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Trends in the Development of Rhythmical Hand Behaviours in Infants

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Abstract

Infants are reported to produce large amounts of rhythmical behaviours, like kicking, banging, rocking, waving, bouncing, swaying and such. The present study examined the development of rhythmical hand behaviours, in order to understand the trends in the emergence of these behaviours. Participants included nine infants who were longitudinally studied for the duration of 10 months, between 3 and 12 months of age. The infants were observed for six types of rhythmic behaviours (cycling, bang, swing, shake, flex and twist) as they co occurred with speech behaviors, and a measure of rate of co-occurrence was calculated. Results indicated that rhythmical behaviours were present from the young age of 3 months, with changes in the occurrence rate as they grew older. There were also variations seen in the rates of occurrence with respect to hand preference and some indicators of cultural variations with respect to few of these rhythmical behaviours.

Key words: Rhythmical hand behaviours; longitudinal design; rate of occurrence; growth trends.

Introduction

Rhythmical stereotypes are a part of the behavioral repertoire of insects, fish, birds and is less common in mammals (Schleidt, 1974). In primates, these stereotyped behaviours

are uncommon and are considered pathological. Among non-human primates, these have not been observed in free animals, but are seen in animals caged in small enclosures or those raised in social isolation (Berkson, 1968). In humans, stereotypy is usually associated with not-so-typical populations, like children with autism, individuals who are blind, and those who are emotionally disturbed (Berkson & Davenport, 1962).

When compared to other primates, stereotypy is the hallmark of typically developing human infants during a stage in the lifecycle (Kravitz & Boehm, 1971). Infants are reported to produce large amounts of rhythmical behaviours, like kicking, banging, rocking, waving, bouncing, swaying and such. These behaviours occur very frequently and infants are seen to enjoy and absorb these acts, though it is difficult to ascribe a purpose for these movements.

There has been considerable debate regarding the functions of these stereotypical behaviours seen in infants. Psychoanalysts have suggested that stereotypy could be a sign of emotional development, such as an attempt to recreate rhythmical prenatal experiences or as a result of an infant being confined to a small space (Kris, 1954; Levy, 1944). Piaget (1954) observed that the repetitive movement are 'secondary circular reactions' since an infant repeats activities that have an interesting effect on the environment, thus serving as a sign of cognitive development. It has also been noted that certain rhythmical behaviours are associated with particular stages of neuromuscular maturation, and therefore suggest that rhythmic patterns appear in the transition stages of motor development (Kravitz & Boehm, 1971).

Schleidt (1974) proposed that repetition of a signal could increase its potency for communication, since caregivers may consider these behaviours as intentional. A study on 'fussy' infants reported that the increased levels of arousal in a baby facilitated the release of rhythmic motor output, which in turn accentuated their cry for distress and received a

hastened response from the caregiver (Thelen & Fisher, 1982). This result suggests that rhythmic movements may communicate infant affect.

Thelen (1979) observed 20 American infants between the ages of 4 and 52 weeks and concluded that there seemed to be multiple contexts that elicited rhythmical behaviours in the infants. These were categorized as interactions with caregivers, other people, interest in objects, feeding times, passive or active kinesthetic changes and non-alert states like that of drowsiness. Further, developmental trends in the interactions of these contexts and rhythmic movements were also observed. It was observed that in 3-5 month old infant's interactions with caregivers occurring frequently in object related interactions with older infants served as strong elicitors of stereotypy, . It was also seen that all types of contexts elicited stereotypy during6-7 months and showed a decline when the infants were approaching 12 months of age. Thelen (1979) also documented a wide range of rhythmical stereotypies that involved various parts of the body such as legs, head, torso, arms and face in infants. Among the movements of legs and feet, rhythmical kicking was observed in early age and was found to persist for a number of months. These bouts were often seen in infants between 6 and 14 weeks of age, when they were in prone or supine position. . The rhythmic movements seen were alternate-leg kicking, single-leg kicking, foot rubbing, both-legs-together kicking, foot flexion, foot stomping and foot rotation.

Movements of torso observed in the study included bouncing, swaying, rocking, hand-and-knees rock, hands-and-feet rock, rocking and bouncing while sitting, kneeling and standing. These stereotypies were observed while the infants were in prone, sitting, kneeling or standing positions as well as when they were supported on hands, knees and feet. These movements were observed in infants at various ages; abdomen movements by 16 to 34

weeks, hands and knees movements by 18 to 44 weeks, sitting movements by 18 to 48 weeks, kneeling movements by 30 to 50 weeks and standing movements by 22 to 44 weeks.

It was also documented that infants performed many bouts of stereotyped movements of the arms, hands and fingers, which were often found to incorporate objects as part of the movement itself. These behaviours included arm waving, arm banging, hand clapping, push-pull movement of elbow (bend), ear/hair rub, flexing of hands, rotating of hands and flexing of fingers. . It was also noted that flexing of fingers was not seen in all infants. Rhythmical movements of arms began by 6 to 22 weeks, movements of hands by 22 to 46 weeks and movements of fingers were seen by 4-16 weeks. Movements of head and face were reported to be infrequent when compared to the rest of the body. Head shake and head nod were seen along with tongue protrusions, tongue swipes, non-nutritive sucking and small rhythmic mouthing movements.

Thelen (1981) concluded that rhythmic stereotypies appeared to be under strong central control. The first evidence that points in this direction is the regularity seen in the age of onset of these behaviours and the close association of these ages to other aspects of neuromuscular maturation. Therefore, the production of these behaviours seem to be dependent on the maturation of the nervous system and these events are intrinsic to the infant. But this does not rule out the variability in the developmental course of these behaviours, which might reflect the influence of factors extrinsic to the infant. However, Thelen (1981) observed that despite the variability, these behaviours develop in an orderly manner. Evidence that also supports this view can be found in the appearance of these behaviours before the infant gains postural control over a new position. For example, rhythmical kicking may precede both the ability to support weight on legs as well as the use of legs for crawling or walking. This might suggest that simple motor patterning actually reflects some degree of

functional maturity of a neuromuscular pathway, even though the pattern is not under complete voluntary control and there is imperfect goal-correction.

Thelen (1981) also suggested that these stereotypies could also be the result of an overload in the neural processing capacity, since the available pathways are immature to process heavy demands; implying that when maturation enhances the processing capacity of the system, the stereotypical behaviours will be replaced by variable and goal-corrected activity. This observation could be extended to human infants since their neuromuscular maturation is much slower when compared to infants of non-human primates. But, it can also be the case that these behavioural 'by-products' are used as per the opportunities by infants and may serve a variety of complex functions when mature behaviours are not available to them.

These views do suggest that there are various aspects of the development of rhythmical movements that are not clearly understood. Since infants are constantly engaged in producing these movements, tracing their development from a very young age could possibly shed some light on the factors that govern the emergence and in some cases there is decline in these behaviours with progress in age. Also, if these movements are a part and parcel of the process of neuromuscular maturation, then it must be deemed important to document the development and patterns of occurrence of these rhythmic movements. This is especially true for hand movements as they form a communicative system that develops in conjunction with the speech/linguistic system. Keeping this background in mind, this study has been undertaken to document the patterns of development of rhythmical hand behaviours in typically developing infants.

Aim of the Study

This study aimed to document the development of rhythmical hand movements in typically developing infants from the age of 3 to 12 months, using a longitudinal design.

Method

Participants

The study included nine typically developing infants, three female and 6 male infants. These infants were followed longitudinally for a period of 10 months, and the first recording was made at the age of 3 months and ended when the infants turned 1 year of age. On an average, there were 8 recordings per child. This was because of unavoidable circumstances where some infants could not be recorded for all the 10 months of the study period. All the participants were full term babies, with no major birth complications, and passed a hearing, vision and language screening test before they were included in the study. They were also from Kannada speaking families with the mother as the primary caregiver.

Procedure

The recordings were done in the homes of the infants while they were interacting with their mothers, using a Sony HDR video and audio recorder. Each recording was done once a month for the duration of 1 hour, when the child was most playful and alert. The recordings were not continuous, since there were breaks when the child was fussy/ uncomfortable. The mother was instructed to talk to/ stimulate/ play with the infant as normally as possible, either when the infant was lying on the floor or when placed on the lap of the mother or sitting independently in the later months. The videos were later edited and only those portions of the data that could be used for the analysis were retained. The average duration of the data

used for the analysis was 10 - 15 minutes per recording, from the 3rd to 6th months and 20-25 minutes per recording for the later months.

Coding of Rhythmic Behaviours

The rhythmic behaviours of the infants were coded using ELAN software (Lausberg & Sloetjes, 2009), which provides a frame- by- frame analysis of the recording. A key for coding all the behaviours was developed by the principal investigator (Appendix 1) and the same was compiled based on a review of existing literature (Thelen, 1981). Each item in the key thus developed was provided with an operational definition, in order to facilitate uniformity in the coding across coders. The coding of the samples was done by three independent coders (speech language pathologists), one being the principal investigator and two other coders who were trained in the use of the coding scheme using the video sample of an infant who was not part of the main study.

Initially, the principal investigator identified and labelled the rhythmic behaviours exhibited by the infants. Then the two coders were instructed to go through the coded samples and indicate whether they agreed or disagreed with the annotations of the principal investigator. The coders were required to do this exercise on 10% of the samples, which were randomly selected, i.e.10 videos, and they were asked to carry out this independently. The 10 videos were selected from the data pool, keeping in mind that each month of study was represented in the reliabilities check.

The mean percentage agreement was calculated for both the coders for rhythmic hand behaviours, and this is as shown in Table 1.

Table 1: The percentage agreement between coders for gaze behaviours.

Month	Total number of rhythmic behaviours	Mean percentage of agreement (%)
3	66	94.97
4	71	88.67
5	71	86.71
6	98	89.45
7	87	93.49
8	69	91.11
9	61	88.61
10	45	93.73
11	43	91.19
12	54	93.59

Results

The aim of the study was to document the development and patterns of occurrence of rhythmic behaviours between the ages of 3 and 12 months in typically developing infants from Kannada Speaking families. The following hand behaviours were analyzed in the study: 'bang', 'cycling', 'shake', 'swing', 'flex' and 'twist'. These were annotated separately for the left and right hands. A measure of *rate of occurrence per minute* was computed. This rate was calculated in ELAN software for each month, and it is defined as the total number of individual rhythmic behaviours divided by the duration of the observational segment for that month.

The means and standard deviations for the rates of occurrence of pre-symbolic rhythmic gestures of the left hand are as shown in table 2 and figures 2 (a, b, c, d, e & f) show the mean rates and the quadratic growth models for each behaviour. Kruskal-Wallis test revealed a significant difference in the rates across the months for 'bang' [χ^2 (7, N=937)=47.150; p=0.000], 'shake' [χ^2 (8, N=789)=40.738; p=0.000] and 'swing' [χ^2 (9, N=1603)=28.355; p=0.001] at 0.001 levels of significance.

The post-hoc analysis revealed that for 'bang' gesture, the differences were due to the variations seen in the rates between the means of the 8th and 3rd, 4th and 5th months and in the case of 'shake' gesture variations were seen between the means for the 10th and 3rd, 4th and 5th months. For 'swing' gesture, the differences were noted between the means for the 4th month and all the months from the 6th month.

Table 2: Means & SDs for rates of occurrence of left hand rhythmic behaviours.

Month	Bang	Cycling	Shake	Swing	Flex	Twist
		0.195		1.582	0	0
3	0 (0)	(0.163)	0 (0)	(0.807)	(0)	(0)
		0.244	0.165	1.96	0	0
4	0 (0)	(0.338)	(0.48)	(1.35)	(0)	(0)
	0.313	0.23	0.226	1.236	0	0
5	(0.538)	(0.176)	(0.195)	(0.433)	(0)	(0)
	0.469	0.444	0.682	0.796	0.072	0.036
6	(0.427)	(0.674)	(0.367)	(0.305)	(0.205)	(0.102)
	0.367	0.224	0.245	0.427	0.086	0
7	(0.179)	(0.263)	(0.202)	(0.265)	(0.16)	(0)
	1.307	0.341	0.419	0.708	0	0.023
8	(1.391)	(0.406)	(0.311)	(0.624)	(0)	(0.048)
	0.675	0.158	0.465	0.29	0.006	0
9	(0.626)	(0.133)	(0.46)	(0.148)	(0.015)	(0)
	0.794	0.199	1.099	0.56	0.087	0.063
10	(0.59)	(0.326)	(1.138)	(0.668)	(0.194)	(0.099)
	0.784	0.454	0.711	0.726	0.012	0.011
11	(0.425)	(0.557)	(0.363)	(0.569)	(0.021)	(0.021)
	0.882	0.267	0.796	0.589	0.013	
12	(0.781)	(0.291)	(0.507)	(0.422)	(0.024)	0 (0)
P	0.000***	0.915	0.000***	0.001***	0.326	0.089

Note: ***p≤0.001

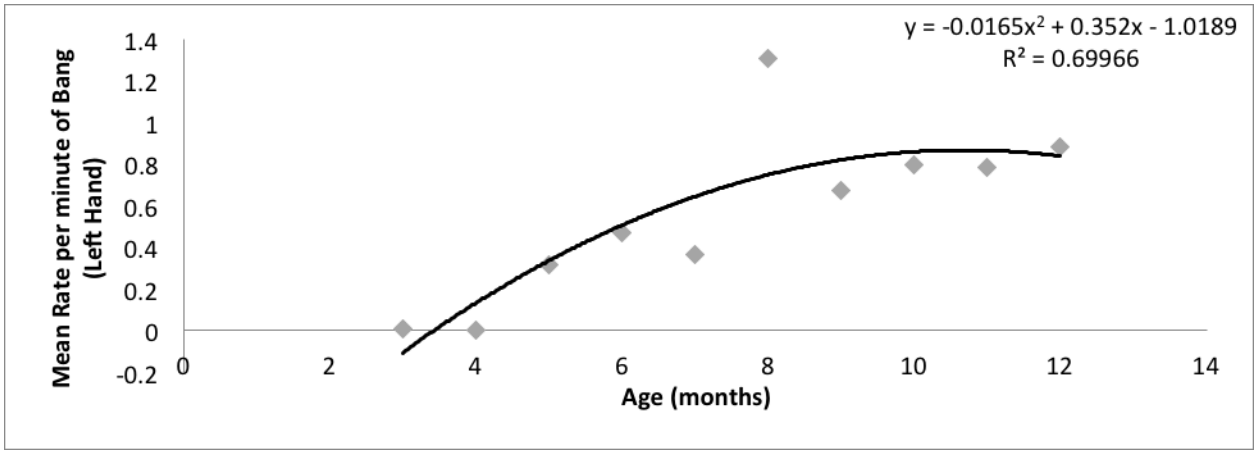

Figure 1(a): Mean rate and growth model for bang (left hand).

From the Figure 1(a), it can be understood that 'bang' gesture is only present from 5 months of age in these infants. The rate of occurrence was highest in the 8th month, beyond which there was a decrease seen between the 8th and 12th month. However, there was an overall increase in the production of this behaviour in this age group than when compared to that between 3rd and 7th month. Correspondingly, the quadratic growth model predicted a polynomial growth trajectory for this gesture, with the quadratic regression predicting a good fit for the model (R^2= 0.6996). This would then suggest that 'bang' is a hand movement that increases with a corresponding increase in age during infancy.

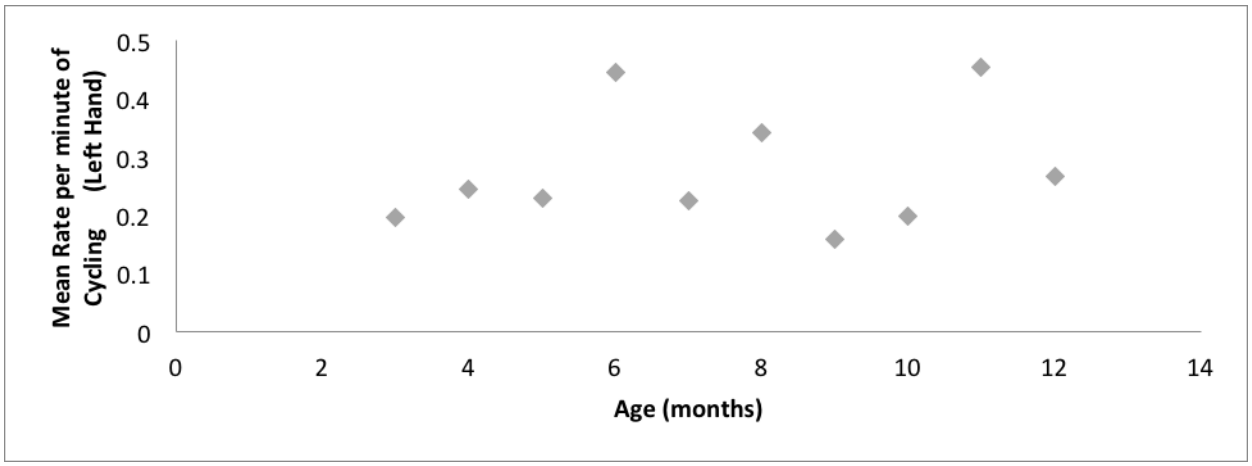

Figure 1(b): Mean rate and growth model for cycling (left hand).

From figure 1(b), it is evident that 'cycling' gesture was seen across all the months of study, although there is no clear pattern of increase or decrease in the rates. The highest rate of occurrence was noted in the 11th month. Correspondingly, the quadratic growth model revealed an unpredictable growth trajectory for this behaviour.

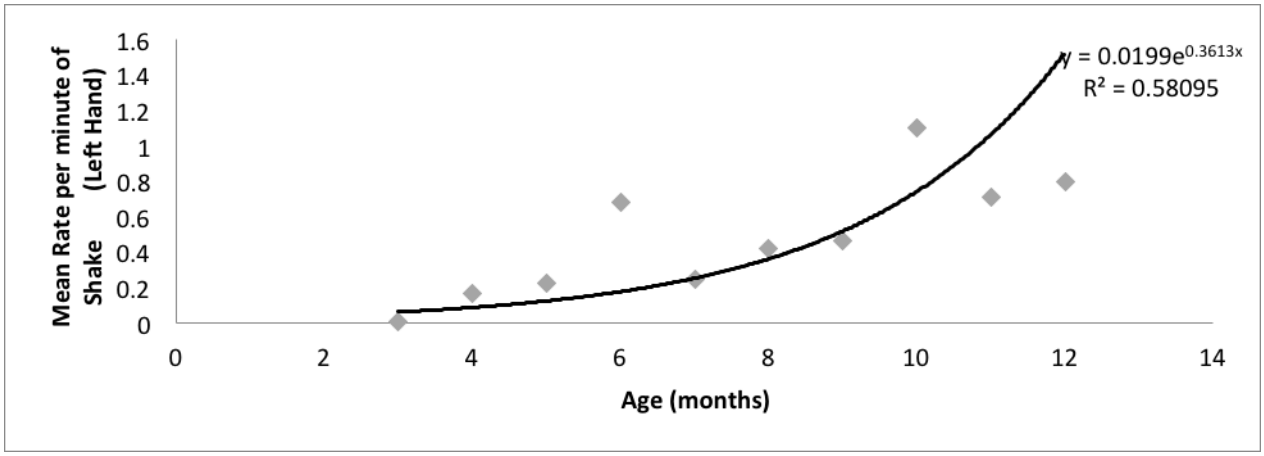

Figure 1(c): Mean rate and growth model for shake (left hand).

From figure 1(c), it can be observed that 'shake' gesture was noted from the 4th month onwards in the sample, with a near-steady rise till the 12th month. It was also clear that two months, namely, the 6th and the 12th recorded frequent instances of production of this behaviour, although, the highest rate was seen in the 10th month. Correspondingly, the quadratic growth model predicted an exponential growth trajectory for this gesture, with the quadratic regression predicting a low fit for the model (R^2= 0.5809). This would then suggest that the occurrence of 'shake' may vary with an increase in age during infancy.

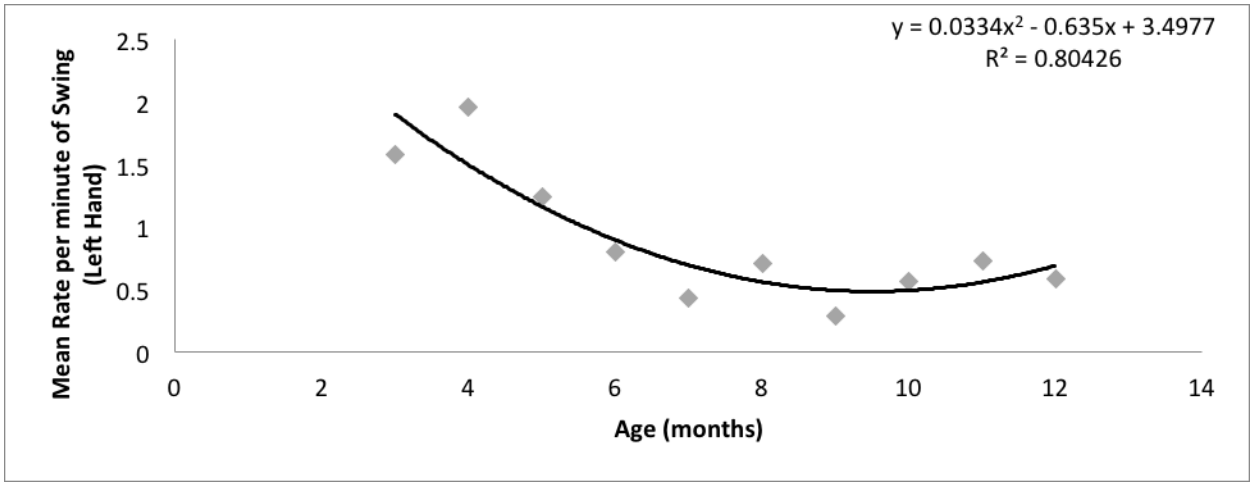

Figure 1(d): Mean rate and growth model for swing (left hand).

From the above figure, it is evident that 'swing' gesture was seen from the 3rd month in these infants, and the occurrences seem to reduce as age increases. The highest rate was noted in the 4th month, and thereafter the rates decreased between 5 and 7 months of age. There was also a slight increase in rates observed between 8 and 11 months. Correspondingly, the quadratic growth model predicted a polynomial growth trajectory for this gesture, with the quadratic regression predicting a good fit for the model (R^2= 0.8042). This would then suggest that 'swing' is a behaviour that decreases with a corresponding increase in age during infancy.

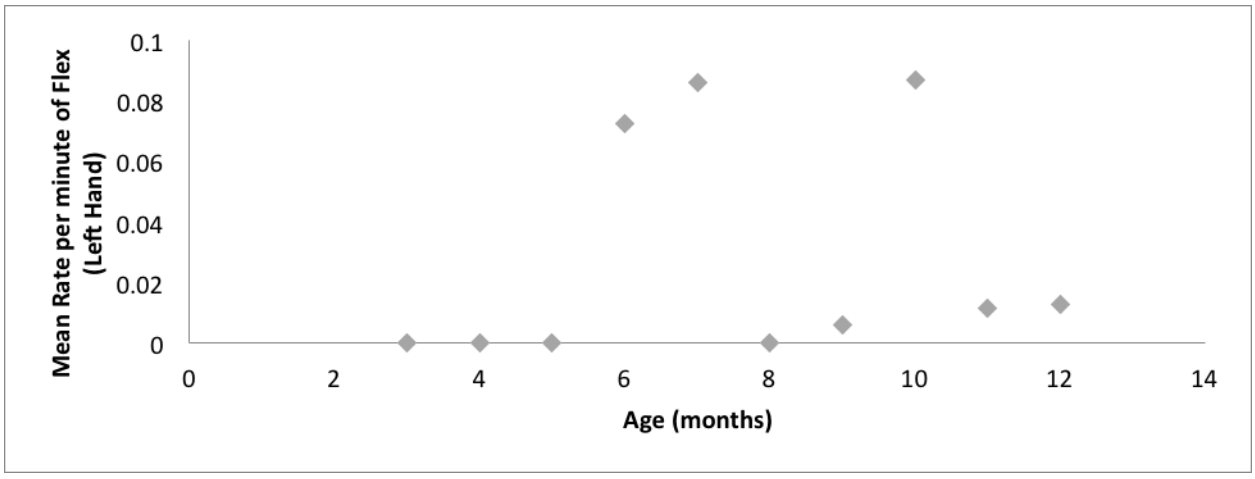

Figure 1(e): Mean rate and growth model for flex (left hand).

From figure 1(e), it is clear that 'flex' gesture was not produced frequently by the infants throughout the study period. It was observed only between 6 and 12 months, and there was a lot of variation seen in the occurrence within this age range. The highest rates were seen for both 7and 12 months of age. Correspondingly, the quadratic growth model revealed an unpredictable growth trajectory for this behaviour.

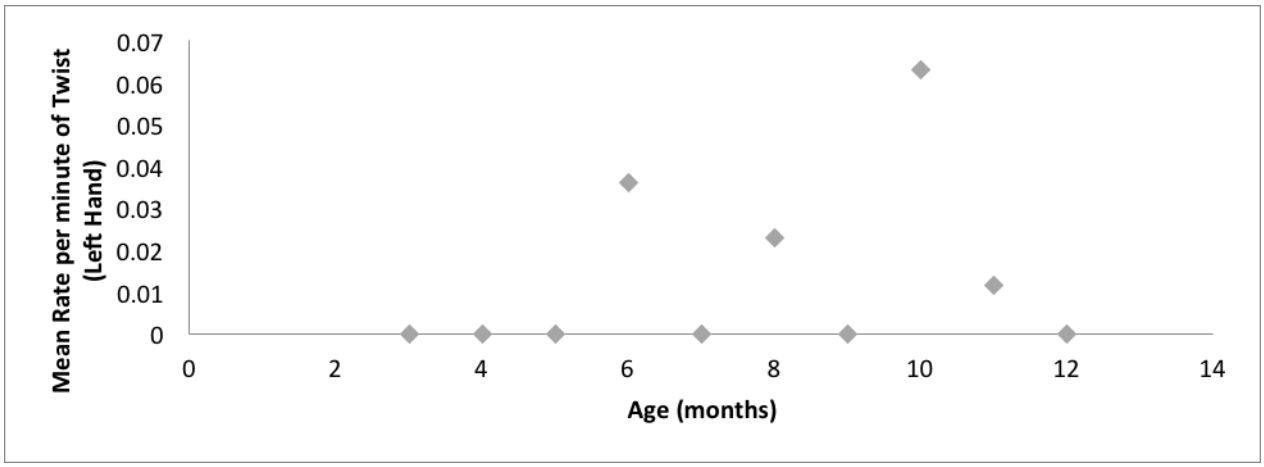

Figure 1(f): Mean rate and growth model for twist (left hand).

From the figure 1(f), it can be understood that infants rarely produced 'twist' gesture. It was noted to be present between 6 and 11 months of age, although there were variations in the rates of occurrences within these months. And the highest rate of occurrence was seen in the 10th month. Correspondingly, the quadratic growth model revealed an unpredictable growth trajectory for this behaviour.

The means and standard deviations for the rates of occurrence of pre-symbolic rhythmic gestures of the right hand are as shown in table 3 and figures 2 (a, b, c, d, e & f) which show the mean rates and the quadratic growth models for each gesture. Kruskal-Wallis test revealed a highly significant difference in the rates across the months for the gestures 'bang' [χ^2 (8, N=1789)=53.774; p=0.000], 'shake' [χ^2 (9, N=1191)=42.515; p=0.000] and 'swing' [χ^2 (9, N=1920)=31.332; p=0.000] at 0.001 levels of significance.

The post-hoc analysis revealed that for 'bang', the differences were due to the variations seen in the rates between the means for the 9th month and those below the 6th month, and in the case of 'shake' gesture, variations were seen between the means for the10th and all the other months. For 'swing' gesture, these differences were noted for the means of the 4th and 3rd months and all the months from the 8th.

Table 3: Means & SDs for rates of occurrence of right hand pre-symbolic rhythmic gestures.

Month	Bang	Cycling	Shake	Swing	Flex	Twist
3	0 (0)	0.207 (0.187)	0.036 (0.068)	1.941 (0.936)	0 (0)	0 (0)
4	0.006 (0.017)	0.269 (0.227)	0.143 (0.273)	2.033 (1.325)	0 (0)	0 (0)
5	0.449 (0.483)	0.228 (0.263)	0.323 (0.28)	1.656 (0.63)	0 (0)	0 (0)
6	0.486 (0.487)	0.428 (0.501)	0.459 (0.351)	0.75 (0.445)	0.066 (0.123)	0.01 (0.029)
7	0.853 (0.628)	0.326 (0.108)	0.469 (0.34)	0.631 (0.431)	0.226 (0.363)	0.027 (0.048)
8	2.28 (2.041)	0.611 (0.519)	0.883 (0.859)	1.072 (0.664)	0.037 (0.062)	0.032 (0.049)
9	1.998 (1.945)	0.272 (0.15)	0.878 (0.565)	0.272 (0.137)	0.012 (0.03)	0.006 (0.015)
10	2.192 (1.051)	0.331 (0.329)	2.306 (1.712)	0.746 (0.595)	0.079 (0.152)	0.036 (0.059)
11	1.317 (0.731)	0.498 (0.39)	1.035 (0.337)	0.884 (0.636)	0.005 (0.015)	0.016 (0.032)
12	1.525 (0.954)	0.353 (0.331)	1.094 (0.64)	0.81 (0.723)	0.012 (0.022)	0 (0)
P	0.000***	0.576	0.000***	0.000***	0.101	0.097

Note: ***p≤0.001

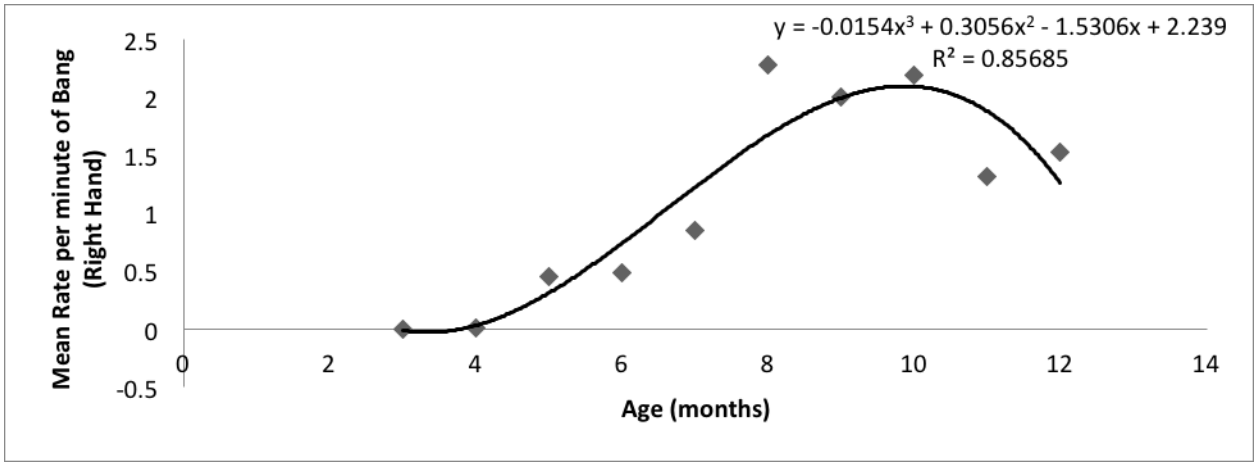

Figure 2(a): Mean rate and growth model for bang (right hand).

From the figure 2(a), it can be understood that 'bang' gesture is only present from 5 month of age in these infants. The rate of occurrence was highest in the 8th month, beyond which there is a decrease seen between the 8th and 12th month. However, there was an overall increase in the production of this behaviour in this age group than when compared to that between 3rd and 7th month.

Correspondingly, the quadratic growth model predicted a polynomial growth trajectory for this gesture, with the quadratic regression predicting a good fit for the model (R^2= 0.9344). This would then suggest that 'bang' is a behaviour that shows an increase as well as a decrease in occurrence with a corresponding increase in age during infancy.

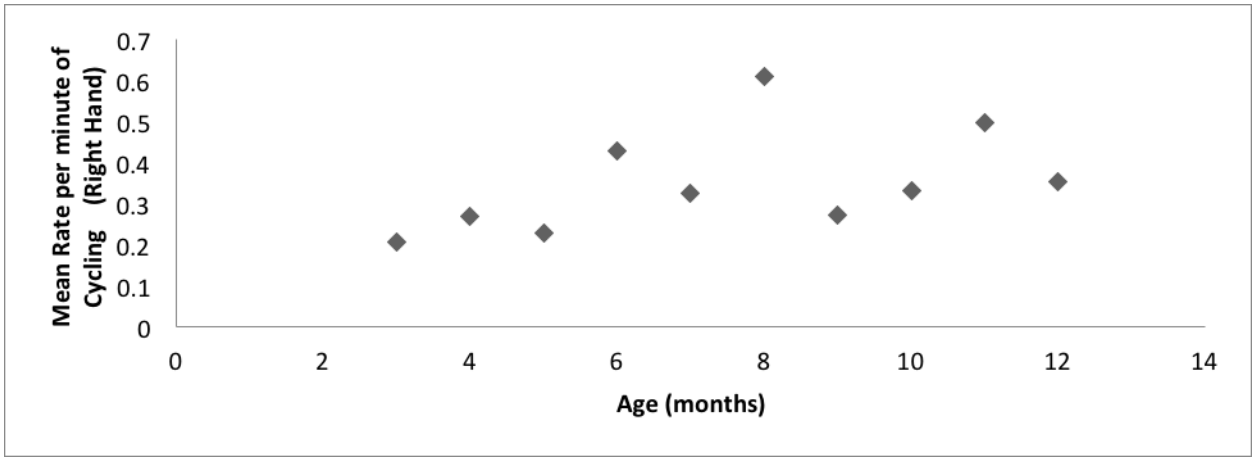

Figure 2(b): Mean rate and growth model for cycling (right hand).

From figure 2(b), it is evident that 'cycling' gesture was seen across all the months under study, although there is no clear pattern of increase or decrease in the rates. The highest rate of occurrence was noted in the 8th month. Correspondingly, the quadratic growth model revealed an unpredictable growth trajectory for this behaviour.

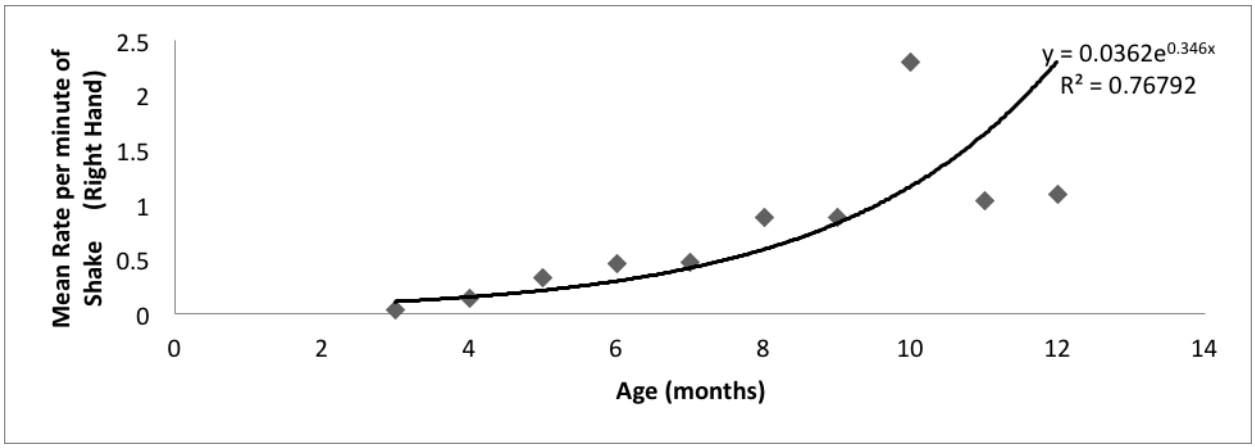

Figure 2(c): Mean rate and growth model for shake (right hand).

From figure 2(c), it can be observed that 'shake' was noted from the 4th month, with a near-steady rise till the 12th month. The highest rate of occurrence was seen in the 10th month. Correspondingly, the quadratic growth model predicted an exponential growth trajectory for this gesture, with the quadratic regression predicting a good fit for the model (R^2= 0.7679).

This would then suggest that the occurrence of 'shake' gesture increases with a corresponding increase in age during infancy.

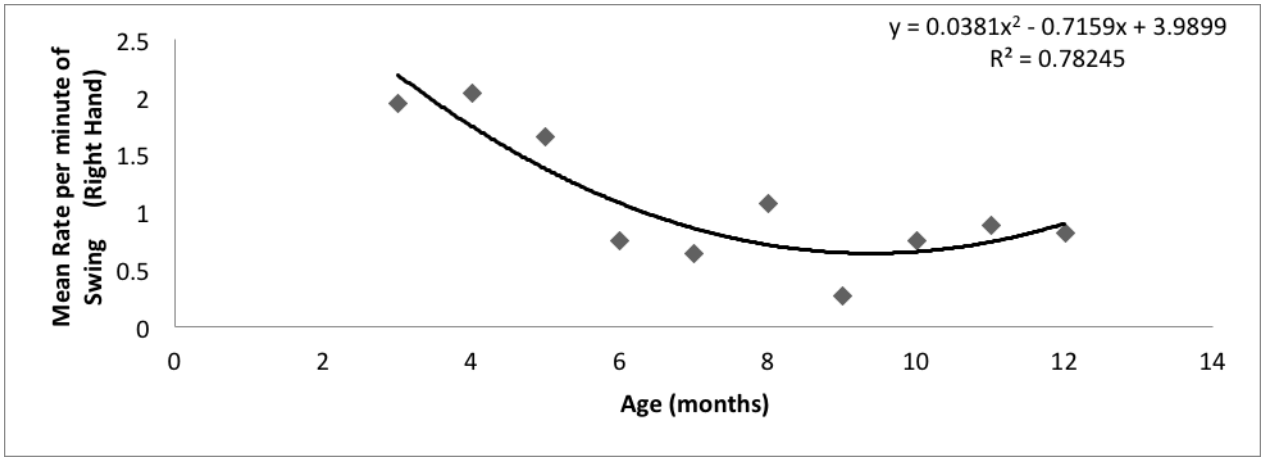

Figure 2(d): Mean rate and growth model for swing (right hand).

From the figure 2(d), it is evident that 'swing' gesture was seen from the 3rd month in these infants, and the occurrences seem to reduce as age increases. The highest rate was noted in the 4th month, and thereafter the rates decreased between 5 and 12 months of age, although variations were observed across this age range. Correspondingly, the quadratic growth model predicted a polynomial growth trajectory for this gesture, with the quadratic regression predicting a good fit for the model (R^2= 0.7824). This would then suggest that 'swing' is a behaviour that decreases with a corresponding increase in age during infancy.

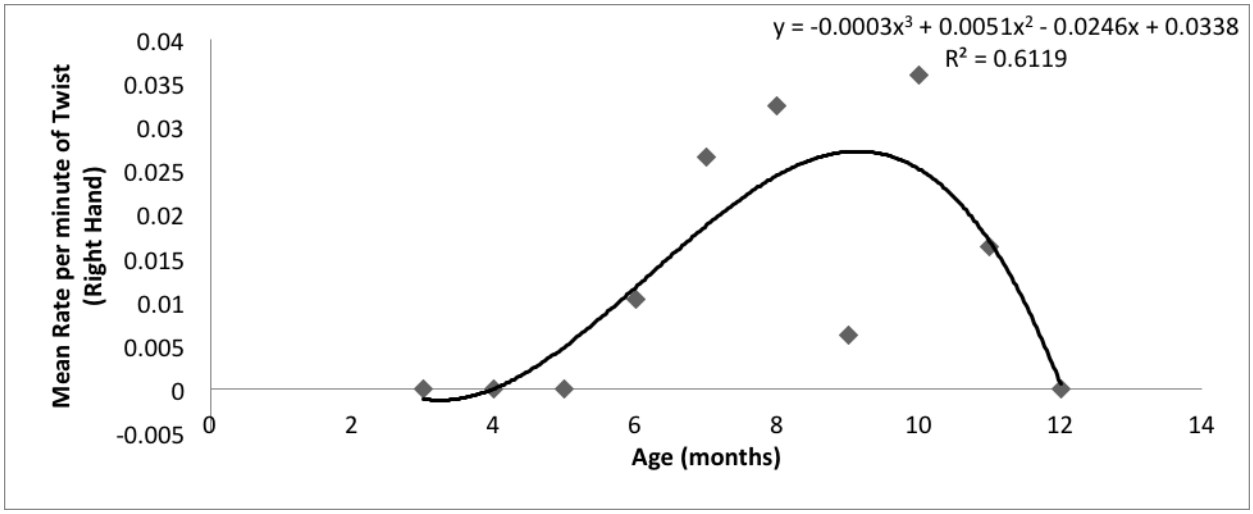

Figure 2(e): Mean rate and growth model for twist (right hand).

From the figure 2(e), it can be understood that 'twist' was only seen from the 6th month and it was not observed in the 12th month. There were also variations in the rates of occurrences between 6 and 11 months, and the highest rate was seen in the 10th month. Beyond this age there was a decrease seen in the rates between 11 and 12 months. Correspondingly, the quadratic growth model predicted a polynomial growth trajectory for this gesture, with the quadratic regression predicting a good fit for the model (R^2= 0.6119). This would then suggest that the occurrence of 'twist' increases and then decreases with a corresponding increase in age during infancy.

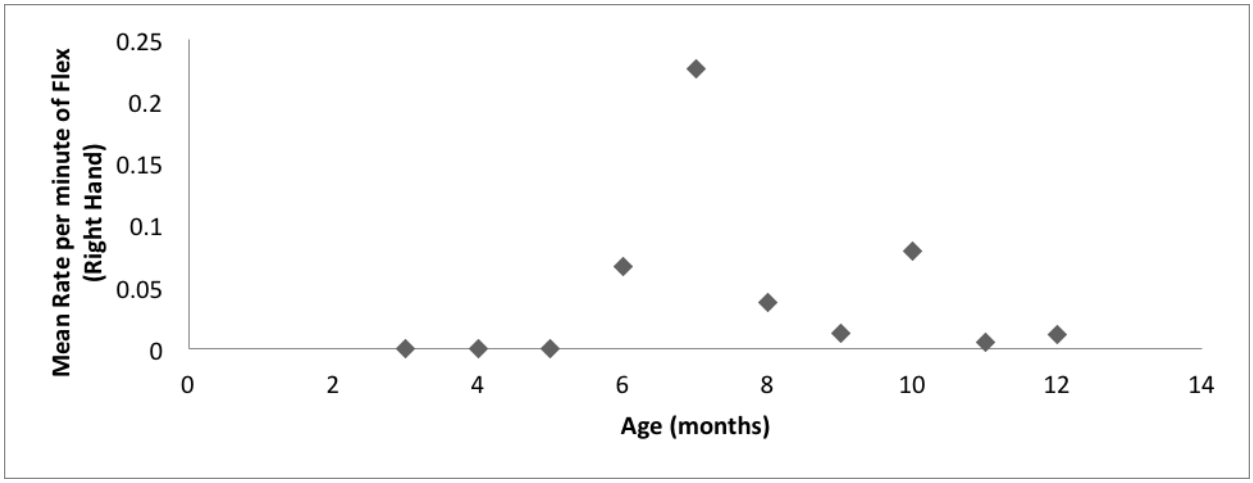

Figure 2(f): Mean rate and growth model for flex (right hand).

From figure 2(f), it is clear that this gesture was seen only from the 6th month and there was an overall decrease in the production as well as variations seen in the occurrence between 6 and 12 months. The highest rate was seen in the 7th month. Correspondingly, the quadratic growth model revealed an unpredictable growth trajectory for 'flex'.

Wilcoxon Signed-rank test was carried out to see if there were significant differences in the rate of occurrences for the rhythmic behaviours produced using the right and left hands. The results revealed that there were statistically significant differences in the usage of hands for bang in the 9th (Z=2.201; p=0.028), 10th (Z=2.023; p=0.043), 11th (Z=2.240; p=0.025), and 12th (Z=1.963; p=0.050) months, at 0.05 levels of significance. These differences were also seen for 'shake' gesture in the 7th (Z=2.201; p=0.028), 9th (Z=2.201; p=0.028), 10th (Z=2.023; p=0.043), and 11th (Z=2.100; p=0.036) months, whereas for 'swing' gesture, these were seen in the 5th (Z=2.666; p=0.008) and 11th (Z=2.201; p=0.028) months at 0.05 and 0.01 levels of significance respectively. The mean rates of occurrences for these behaviours were higher for the right hand for all these months.

Discussion and Conclusions

The present study looked into the emergence of rhythmic hand behaviours in typically developing children from Kannada speaking families, incorporated in a longitudinal design. There were some interesting trends observed for these behaviours in the study. Rhythmic gestures of fingers (cycling) and arms (swing & shake) were seen from the 3rd month, while other gestures of arms (bang) were seen from the age of 5 months and wrist (flex & twist) were seen from the 6th month of age. This goes on to suggest that infants are engaged in

rhythmical activities of the hand throughout the first year, although there were some variations observed in the rates of occurrences of these behaviours.

Infants were observed to produce 'cycling' behaviours from the very beginning of the study period, i.e. 3 months of age and were seen throughout the study period. There was a peak in the occurrence of this behaviour produced by the left hand in the 6th and 11th month of age, and in the 8th month for the same behaviour produced using the right hand. However, these trends were not significant to suggest that there was a developmental influence on the occurrence of this behaviour. This finding is similar to that reported by Thelen (1979). In her study it was found that finger movements were produced with equally low frequency throughout the first year of life. In the present study, the growth model revealed an unpredictable growth trend for this behaviour, which provides further evidence to the lack of influence of age on the development of 'cycling'.

'Cycling' was mostly observed when the children were idle, with the arms/hand in resting position or while either looking at object or the mother. Since this behaviour seemed to occur randomly and was not accompanied by purposeful actions, this could have attributed to the variations in the occurrence of these behaviours across the months. Also, it was interesting to note that there was a decline in the rate of occurrence of this behaviour with the emergence of 'reach' and 'grasp'. Previously, Thelen (1981) had also suggested that cycling might precede grasping.

'Swing' was behaviour that was observed from the 3rd month of age in these infants. There was a clear trend, which suggested that the rates of occurrence of this behaviour produced by both hands peaked in the 4th month. It was also noted that there was a statistically significant developmental influence on the occurrence of this behaviour. However, this finding is not similar to that by Thelen (1979), where she reported that

rhythmic stereotypies involving hands were seen at significantly higher frequencies at around 6 months of age. This could also point out to possible cultural variations in the development of this behaviour. In the present study, the growth model revealed a polynomial trend for 'swing', which suggests that this behaviour decreases from the 3rd month till the 7th month, after which there is a slight increase in the occurrence.

Infants were noted to produce 'shake' from the 3rd month of age in the study. There was a clear trend which suggested that the rates of occurrence of this behaviour produced by the left peaked in the 6th and 12th month, while that produced by the right hand peaked in the 10th month of age. It was also noted that there was a statistically significant developmental influence on the occurrence of this behaviour. Again, these findings are different from that reported by Thelen (1979). In her study rhythmic stereotypies involving hands were seen at significantly higher frequencies at around 6 months of age. This could also point out to possible cultural variations in the development of this behaviour. In the present study, the growth model revealed an exponential trend for 'shake', which suggested that this behaviour increases till the age of 10 months.

'Bang' was observed to be produced by infants from the age of 5 months in the study. There was a clear trend, which suggested that the rates of occurrence of this behaviour produced by both hands, peaked in the 8th month. It was also noted that there was a statistically significant developmental influence on the occurrence of this behaviour. These findings are different from that reported by Thelen (1979), where she suggests that rhythmic stereotypies involving hands were seen higher frequencies at around 6 months of life. This could also point out to possible cultural variations in the development of this behaviour. In the present study, the growth model revealed a polynomial trend for 'bang', which suggests

this behaviour increases from the 5th month till around the 10th month, after which there is a slight decrease in the occurrence.

Lew and Butterworth (1997) have suggested that, during the early months, the ability of an infant to interact with their environment is limited. This is because infants are often confined to a supine position, even while being held by caregivers due to their poor posture and neuromuscular control. This would explain the early occurrence of behaviours such as 'swing', 'shake' and 'bang' that are easily produced with minimal muscular effort and their subsequent decline over the coming months, when infants are more capable of interacting independently with their surroundings. These may provide the infants with opportunities to explore their surroundings within the constraints of their physical system, and also might serve as trial and error behaviours that pave the way for more stable hand gestures.

It is also possible that the occurrence of these behaviours coincides with a shift in the interaction opportunities due to the maturation of the visual, tactile and neuromuscular systems (von Hofsten, 2007). From the 6th month, almost all the infants were able to sit independently and were able to manipulate and explore their environment effectively. It may be assumed that with age, these skills will get stable, as the child will have better control over these behaviours and will exhibit these movements with purposeful activities based on their internal motives. For example, the children were seen to produce 'bang' and 'shake' with objects held in their hands.

'Flex' and 'Twist' were gestures that were produced by infants from age of 6 months. The rates of occurrence of 'flex' produced by the left hand peaked in the 7th and 11th months, while that produced by the right hand peaked in the 7th month. However, these trends were not statistically significant to suggest that there was a developmental influence on the

occurrence of this behaviour. The growth model revealed an unpredictable growth trend for 'flex', which provides further evidence to the lack of influence of age on development.

The rates of occurrence of 'twist' produced by both hands peaked in the 10th month, although, these trends were not statistically significant which suggests that there was no influence of development on the occurrence of this behaviour. The growth model for 'twist' produced using the right hand showed a polynomial trend, which suggests that this behaviour increases till the 10th month, after which there is a decrease in the occurrence. However, the same was not seen in the case of 'twist' produced using the left hand. The growth model showed an unpredictable trajectory.

Rhythmic movements of the wrist, namely, flexing and twisting of wrists were seen when the infant was idle and mostly observing their own hands. These were noted to have fewer instances of occurrence throughout the study and were produced only by few infants in the study. A possible explanation for the same could be that, since these were not associated with meaningful actions, the behaviours did not occur at regular intervals; however, their presence might indicate that these are needed for further motor development. Thus, although these behaviours emerged, there was relative instability seen across the months and a subsequent decline in these behaviours towards the end of the first year. This was evidenced in the variations in the rates of occurrences seen across the months.

With regard to handedness, significant differences were only seen for few of these behaviours, namely, 'swing', 'bang' and 'shake', with a notable right hand preference. Previously, Iverson, Hall, Nickel and Wozniak (2007) have reported that there was no shift in the arm preference for rhythmic stereotypes till the age of 9 months. The findings in this study show otherwise, as there were differences seen even in the younger months. However,

one has to keep in mind that there were only few the instances of right hand bias recorded in the study.

Thus, it can be understood that infants were found to engage in rhythmical movements from the first 6 months of their life, although there were slight differences noticed in the ages of emergence of each of these behaviours. However, most of these movements showed a decline in the occurrence towards the end of the first year. Also, all the behaviours that were studied showed non-linear trends in the growth, although the growth trajectories were different for each behaviour. This would then suggest that every behavior in an infant follows a different growth trajectory and therefore, it is important that these are documented and understood especially in the case of atypical infants. Also, this might even suggest that development occurs in stage-like shifts.

Rhythmic stereotypes have been considered as transition or by product behaviours of the normal maturation process (Lourie, 1949; Thelen, 1981). These are assumed to be available to infants when higher-order complex behaviours are not available, although they are simple, repetitive, devoid of goals and are largely not under sensory regulation. This view would therefore propose that all rhythmic gestures are part and parcel of normal maturation and might pave the way for meaningful manual actions. The data from the present study also tends to lean towards this hypothesis. Most behaviours that were studied did have a developmental trend which seemed to vary based on the context and maturation of the neural mechanisms within the infants.

This data also points towards possible variations in the emergence of these behaviours based on culture, especially for movements of ‘swing’, ‘shake’ and ‘bang’. The findings in this study suggest that children from American and Kannada speaking backgrounds may

differ in the ages of acquisition of rhythmic hand movements. However, this could also point out to possible differences in the rearing practices seen in both cultures.

The findings in this study also seem to support the presence of hand preferences for rhythmic arm movements. However, one has to bear in mind that this study included only 9 participants, and therefore, it is suggested that further studies need on a larger population to substantiate these results. But the results of this study sheds light on the need to document the emergence of every skill in an infant which will further advance our knowledge into the understanding of the development of mature communication systems in an infant.

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Appendix 1

Appendix 1: The operational definitions of hand gestures as adopted in the study

Sl No.	*Gesture*	*Operational definition*
1	Flex	Bending and extending of wrist
2	Twist	Rotation of wrist back and forth
3	Cycling	Any movement by the fingers; rhythmic tapping, flexing and extending of fingers
4	Swing	Vertical movement of the arm from the shoulder with no object in hand
5	Shake	Vertical movement of the arm from the shoulder with an object in hand
6	Bang	Movement with the hand or object held in hand makes firm contact with a surface

Source: Thelen, 1981

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