The Interplay between Coordinated Motor-Vocal Imitation and Development in Toddlers

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Abstract

Background: Toddlers learn naturally through imitation of multi-modal stimuli. This study aimed to characterize toddlers' imitation of motor and/or vocal parameters of a demonstrated sequence of actions with or without an object in hand, and to test the association between vocal and motor imitation with motor and language development. **Method:** Sixty-four toddlers between 12-14 months (M=12.48, SD=0.67) participated of whom 12 were at risk for autism spectrum disorders (ASD). Toddlers imitated sequences of actions demonstrated with vocalizations from the Autism Observation Scale for infant hand tapping, stick tapping, and toy sheep hopping. Each task was coded for imitating a single motor action, imitating a sequence of actions, imitating a single sound, imitating a sequence of sounds, and the coordinated imitation of motor and vocal parameters. The Mullen Scales of Early Learning (MSEL) were administered. **Results:** 95% of toddlers showed some form of motor imitation, 47% showed vocal imitation, and 20% presented coordinated motor-vocal imitation. Imitation of actions with objects (sheep and stick) elicited significantly higher imitation scores than actions without objects (hand tapping). Higher vocal imitation scores were significantly correlated with higher MSEL expressive language and fine motor scores. **Conclusions:** Toddlers show a preference to the motor representation of actions in the presence of a competing vocal stimulus. Actions with objects facilitate imitation performance. Findings have implications for understanding the mechanisms of imitation and for designing developmentally appropriate imitation tasks.

Introduction

Imitation, the developmentally engraved give-and-take process of observing and enacting the actions of others, forms the basis for unsupervised social learning. In early childhood imitation plays a crucial role in the cultural transmission of knowledge and in the acquisition of language and tool use (Hewlett, Fouts, Boyette, & Hewlett, 2011; Shea, 2009; Vygotsky, 1978). While imitation has been recognized as fundamental in human phylogenetic and ontogentic development (Shea, 2009) its mechanisms remain unclear. Some models of imitation propose a unitary innate mechanism, which implies the presence of a brain system dedicated to imitation at birth (Meltzoff & Moore, 1997; Shea, 2009). Others view imitation as a product of specific developmental capacities (Pfeiffer, Iacoboni, Mazziotta, & Dapretto, 2008). Children with various developmental disorders such as autism spectrum disorders (ASD) show impaired imitation (Rogers, Hepburn, Stackhouse, & Wehner, 2003), which may relate to their social (Ingersoll, 2008; McDuffie et al., 2007) or sensory-motor deficits (McDuffie et al., 2007). Therefore, imitation has been included in many early child development screening and diagnostic measures predominantly through the evaluation of motor imitation. Imitation is also an important element in intervention (Ingersoll, 2010). As occupational therapists we often create situations for spontaneous learning through imitation, prompted imitation, or directly teach imitation to advance the patient's capacity to learn independently from the environment (deRenne-Stephan, 1980).

The goals of the study were to: (1) characterize the capacity of 12-14-month-old toddlers to imitate the motor and vocal parameters of a demonstrated sequence of actions, (2) compare the level of imitation elicited by different types of tasks, and (3) test the association between vocal and motor imitation with language and motor development.

Our study aimed to contribute to the understanding of motor vocal imitation development at the beginning of the second year of life. We focused on toddlers 12 to 14 months as evidence shows that during this age toddlers can voluntarily imitate (Elsner & Aschersleben, 2003; Schwier, Maanen, Carpenter, & Tomasello, 2006). Toddlers in this age range show the ability to imitate actions at a rate above that of the spontaneous occurrence of these actions compared to the end of the first year (Jones, 2007) and can capture the intentions and form of the demonstrator as well as the demonstrated action's circumstances (Carpenter, Akhtar, & Tomasello, 1998; Jones, 2009). Among children between 6-15 months, 2% showed imitation of bodily gestures (i.e., actions without objects) while 24-61% showed imitation of actions with objects, depending on the task (Christie & Slaughter, 2009). Actions with objects may facilitate imitation given the external cues they provide, reliance on prior knowledge, and their affordances. Affordances are the perception of the actions that are physically possible with a given object (Gibson, 1986). Based on these findings we expected to find higher levels of imitation of actions with objects as opposed to without objects at the beginning of the second year of life.

Natural learning often involves multi-modal stimuli to attend to and enact. We were interested in studying the young child's capacity to imitate a motor-vocal demonstration in order to more closely mirror real-world imitation situations. Coordinating vocal and motor behaviors in infancy is important for its link to later speech-gesture coordination (Iverson, 2010). Evidence suggests that unique brain areas are activated by the presentation of motor-vocal demonstrations versus motor only or vocal only demonstrations (Kaplan & Iacoboni, 2007). Developmentally *spontaneous* vocal-motor coordination was observed in most typically developing infants 6-9 months of age. The rate of producing vocal-motor coordination increased dramatically across this age range (Iverson & Fagan, 2004). However, when looking at the *imitation* of a combined motor and vocal demonstration, research shows that only 5.7% of typically developing 12-month-olds can coordinate the imitation of motor and vocal aspects (Carpenter, Call, & Tomasello, 2005). Research demonstrated that at 13 months toddlers at low risk for ASD can be differentiated by their higher rate of combined speech with gesture versus toddlers at high risk, and that this capacity is extremely delayed in high risk toddlers eventually diagnosed with ASD (Iverson & Wozniak, 2007). Coordinated motor and vocal imitation reflects the toddler's ability to both represent and execute two features of the same action.

Imitation is depicted as a behavioral product of developmental attainments in several domains such as: sensory-motor development (e.g., motor planning, action-effect associations; Paulus, 2014; Vanvuchelen, Roeyers, & Weerdt, 2007), and/or social development (e.g., social attention, motivation, and shared intentionality; Allen & Courchesne, 2001; Carpenter, 2006; Ingersoll, Schreibman, & Tran, 2003; Ingersoll, 2008). Therefore, we hypothesized that motor imitation would correspond with level of motor development and vocal imitation would correspond with language development.

Scholars propose that imitation of gestures and language productions are linked by a shared underlying capacity for semantic representation (Bates & Dick, 2002; Willems & Hagoort, 2007). This is supported by the association between gesture imitation and verbal mental age in typical and clinical samples (Rogers, Young, Cook, Giolzetti, & Ozonoff, 2008; Rogers, Young, Cook, Giolzetti, & Ozonoff, 2010) and with expressive verbal communication in typically developing one-year-olds (Reznick, Baranek, Reavis, Watson, & Crais, 2007). Furthermore, a review of the research shows that the development of imitation of symbolic gestures around 12-months predicts the next language milestone hinting to their interplay (Capone & McGregor, 2004). We hypothesized that higher receptive and expressive language levels would correlate with higher levels of vocal imitation.

Imitation has been applied as a measure of motor planning (Dewey & Bottos, 2006). Imitation of meaningless actions in particular has been described as a process of matching visual stimuli to motor action (Rumiati & Tessari, 2002). Evidence shows a high correlation between motor development and imitation of actions with objects found in typically developing 6-15 month-old infants (Christie & Slaughter, 2009). In young children with ASD, studies indicate a moderate association between imitation and motor skills (18-33 months; Luyster et al., 2008) and between motor imitation and fine motor development (24-36 months; McDuffie et al., 2007). We hypothesized that motor imitation would correspond with motor competencies.

The hypotheses of the study were that: (1) motor imitation will be more prevalent than vocal and vocal-motor integrated imitation at the beginning of the second year of life, (2) tasks with objects will yield higher imitation performance than those without object in hand, and (3) motor and vocal imitation performance will relate to scores in corresponding developmental areas.

Method

Participants

This study describes the imitation of 64 toddlers who participated in a larger longitudinal ASD screening study in a community sample (see details [withheld for blind review]). This subsample comprised of both toddlers at risk for ASD (n=12), and those not at ASD risk, based on the First Year Inventory (FYI: Reznick et al., 2007), an ASD screening questionnaire. Initially, we had 20 additional toddlers who were excluded from this study for the following reasons: (1) Nine were not administered all three types of imitation tasks from the Autism Observation Scale in Infants (AOSI; Bryson, Zwaigenbaum, McDermott, Rombough, & Brian, 2008), (2) six had their face and hands unclearly viewed in the video, and (3) five had incomplete data or task administration errors.

The study focused on 12-14 month-old toddlers since at around this age, toddlers have already established directed imitation. The average age of the sample was 12.48 months (*SD*=0.67 months). The sample comprised of 36 boys (56.3%) and 28 girls (43.75%); 42.2% of the sample was first-born and 32.8% second-born. Average birth weight was 3.2 kg (*SD* = 0.53) after an average of 39.1 weeks of gestation (*SD*=1.5). Average Early Learning Composite Score on the Mullen Scales of Early Development (MSEL; Mullen, 1995) was 92.16 (*SD=12.74*). Seventy-eight percent of the parents were of non-minority ethnicity, 57.9% of mothers had a bachelor's degree or above level of education, 82.8% were married, and 62.5% of mothers worked full-time.

Measures

The Autism Observation Scale for Infants (AOSI; Bryson, Zwaigenbaum, McDermott, Rombough, & Brian, 2008) is a semi-structured play observation research tool, designed to assess and monitor the emergence of target ASD behaviors in infants, ages 6–18 months and takes about 20 min to administer. The child is seated on his/her parent's lap in front of a table and facing the examiner. The AOSI includes 16 markers: visual tracking, disengagement of visual attention, orienting to name, differential facial emotion, anticipatory social response, imitation, eye contact, social babbling, social smiling, face-action coordination, reactivity, social interest and affect, transitions, motor control/coordination, atypical motor behavior, and atypical sensory behavior. Some behaviors are rated on a scale from 'normal function' to 'deviates from normal development'. This measure has shown good inter-rater reliability at 6, 12, and 18 months (0.68-0.94); and acceptable test-retest reliability (0.61-0.68; Bryson et al., 2008).

The current study focused on the AOSI imitation task. The imitation task at 12 months consists of three tasks, one without object in hand-hand tapping on table; the second, with object in hand-stick tapping on table and the third, hopping a small sheep toy across the table. Each demonstrated task presents a sequence of repeated actions accompanied by different neutral vocalizations (e.g., ba-ba-ba during three hand taps in sequence). After each demonstration there is a pause and a statement "now it is your turn". This is repeated three times for each task. The child is requested to imitate nine times (3- hand sequence, 3- stick sequence, 3- sheep sequence). The examiner can choose to order the tasks in a manner that suits the child. For instance to rule out non-imitative actions if the child tended to hand tap spontaneously, the examiner started with the sheep hopping task in order to elicit a clear directed imitation response. Sheep hopping was the most novel action as it required disengaging from symbolic play and moving this object in a non-typical manner. The AOSI coding rules denote that if a child shows one good approximation of motor imitation out of nine, he/she passes (Bryson et al., 2008).

Development of the Coding Imitation System (CIS). The CIS was developed for this study to capture different types of imitation capacities during the AOSI imitation task. The CIS analyzes motor response to the visual aspect of demonstration and vocal responses to the auditory component as well as a coordinated motor-vocal response. The CIS was developed based on previous imitation studies (Campanella & Rovee-Collier, 2005; Carpenter et al., 1998; Carpenter et al., 2005; Devouche, 2004; Hanna & Meltzoff, 1993; Nielsen, 2006). Five parameters were coded: motor imitation – single action within the presented sequence, vocal imitation – single sound within the sequence, motor imitation of a sequence of actions, vocal imitation of a sequence of sounds, and motor-vocal integrated imitation – coordinated imitation of at least one demonstrated action and one sound. The parameters were coded as “present” or “not” in each of the nine AOSI imitation trials for a possible total raw frequency score of 9. Actions resembling the demonstration were coded as present only following demonstration. Imitating more than one action in a row uninterrupted by another action was coded as sequence motor imitation and as motor imitation. The same rule pertained to vocal imitation. Aside from analyzing the raw scores, CIS mean scores were created for total imitation score across tasks and parameters, parameter scores (5 parameters across tasks), and task scores (3 imitation tasks * 5 parameters). Each mean score ranged from ‘0’, no imitation to ‘1’, full imitation. Each mean score corresponds to a percentage. For instance a 0.70 mean motor imitation score in hand tapping can be interpreted as 70% presentation of motor imitation in the hand tapping trials.

The CIS showed high internal reliability for the 45 codes (5 parameters * 9 trials) as indicated by a Cronbach’s alpha of 0.91. Scores within each parameter (i.e., number of times the parameter was coded across 9 trials) also yielded high internal reliability as follows: Motor imitation α=0.74, Vocal imitation α=0.81, Motor sequence imitation α=0.74, Vocal sequence imitation α=0.85, Motor-vocal integration α=0.86. Within task Cronbach’s alpha was 0.81 for hand tapping, 0.75 for stick, and 0.79 for sheep. Imitation score in one task was significantly (p<.05) associated with the other tasks. Spearman correlation coefficients were r=0.28 between hand tapping and stick imitation tasks, r=0.29 between hand tapping and sheep, and r=0.43 between stick and sheep imitation tasks.

Inter-rater reliability of the CIS was examined for 14 randomly selected videos (21.8%). Two pediatric occupational therapists with over 10 years of clinical experience (one is the second author) coded the imitation tasks independently.

Inter-rater reliability was high as evident from a kappa=0.93, *p*<.001.

The Mullen Scales of Early Learning (MSEL: Mullen, 1995). The MSEL is an assessment of motor and language functioning from birth to 68 months. It takes about 30 minutes to administer to toddlers ages 12-36 months. The MSEL yields five scale scores that translate into t-scores (Fine Motor, Gross Motor, Visual Reception, Expressive Language, and Receptive Language) and an Early Learning Composite score (ELCS). In the normative sample of the MSEL, the internal reliability value for the ELCS was 0.91, and for the individual scales values ranged between 0.75-0.83. The 1- to 2- week test-retest reliability in the normative sample of 1- to 24-month-old children was sufficient (0.82-0.96) as described in the manual (Mullen, 1995).

Procedure

The toddlers described in this study were recruited as part of a larger community early screening study of 619 12-month-olds for whom their parents completed an ASD screening questionnaire (details withheld for blind review). A subset of 84 toddlers participated in an in-home assessment, 64 of whom were included in the present study based on the inclusion criteria described above. The assessment included the administration of the AOSI (Bryson et al., 2008) and the MSEL (Mullen, 1995) and was filmed. In the current study we analyzed imitation performance during the AOSI imitation task.

Data Analysis

Given the non-normal distribution of the CIS scores, non-parametric tests were applied. In addition, since there were six different orders of imitation tasks, we examined the difference in imitation according to the most frequent order (62.5%) ,which was stick, sheep, and hands. To determine whether learning effects should be taken into consideration in the analyses we compared the imitation scores across trials. Friedman's test showed no significant difference between imitation trials when divided into parameters or to tasks (*p*>.05).

There was a significant association between the total CIS score and the 12-month-old FYI screening score of the child (*r*=-.26, *p*<.05). There was a non-significant difference in the CIS score between the at ASD risk (n=12) and not at risk (n=52) groups. Therefore, we did not separate these groups in our analyses.

Results

Imitation Descriptions

Figure 1 displays the imitation parameters such that '0' indicates no manifestation of that parameter across trials, 1-4 indicates that parameter manifest in less than half the trials and 5-9 indicates that parameter manifest in over half the imitation trials. All toddlers but one were able to perform some form of motor imitation (imitation of a single action, imitation of a sequence of actions, or motor-vocal imitation) in at least one trial (one toddler did not display motor or vocal imitation in any trial). Seventy four percent of the toddlers showed motor imitation in more than half the imitation trials (5-9 trials). This is compared with less than 50% who imitated the vocal aspect of the task. Coordinated motor-vocal imitation was presented by 20.3% of the toddlers with one toddler who showed this capacity in all nine trials. Mann-Whitney tests indicated that there were no significant imitation differences between males and females on the five imitation parameters (*p* .05).

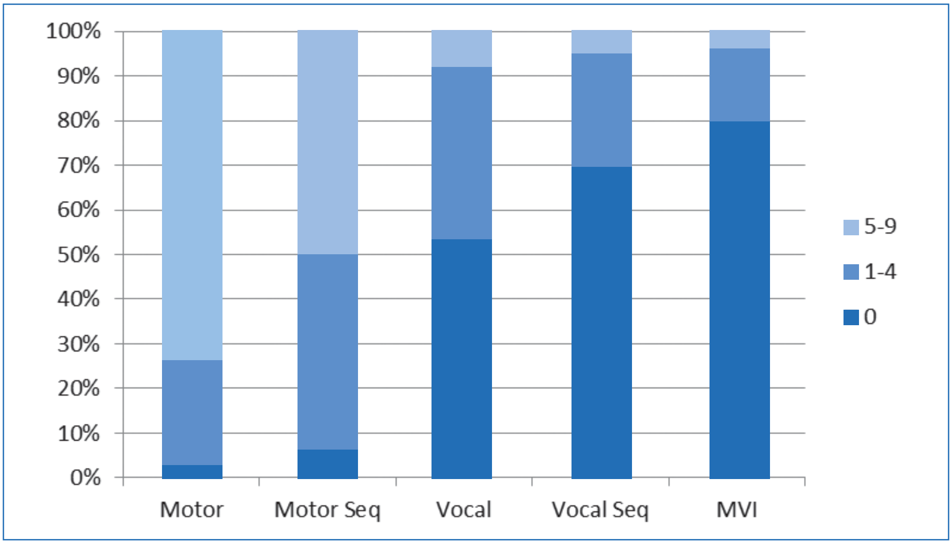

Figure 1. Percentage of occurrences of each of the CIS parameter scores across trials

Note. The raw CIS parameter scores are presented for describing the range of performance. Motor: imitation of an action. Motor Seq: imitation of a sequence of actions. Vocal: imitation of a sound. Vocal Seq: imitation of a sequence of sounds. MVI: combine imitation of motor action and sound.

Comparison of Imitation across Tasks

Figure 2 presents mean CIS scores by task that can be interpreted as percentages. The Friedman Test indicated significant differences between the three imitation tasks for the following parameters: vocal imitation (χ^2=12.26, $p<.01$), and vocal sequence imitation (χ^2=6.26, $p<.05$). Motor imitation was marginally significant (χ^2 =5.43, p=.07). Pairwise comparisons using Wilcoxon Signed

Ranks Tests showed that the significant differences in imitation were between the hand versus stick and sheep tasks. In the stick versus the hand tapping task toddlers had significantly higher motor imitation and higher vocal imitation (Z=-2.87, *p*<.01, Z=-2.44, *p*<.01, respectively). In the sheep versus hand tapping task, toddlers had significantly higher scores in vocal imitation, vocal sequence imitation, motor sequence imitation, and marginally in motor imitation (Z =-5.59, *p*<.001, Z=-2.56, *p*=.01, Z=-1.82, *p*=.07, respectively).

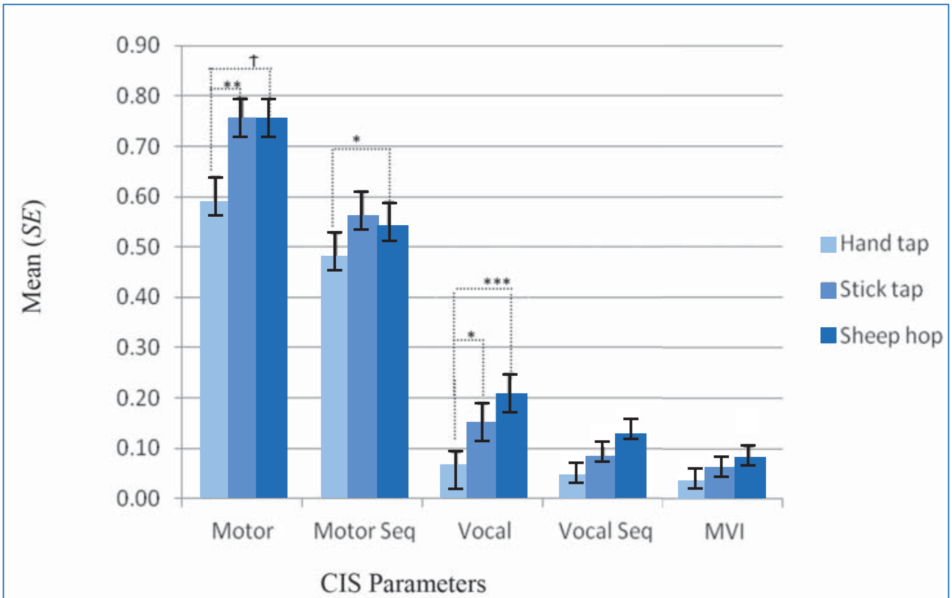

Figure 2. Distribution of CIS mean scores between tasks

Note. CIS mean scores range between 0-1 and correspond to percentages. Motor: imitation of an action. Motor Seq: imitation of a sequence of actions. Vocal: imitation of a sound. Vocal Seq: imitation of a sequence of sounds. MVI: combine imitation of motor action and sound.

*† p≤ 07. *p≤.05. ** p<.01. ***p<.001.*

Association of Imitation with Language and Motor Development

To examine the association between CIS imitation parameters and tasks relative to MSEL motor and language t-scores we conducted Spearman Rho correlations. Significant (*p*< .05) correlations were identified between MSEL expressive language t-score and vocal and vocal sequence imitation scores, (r=0.33, 0.29, respectively). In addition, the MSEL fine motor t-score was significantly associated with vocal imitation (r =0.29, p=.02). Interestingly, of all tasks the sheep mean imitation score was significantly correlated with MSEL expressive language t-score (r=0.40, p<.01).

Discussion

Imitation is a fundamental capacity which enables unsupervised social and motor skill learning; thus, is included in early screening tools and is a target behavior in many early intervention programs (Ingersoll, 2010). In the current study motor imitation was prominent in toddlers 12-14 months old, while vocal and combined vocal motor imitation were infrequent. Imitation tasks with objects (i.e., stick and sheep) facilitated higher imitation performance relative to imitation of an action without an object. Moreover, imitation of an action with an object that holds symbolic meaning (i.e., toy sheep) facilitated higher vocal as well as coordinated motor-vocal imitation. Vocal imitation, which was variable in this age group, was associated with expressive language and fine motor development. Findings can guide the setting of developmentally appropriate imitation goals with effective prompts for advancing early learning through imitation.

Most of the toddlers in our study imitated one parameter at a time, particularly the visual one (95%). About 20% of the sample was capable of producing a combined motor and vocal action in at least one trial, which is more than the previously reported rate of 5.7% (Carpenter et al., 2005). In our study rates may be higher due to the demonstrated actions being less complex. Nonetheless, simultaneously copying competing auditory and visual stimuli is not well established at this stage of life. This may correspond with the immaturity of the superior temporal sulcus (STS), a brain region activated by combined auditory-visual stimuli and with perceiving the intentions of others (Kaplan & Iacoboni, 2007). The capacity to spontaneously combine motor and vocal behaviors has been found to differentiate toddlers at low versus high risk for autism (Iverson & Wozniak, 2007); hence, it is important to further investigate the typical development of this capacity without the imitation demand.

According to the visuomotor imitation model observing actions with objects prompts a direct motor response (Rumiati & Tessari, 2002). This priming effect was supported by the higher imitation scores we found for actions with an object versus hand tapping both in terms of the motor and vocal imitation (see Figure 2; rates of single motor imitation in the sheep task=69%, stick=76% and hand=59%; rates of single vocal imitation in the sheep task=21%, stick=15%, and hand=7%). This is consistent with previous research with typically developing children as well as those with developmental disorders who showed higher rates of imitation of actions with objects (Stone et al., 1997). The sheep trials had significantly higher rates of both imitation of a single sound and of a sequence of sounds and marginally higher rates of imitating a single action. The symbolic nature of the object and the novelty of the action may have facilitated attention and expression of the vocal aspects of the demonstration. One could also interpret the low hand tapping scores in relation to the high rate of the spontaneous production of hand tapping between ages 6-10 months (Jones, 2007). Hand tapping during the modeling phase was not counted as imitation potentially masking detection of a clear response to the demonstration. Future research is needed to determine whether it was the novelty of the action (hopping a sheep across the table) or the symbolic nature of the object in hand (toy animal) that elicited higher imitation skills and particularly vocalizations.

One of our goals was to test whether imitation is interdependent upon motor and language developmental attainment. We found that the vocal parameters of imitation were closely associated with expressive language and fine motor development in the MSEL rather than with receptive language, visual perception, and gross motor development. Toddlers with higher expressive language were also better imitators of the sheep task which, as noted above also produced the highest rates of vocal imitation. This is consistent with previous evidence for an association between imitation and language in typically developing children (Charman et al., 2000; Reznick et al., 2007). These findings can be explained by the parallel development of gestures and words and their shared reliance upon internal representations (Capone & McGregor, 2004). Imitation and language development both rely on learning through observing and attending to the intentions of others, creating internal representations, reciprocating, and both are driven by social motivation. Imitation is an indicator of the child's capacity to create internal representations and replicate them in one's own actions (Charman, 2006). Another interpretation is that many items on the Fine Motor and Expressive Language Mullen scales in this age band demand imitation; hence, were associated with the vocal imitation scores that had the greatest variance to explain.

In contrast to our hypothesis, there were no significant associations between motor development and motor imitation. This may be explained by the low variability in motor imitation scores in our sample and/or by the low motor complexity of the demonstrated actions. The imitation scoring in this study demanded a crude replication of the action and did not measure differences in spatial and temporal accuracy of the action. For instance hopping the toy sheep horizontally or vertically would gain the same score. Further research with tasks of greater motor complexity and measures of quality of actions are needed in order to validate the utility of imitation as a measure of motor development in early childhood.

Study Limitations

In planning future studies limitations in the imitation tasks and coding system used in this study should be taken into consideration. The imitation tasks were adopted from the AOSI. The presented actions did not differentiate between imitating actions demonstrated with versus without vocalizations. A comparison of imitating an action or sound demonstrated with versus without vocalization would enable the determination of the presence of an attention bias in imitating vocalizations in the presence of competing visual stimuli. It is plausible that more toddlers would imitate vocalizations if they were presented alone or were meaningful. To further explore the question of the development of coordinated multi-modal imitation it would be necessary to demonstrate a larger pool of novel actions and in different age groups. In addition, the CIS was not sensitive in identifying toddlers at risk for ASD. A coding system which captures the quality of imitation (e.g., number of taps, errors in space) may be more sensitive to developmental differences. The CIS may be better in differentiating ASD at an older age in which the gap in imitation skills is more pronounced.

Conclusions

This study showed that the majority of toddlers can attend to one action modality at a time while giving precedence to the visual modality. Imitation of actions with objects elicited higher motor and vocal imitation and imitation of actions with a symbolic object specifically facilitated vocal imitation. Expressive language development was associated with motor and vocal parameters of imitation, supporting their common reliance on a symbolic representation mechanism (Bates & Dick, 2002; Willems & Hagoort, 2007). The lack of association between imitation and receptive language, visual perception, and gross motor development was surprising. Social and skill learning require attending to and producing combined motor and vocal behaviors; hence, it is important to further investigate the maturation of this coordinated ability. Longitudinal research with a larger sample is needed for fully understanding the development of different types of imitation and its prediction of developmental attainment. The dominance of uni-modal imitation at this early age may reflect immaturity at the perceptual, representation, and execution levels calling for further inquiry. When planning imitation training this knowledge can be applied to design tasks that facilitate different types of imitation (e.g., motor versus vocal imitation), that differentiate between the parameters that the toddler is asked to imitate, and set developmentally appropriate standards when interpreting a delay in combined motor vocal imitation.

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