13.0 $\pm$ 3.8	13.0 $\pm$ 4.0
Gestational age (weeks)	28.4 $\pm$ 2.4	29.0 $\pm$ 3.1	28.7 $\pm$ 2.8
Birthweight (g)	1060 $\pm$ 281	1043 $\pm$ 299	1052 $\pm$ 289
LFD	14 (28.6)	19 (41.3)	33 (34.7)
Twins	4 (16.3)	5 (21.7)	9 (18.9)

LFD, light for date; VLBW, very low-birthweight.

## Results

The prevalence and the mean age of appearance of bye-bye in the two groups are shown in Figure 1. Full-term infants began to imitate bye-bye at 9 months of age (mean age,  $9.8 \pm 1.9$  months). In contrast, VLBW infants started to imitate this gesture at 10 months of corrected age (mean age,  $10.6 \pm 2.5$  months). The time of the initial appearance of bye-bye in VLBW infants was significantly later compared with term infants ( $P < 0.05$ ). The passage ratio of bye-bye in full-term infants was 36.6% at 9 months, 61.4% at 10 months, 76.9% at 11 months, 91.8% at 12 months, and 100% above 16 months old. In contrast, in VLBW infants the passage ratio was 18.2% at 9 months, 42.9% at 10 months, 66.7% at 11 months, and 57.1% at 12 months of age. Although the behavior of bye-bye appeared significantly later in VLBW infants ( $P < 0.01$ ), all VLBW infants older than 17 months were able to perform the motion.

The behavior of bye-bye was observed directly in 358 fullterm infants and 61 VLBW infants. The hand motion was divided into five types according to video analysis. The types were ‘palm facing others’, ‘moving wrist up and down’, ‘turning palm round and round’, ‘palm facing them’, and ‘other ways’ (Fig. 2). The motion type at the initial bye-bye in full-term infants was ‘palm facing others’ in 20.4%, ‘moving wrist up and down’ in 37.2%, ‘turning palm round and round’ in 18.4%, ‘palm facing them’ in 11.7%, and ‘other ways’ in 12.3% of cases (Table 2). The motion type ‘moving wrist up and down’ was observed most frequently in the youngest children and their hand motion type changed from 9 to 16 months of age. All of these children were able to imitate ‘palm facing others’ at 16 months old (Table 3).

In contrast, the motion type at the initial bye-bye in VLBW infants was ‘palm facing others’ in 22.9%, ‘moving wrist up and down’ in 62.3%, ‘turning palm round and round’

in 3.3%, 'palm facing them' in 3.3%, and 'other ways' in 8.2% of cases (Table 2). There were significant differences between the two groups. VLBW infants imitated the bye-bye gesture of others using the 'moving wrist up and down' motion more frequently than did full-term infants ( $P < 0.01$ ). Conversely, they moved their hands using the 'turning palm round and round' motion less frequently than did full-term infants ( $P < 0.01$ ). The 'palm facing them' motion was observed in 11.7% of full-term infants (mean age,  $10.3 \pm 1.9$  months) and 3.3% of VLBW infants (mean age,  $10.5 \pm 0.7$  months;  $P < 0.05$ ).

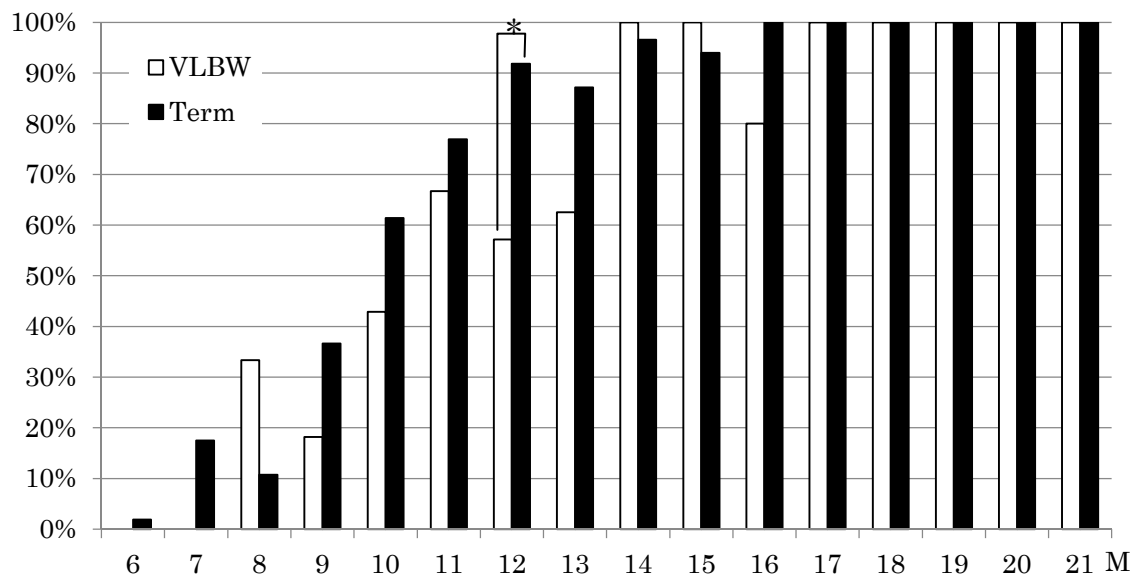


Fig. 1 Prevalence of bye-bye waving in (■) term and (□) very low-birthweight infants. \* $P < 0.05$ .

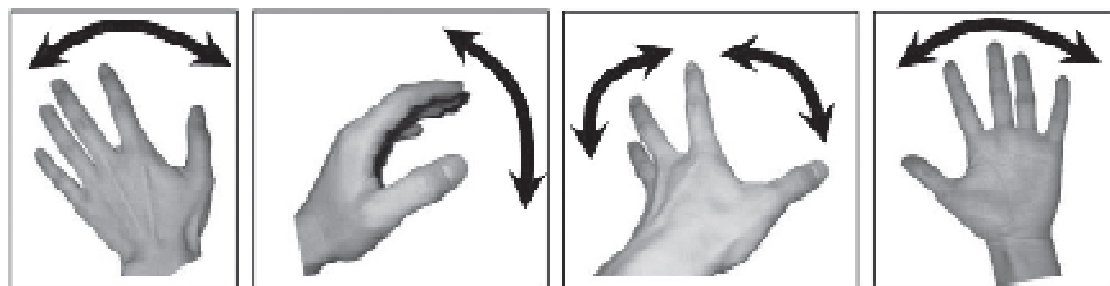


Fig. 2 Types of bye-bye waving motions: (a) palm facing others; (b) moving wrist up and down; (c) turning palm round and round; (d) palm facing them.

Table 2 Initial bye-bye motion vs length of gestation

Type of hand motion	Term (n = 358) (%)	VLBW (n = 61) (%)	P
Palm facing others	20.4	22.9	
Moving wrist up and down	37.2	62.3	**
Turning palm round and round	18.4	3.3	**
Palm facing them	11.7	3.3	*
Other ways	12.3	8.2	

\* $P < 0.05$ , \*\* $P < 0.01$ . VLBW, very low-birthweight.

**Table 3 Change in type of bye-bye motion with age in full-term infants**

Type of hand motion	9 months (n = 49) (%)	10 months (n = 35) (%)	11 months (n = 30) (%)	12 months (n = 90) (%)	13 months (n = 34) (%)	14 months (n = 28) (%)	15 months (n = 31) (%)	16 months (n = 8) (%)
Palm facing others	22.4	25.7	40.0	45.6	47.1	60.7	80.6	100
Moving wrist up and down	34.7	45.7	33.3	33.3	29.4	17.9	6.5	0
Turning palm round and round	24.5	11.4	10.0	3.3	11.8	0	12.9	0
Palm facing them	8.2	0	10.0	11.1	2.9	14.3	0	0
Other ways	10.2	17.1	6.7	6.7	8.8	7.1	0	0

## Discussion

In the present study full-term infants started to imitate bye-bye at around 9 months age. Bye-bye behavior is a fundamental imitation behavior that has been observed frequently in infancy. Jones reported that infants could imitate others' bye-bye gestures at approximately 10–12 months of age.<sup>7</sup> Using the Japanese version of the Denver Development Screening Test, a passage ratio of bye-bye of 50% was noted at 9 months, 75% at 11 months, and 90% at 13 months of age.<sup>10</sup> The present results are consistent with those of previous reports. In contrast, VLBW infants (at a corrected age) exhibited a delay of 1 month in starting to imitate bye-bye compared with full-term infants. Most of the full-term infants could imitate bye-bye at 12 months of age, but only approximately half of the VLBW infants could do this at the same age. The passage ratio of bye-bye in VLBW infants was constantly lower than that of term infants in early infancy, and there was a significance difference between the two groups at 12 month of age. Normal infants usually develop fine and gross motor skills dramatically at around 12 month of age. The difference of the passage ratio was considered to be more distinct due to the different peak period of fine motor development in the two groups. The present VLBW infants did not seem to suffer from permanent delays in imitation ability, because all of them were able to imitate waving bye-bye by the age of 17 months. Dewey et al., however, reported that the prevalence of motor impairment in extremely low-birthweight children at age 5 years was 64% on the Movement ABC.<sup>11</sup> Further follow-up is required to clarify the clinical significance. Here, the development of the ability to imitate bye-bye was delayed in VLBW infants even after correction for gestational age. Imitative behaviors such as bye-bye require the ability to perceive others' hand motions and to change self-motion from visual information. VLBW children were reported to be at high risk regarding the development of cognitive, fine motor and behavioral functions, even if they had no major neurological problems.<sup>9, 12–14</sup>

In the present observational study, hand motion during bye-bye waving was divided into four major types: 'palm facing others', 'moving wrist up and down', 'turning palm round and round', and 'palm facing them.' The wrist joint is the complex joint formed between the distal ends of the radius and ulna. The movements permitted in this joint are flexion, extension, pronation, supination, radial deviation, and ulnar deviation anatomically. The 'moving wrist up and down' motion reflects the movement of flexion and extension. The 'turning palm round and round' motion reflects the movements of pronation and supination. The motion that reflects the movements of radial and ulnar deviations was divided into two forms, 'palm facing others' and 'palm facing them', depending on the direction of the palm. It is well known that bye-bye using the 'palm facing them' form is often observed in children with autism. It has been reported that children with autism have deficits in the visual perception.<sup>15</sup> We consider that the difference of the direction of the palm is related to the development of visual perception. We also defined the 'other ways' motion for movement that could not be specified.

The hand movements of deviation from ulnar side to radial side, pronation and supination require fine coordination of the elbow joint, while the movements of flexion

and extension require only the motion within the wrist joint. The 'moving wrist up and down' motion is thought to be the easiest motion for infants. Full-term and VLBW infants exhibited differences in the type of hand motion used for bye-bye at the initial imitation session. Around 40% of full-term infants imitated others' bye-bye gestures using the 'moving wrist up and down' motion at the initial imitation time point. Their hand motion types gradually changed to 'palm facing others' at 16 months of age. Full-term infants develop hand movements rapidly during infancy. They may be able to take and grasp items with which they want to play during the first year of life.<sup>16–18</sup> We suppose that infants can complete bye-bye with the palm facing others when their fine hand motor skills develop sufficiently to hold and move their arm horizontally.

Conversely, the 'moving wrist up and down' form was observed more frequently in VLBW infants than in full-term infants. Few VLBW infants moved their hands using the 'turning palm round and round' form at an early stage. These findings suggest that VLBW infants have a delay in acquisition of fine movements that require the coordination with elbow joint. The delay in fine motor development might be a reason for late appearance of bye-bye in VLBW infants. VLBW infants have been reported to exhibit clumsiness in fine motion.<sup>13</sup> Many studies have noted that VLBW infants suffer more frequently from problems regarding spatial cognitive function and visual-motor coordination. Fallang et al. reported that preterm VLBW infants might have a dysfunction in the capacity to modulate fine-tuned motor output during the reaching of their hands to targets.<sup>19</sup> The characteristics of cognitive and fine motor abilities in VLBW infants may have caused the differences observed in the bye-bye type between the full-term and VLBW infants.

It is well known that bye-bye using the 'palm facing them' motion is often observed in children with autism. Recently a number of researchers noted the associations between autism spectrum disorders and birthweight, and gestational age.<sup>20</sup> In the present study, 11.7% of the full-term infants and 3.3% of the VLBW infants moved their hands in such a way at the time of appearance of bye-bye. Although this type of bye-bye continued until 10 months of age in both groups, it gradually disappeared with age, and did not reappear during the follow-up periods in both groups. We suppose that bye-bye using the 'palm facing them' form is not abnormal behavior in itself; rather, it seems to be one of the immature forms of waving in the process of the development of the more matured bye-bye gesture.

We should pay attention not only to the time of the appearance of bye-bye waving but also to the type of hand motions used. Additional hints can be obtained by the observation of the simple behavior of bye-bye, which can be used to evaluate the development of imitative functions in infancy. It might be a useful tool to assess the development of high-risk infants in clinical practice.

## Conclusion

The development of the ability to imitate bye-bye was delayed in VLBW infants even after correction for gestational age. It is suspected that delay in fine motor development might be the reason for the late appearance of bye-bye in VLBW infants. Further follow-up study is required to clarify the clinical significance.

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