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Patterns in the Emergence of Hand Actions in Typically Developing Infants

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Abstract

Purpose: The dynamic systems theory regards the development of an infant as a complex and dynamic system. This study investigates the development of the hand system in typically developing infants, in the backdrop of this theory. Specifically, we wanted to document the growth trajectories exhibited by these behaviours within the first year of life and to determine a predictable age at which these hand actions would exhibit a change in occurrence, in the face of variability.

Method: Nine typically developing infants, 3 females and 6 males, were videotaped from the third month till they turned twelve months of age, while interacting with their mothers. Samples were coded for the occurrence of four categories of hand actions (actions during play/rest; actions with objects; actions towards adults; iconic actions) using ELAN.

Results: The hand actions we studied were marked by variability as evidenced in their growth trends, and some of these hand actions, especially those that help manipulate objects and those seen during play/rest demonstrated an age at which reliable change in the rate of occurrence was seen within the developmental period.

Conclusion: Our results demonstrate that the development of the hand system follows some principles of being a dynamic system.

Keywords: Hand actions; Infants; Dynamic development; Growth curves; Change point analysis

Introduction

Many studies [1-5] have suggested that, by the end of the first year the repetitive motor activities of young infants begin to give way to more articulated control and directed communication. Infants are said to begin to communicate intentionally through gestures and vocalizations and later words. Gestures and speech are regarded as parallel modalities, as most often the communicative signals produced by children are in both of these modalities [6]. Some studies indicate that the gestural and vocal modalities are semantically and temporally integrated from the earliest stages [7], while others report that asynchronous combinations of gestures and words are more frequent than synchronous ones during initial phases of development in typical children [8].

Communicative gestures (hand and others) that begin around 7-9 months in children are assumed to be derived from a repertoire of vocal, facial and body signals that an infant is endowed with at birth [5,8-12]. Around 10 months of age, deictic and iconic hand gestures are pervasive in children's speech. Children produce deictic gestures and culturally derived gestural routines such as waving goodbye, before they begin to talk [8,10]. These behaviours are also referred to as prelinguistic gestures (and performatives) because their emergence is observed prior to spoken language. However, pointing continues to be used throughout development. Showing, giving, pointing and requesting emerge in this predictable sequence starting at approximately 10 months of age [2]. These behaviours show a marked increase in occurrence after 11 months, which coincides with a decline in more primitive gestures (e.g. reaching) and emotive gestures (e.g., moving body up and down).

The dynamic systems theory [1] suggests that development is a process of self-organization of multiple individual elements of a system. Coherent behaviours are a manifestation of relationships between the various components, with the constraints and opportunities of the environment. Change in any behaviour is said to occur over different time scales along with other collaborating elements (behaviours) of the same system or even other systems. Therefore, the coherence of time and the levels of the system imply that the dynamics of one time period will be continuous and nested within the dynamics of all the other time periods. That is, every event within or across systems lays the foundation for the next event to occur.

Further this theory states that when an infant achieves a milestone, one does not always see stability or a near-steady increase in the frequency or the rate at which this behaviour is produced at later ages. Therefore, the development of any behaviour could follow both linear and nonlinear paths depending on the changes that occur in one or more components of the system. This could be true if one considers development to be a dynamic and an evolving process.

Therefore, it would seem necessary to consider the developmental pattern of any behaviour and describe the dynamics of change that occurs over a given time frame. This will in turn predict when one can expect reliable change to occur in a developing system, thus aiding in behavioural and cognitive development. Very few studies have attempted to provide evidence for the variability seen in infant

development, with the exception of limb movements [13-17]. A very recent study investigated the dynamic patterns of limb movements (e.g. sitting) and pre-linguistic vocalizations (e.g. canonical babbling) in a single infant and they were able to establish that variability preceded or coincided with the onset of mature developmental milestones across the two motor systems [18].

Drawing influences from the above literature, the aim of this study on hand actions was twofold; the first was to document the developmental trends of hand actions in infants by the means of growth curves. This was done in order to understand if these behaviours reflected linear or non-linear patterns of growth within the developmental period of 3-12 months of age. The second was to document the age at which there was a significant change in the occurrence of these hand actions, using a time series method such as change point analysis.

Method

Participants

Nine typically developing infants (three females and six male infants) participated in the study. They were followed for a period of 10 months, with the first recording taken at the age of 3 months and the last recording taken at 10 months of age. The analysis reported in the study includes on an average 8 recordings per child. This was because all the infants could not be recorded every month either due to ill-health or other reasons within the family. All the participants were full term babies, with no major birth complications, and passed a hearing, vision and language screening before they were included in the study. They were also from Kannada speaking families with the mother as the primary caregiver.

Procedure

Each infant and the mother were videotaped at their home, 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 mothers were instructed to talk to/stimulate/play with their infant as they normally would, 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 usable data for 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 the manual gestures

Hand actions observed in the infants were coded using ELAN software [19], which allows a frame- by- frame analysis of the recording. A key for coding these behaviours was developed by the principal investigator (Appendix 1) and the same was compiled based on the review of literature [2,11]. The key described actions of fingers, palms and arms. Each item in the key thus developed was provided with an operational definition, in order to facilitate uniformity in the coding across coders. Annotation of the samples was done by three independent coders (speech language pathologists), one being the principal investigator and two other coders who were trained using a video sample of an infant who was not included in the study. The following categories of hand actions were annotated in the samples; (1) actions during play/rest which occur randomly while the infant is at play/observing adult/or vocalizing when at rest, (e.g. clap, clasp, hand in mouth, curl, index finger extension, flex, twist, cycling, spread, swing); (2) actions with objects that occur when the infant is manipulating object during play (e.g. holding toy in mouth, reach, grasp, bang, shake); (3) actions towards an adult that occur while the child is interacting with adult to convey a need or information (e.g. up, point, show, request, give, take); (4) and actions that reflect iconicity and convey some aspect of the referent (e.g. hand configurations).

The principal investigator identified and labeled the hand actions exhibited by the infants in every second of the frame in all the samples. 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 the same exercise independently. These videos were selected randomly from the data pool, keeping in mind that each month of study was represented in the reliabilities check. Then the principal investigator went through all the coded samples and noted the instances of agreement and disagreement between the coders. The mean percentage agreement between all the three coders was calculated and this is as shown in Table 1. The cohen's kappa was found to be 0.84.

Month	Total number of hand actions	Mean percentage of agreement (%)
3	245	82.97
4	770	90.57
5	583	89.71
6	930	93.02
7	616	89.49
8	928	92.11
9	1125	92.75
10	1198	90.69
11	975	88.19
12	680	91.69

Table 1: The percentage agreement between coders for hand actions.

Analysis

In order to establish the frequency with which the participants produced these behaviours, a measure of rate of occurrence per minute was computed. This rate was calculated for each month, and it was defined as the total number of a hand action (e.g. clasp) divided by the duration of the observational segment for that month. The rates of occurrence were then used to plot growth curves based on quadratic regression analysis. This was done in order to determine the growth trend of behaviours, and we anticipated these trends to be either linear (constant increase or decrease in the rates of occurrence with a corresponding increase in age) or non-linear (polynomial: curvilinear relationship between rates of occurrence and age; or quadratic: exponential relationship between rates of occurrence and age). We carried out change point analysis [20], which is used with time series data in order to determine the age at which there is a significant change in occurrence of hand actions between 3 to 12 months of age.

Results

The aim of the study was to document the trends exhibited by hand actions within the developmental period of 3-12 months in typically developing infants. The study also aimed to document the age at which there was a significant change in the occurrence of these behaviours in order to provide support to the self-organization principles as proposed by dynamic systems theory.

In order to test our prediction regarding the dynamic growth trends of hand actions we plotted growth trajectories of each of the behaviours using quadratic regression analysis (see examples: Figures 1 and 2). We have summarized the growth trends exhibited by each hand action in Table 2 (Please note: supplementary files include mean rate of occurrence and growth curves for all hand actions). As can be seen, there are more instances of hand actions exhibiting a non-linear growth trend than a linear one. There were also few instances where the growth trend could not be predicted, either due to extremely variable occurrence across months (e.g. flex) or because of reduced frequency of occurrence of the hand action (e.g. hands up).

Categories of behaviours	Hand action	Growth trend	Level of significance
Hand actions during play/ rest	Clap	Unpredictable	
	Clasp	Polynomial	R2=0.913 (F=345.21 ; p=0.000)
	Hand in mouth	Polynomial	R2=0.779 (F=332.56 ; p=0.015)
	Curl	Exponential	R2=0.879 (F=4211.53 ; p=0.036)
	Index finger extension	Polynomial	R2=0.932 (F=140.03 ; p=0.000)
	Flex	Unpredictable	
	Twist	Polynomial	R2=0.611 (F=30.03 ; p=0.046)
	Cycling	Unpredictable	
	Spread	Linear	R2=0.859 (F=188.60 ; p=0.000)
	Swing	Polynomial	R2=0.782 (F=3067.82 ; p=0.001)
Hand actions with objects	Holding toy in mouth	Polynomial	R2=0.715 (F=998.03 ; p=0.018)
	Grasp	Linear	R2=0.910 (F=1240.08 ; p=0.000)
	Bang	Polynomial	R2=0.934 (F=1998.60 ; p=0.001)
	Shake	Exponential	R2=0.767 (F=1732.66 ; p=0.023)
	Reach	Linear	R2=0.962 (F=7568.10 ; p=0.006)
Hand actions towards an adult	Up	Unpredictable	
	Point	Polynomial	R2=0.669 (F=71.24 ; p=0.033)
	Request	Unpredictable	
	Show	Polynomial	R2=0.836 (F=19.06 ; p=0.001)
	Give	Polynomial	R2=0.637 (F=56.90 ; p=0.044)
	Take	Unpredictable	
Iconic hand action	Hand configurations	Polynomial	R2=0.789 (F=185.43 ; p=0.036)

Table 2: Growth trends for hand actions (per category).

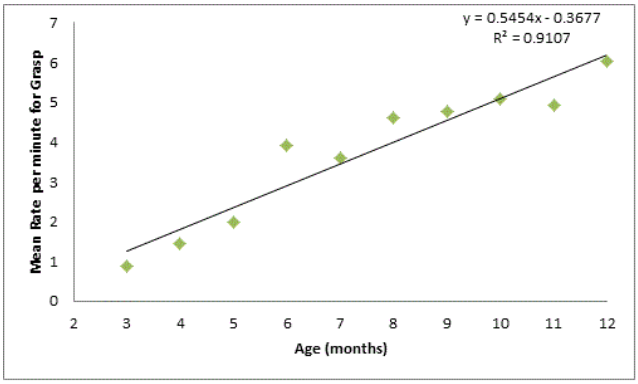

Figure 1: Growth curve (linear) for grasp.

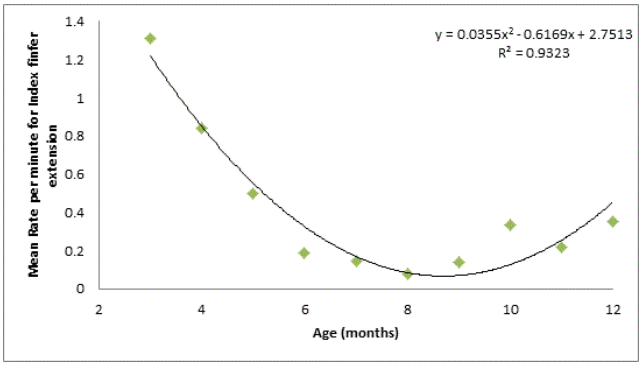

Figure 2: Growth curve (linear) for index finger extension.

Subsequently, change point analysis was carried out in order to understand the age at which there was a significant change in the rate of occurrence of each of these hand actions. We only found significant change for eight hand actions (Table 3), under the categories of 'action with objects' and 'actions during/playrest'). As can be seen the robust change for most of these hand actions occurs from the age of 6 months, except in the case of 'index finger extension', where the change occurs at an early age of 4 months. Post the age of significant change, there is a decrease in the occurrence of only three behaviours, namely, 'holding toy in mouth', 'swing' and 'index finger extension'.

Categories of hand behaviour	Hand action	Month of significant change	Confidence level (%)	Pattern of change in rate of occurrence post change
Hand actions with objects	Bang	8	95	Increase
	Grasp	6	97	Increase
	Reach	7	96	Increase
	Shake	10	96	Increase
	Holding toy in mouth	10	95	Decrease
Hand actions during play/rest	Swing	6	93	Decrease
	Index finger extension	4	92	Decrease
	Spread	6	92	Increase

Table 3: Change point data for hand actions.

Discussion

The current study documented the emergence of hand actions in typically developing infants, between the ages of 3 and 12 months, within the dynamic systems framework. The goals were to determine; (1) the growth trends of hand actions, (2) the age at which a significant change is seen in the occurrence of behaviours over time. We hypothesized that in order to be a dynamic system, hand actions that we studied would show mostly linear or non-linear growth trends, and would demonstrate an age at which reliable changes in occurrence could be predicted amidst variability. We find that the hand system does follow principles of being a dynamic system, which is similar to that demonstrated for the even other systems, such as the limb or both vocal and limb systems [13-18]. However, within this system not all the hand behaviours that were studied satisfied the principles of being dynamic.

Growth trends of hand actions

True to the predictions of dynamic systems theory [1], hand actions demonstrated non-linear (most frequent) and linear (less frequent) trends. Only few of these hand actions demonstrated unpredictable trends within two categories of behaviours that were studied, namely, 'actions during play/rest' (e.g. flex) and 'actions with adults' (e.g. up). A possible reason for this could be that the occurrence of these behaviours showed considerable variation across months. For example, 'up' was seen only during months 5, 6 and 10. Interestingly, linearity was demonstrated by mostly those hand actions that were seen from the age of 3 months itself, such as 'spread', 'grasp' and 'reach'. However, majority of the hand actions across different categories exhibited non-linear trends. Such patterns might indeed suggest that within the first year of life the hand system in undergoing re-organization constantly within a span of few months. This would then imply that variability is a norm during development. Future studies should consider including a larger age group in order to determine if there is an age at which these behaviours stabilize. It might also help if more participants are included, since this will help determine the contributions of intra- and inter-subject variability, especially since this will have implications when one looks at the developmental pattern in atypical children. Other factors, such as the role of caregiver's interaction and levels of exposure to environmental stimuli also might affect the production of these behaviours, and these need to be documented in future studies.

Significant change in the occurrence of hand actions

Since most behaviours showed evidence of variability (according to growth trends), we had assumed that most hand actions would demonstrate an age at which change in the occurrence of behaviour was predictable. On the contrary, the predictions of dynamic systems theory [1], held good only in the case of select hand actions. All actions of hands involving objects and few involving play/rest showed an explicit age within the developmental period where a significant change in the occurrence of behaviour is evident (based on change point analysis). This is similar to what has been reported for other developing systems in infants [13-18]. But, the results might also imply that not all behaviours of the hand system show significant changes within the first year of life, which would then contradict the expectation of a dynamic system. Alternatively, it is also possible that a change in these behaviours might occur beyond the age of 1 year. Therefore, it substantiates the need for testing this in future studies with older infants. Similarly, change was found to occur at various months for different hand actions, suggesting that within the hand system, behaviours do not exhibit similar trends in variability.

Interestingly, except in the case of 'bang', the age at which there was a reliable change in the occurrence of these hand actions did not coincide with those months that showed a peak in the occurrence of the same behaviours, possibly suggesting that reliable change in behaviour is not related to its frequency of occurrence. The predicted growth trends of each of these hand actions were also varied; it was a mix of linear and non-linear trends. This might then suggest that behaviour is characterized by a specific expectation for when a change will occur, irrespective of the type of variability seen.

Following the age at which a significant change was observed it was also noted that those hand actions which were seen in infants from the age of 3 months tended to show a decrease in the rates following the age at which there was a significant change in occurrence (e.g. holding toy in hand (action with object), swing and index finger extension (actions during play/rest)). Other hand actions with objects, (e.g. reach, bang) showed the opposite trend, and were found to increase. This might possibly suggest that the variability seen in these behaviours might be seen even beyond the age of 12 months, and that

there could even be multiple points of change as part of reorganization within the system when novel behaviours are learnt [17]. This is especially considering the observation that novel behaviours seen after the age of 7 months (e.g. point, hand configurations) did not suggest the presence of a predictable age of change within the time frame that we studied. Future studies looking at children above the age of 12 months will be able to provide evidence to either support or refute this.

Conclusions

This study tracking the occurrence of hand actions in nine infants demonstrates that development of the hand system seems to echo the characteristics of a dynamic system. We found that the growth trajectories of most hand actions were marked with variability and revealed both linear and non-linear trajectories. However, even in the face of this variability, we found that only 'hand actions with objects' and few 'hand actions during play/rest' demonstrated significant and reliable changes in the rates of occurrence within the first year of life. All these raise questions regarding our current understanding of infant development and the requirement that there must be a change in our outlook towards the assessment of communicative behaviours in atypical children. However, the current study has its limitations since it has included only 9 infants and has only studied the development of hand actions till the age of 12 months. Therefore, future work with a larger sample and over longer observational timeframes, which also includes other co-developing behavioural systems, such as the vocal system, is warranted. The results of future studies may also help us better understand the developmental processes in atypical children.

References

1. Thelen E, Smith LB (1994) A dynamic systems approach to the development of cognition and action. Massachusetts: MIT Press.
2. Bates E, Benigni L, Bretherton I, Camaioni L, Volterra V (1979) The emergence of symbols: cognition and communication in infancy. New York: Academic Press.
3. Capone NC (2010) Gesture development. In: Shulman BB, Capone NC (eds.) Language development foundations, processes, and clinical applications. Massachusetts: Jones and Bartlett Publishers, 177-194.
4. Thelen E, Kelso JAS, Fogel A (1986) Self-organizing systems and infant motor development. Developmental Review 7: 39-65.
5. Trevarthen C (1977) Descriptive analyses of infant communication behaviour. In: Schaffer HR (ed) Studies in Mother-Infant Interaction: The Lock Lomond Symposium. London: Academic Press, 227-270.
6. Gullberg M, de Bot K, Volterra V (2010) Gestures and some key issues in the study of language development. In G Marianne & K De Bot (Eds.), Gestures in Language Development. Amsterdam: John Benjamins Publishing Co., 3-33.
7. Capirci O, Contaldo A, Caselli MC, Volterra V (2005) From action to language through gesture: a longitudinal perspective. Gesture 5: 155-177.
8. Butcher C, Goldin-Meadow S (2000) Gesture and the transition form one- to two- word speech: When hand and mouth come together. In D McNeill (Ed.), Language and Gesture. New York: Cambridge University Press, 235-257.
9. Feyereisen P, De Lannoy J (1991) Gestures and Speech: Psychological investigations. New York: Cambridge University Press.
10. Bates E (1976) Language and Context: studies in the acquisition of pragmatics. New York: Academic Press.
11. Fogel A, Hannan TE (1985) Manual actions of nine-to fifteen-week-old human infants during face-to-face interaction with their mothers. Child Development 56: 1271-1279.
12. Lew AR, Butterworth G (1997) The development of hand-mouth coordination in 2- to 5-month-old infants: Similarities with reaching and grasping. Infant Behavior and Development 20: 59-69.
13. Haken H, Kelso, JS, Bunz H (1985) A theoretical model of phase transitions in human hand movements. Biological Cybernetics 51: 347-356.
14. Vereijken B, Adolph KE (1999) Transitions in the development of locomotion. In G. J. P. Savelsbergh, H. L. J. van der Maas & P. C. L. van Geert (Eds.), Non-linear Analyses of Developmental Processes. Amsterdam: Elsevier,137-149.
15. Vereijken B, Thelen E (1997) Training infant treadmill stepping: the role of individual pattern stability. Developmental Psychobiology 30: 89-102.
16. Harbourne RT, Stergiou N (2003) Nonlinear analysis of the development of sitting postural control. Developmental Psychobiology 42: 368-377.
17. Smith LB, Thelen E (2003) Development as a dynamic system. Trends in Cognitive Sciences 7: 343-348.
18. Abney DH, Warlaumont AS, Haussman A, Ross JM, Wallot S. (2014) Using nonlinear methods to quantify changes in infant limb movements and vocalizations. Frontiers in Psychology 5: 1-15.
19. Lausberg H, Sloetjes H (2009) Coding gestural behavior with the NEUROGES-ELAN system. Behavior Research Methods, Instruments, & Computers 41: 841-849.
20. Taylor WA (2000) Change-Point Analysis: A Powerful New Tool For Detecting Changes.