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Which Relevant Information Do Preschoolers and Scholars Perceive and Select for Imitating a Series of Walking Movements?

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Abstract

Background: Imitation is commonly considered as a hierarchically organized mechanism. It is frequently used to explore various scientific researches, but few works had studied the imitation of locomotion movements.

Objectives: The current study aimed at investigating what information children of different age groups select and integrate for performing a series of locomotion movements.

Methodology: One hundred and thirty children from 3.5 to 7.5 years of age were separately instructed to walk on and between the obstacles in different imitation forms following gestural demonstration, and in a control condition following verbal instructions. The children's performances were videotaped, coded in binary data, and then transformed in percentage scores.

Results: All children performed the modeled walking movements, but did not necessarily do so with the same step-alternating modes or footedness. The model helped the preschoolers to adopt his step-alternating modes and stabilized the schoolers above 5.5 years of age. The disparity of the children's walking performances was due to the priority to imitate the movement goal rather its aspects.

Conclusion: These findings well confirmed that imitation is a hierarchically organized mechanism.

Keywords: Balance and propulsion; Development; Footedness; Matching process; Step-alternating; Walking movements

Introduction

Imitation is an active decomposed-recomposed process that children use for reproducing motor skills [1,2]. This decomposing-recomposing processis functionally dependent on perception-action matching [3,4]. There are at least two matching levels linking observer and demonstrator; i.e. direct for performing goal-directed movements [5-7], i.e. complex for including other aspects of movements [8,9].

When the demonstrator is an adult person with efficient musculoskeletal and motor control systems, and the observers are children with different ages, body sizes, or leg lengths, imitation requires a complex and different set of mechanisms to match observed coordinated motor skills, sensitively to certain constraints [10,11]. In Newell's system of constraints [12], the match of any motor coordination is the result of features of the task to perform, subject who performs the task, and also environment in which the task is performed. Therefore, the current study aims to investigate what information children of different age groups do select and integrate for imitating locomotion coordination, both in an experimental condition when they observe an adult's gestural demonstrations of walking movements into different imitation conditions, and in a control condition following verbal instructions. To our knowledge, there production of a walking has not been widely investigated in imitation.

Walking is defined as the capability to move forward with a succession of double and simple supports [13] in alternating mode. According to Bril and colleagues [14-16], walking is governed by potential propulsion and balance skills. The control of these skills is a complex mechanism because it demands a compromise between the body's propulsion and maintenance of balance (17A). To this end, Bril and Brenière [14] evoked two essential developmental walking phases. The first one is reserved for the integration of posture and movement. It is characterized by a rapid evolution of walking parameters (e.g. movements and cadence of steps), and lasts for three to five months after the first autonomous steps. During this phase, children learn to resolve the mechanical constraints of body, floor, and gravity. The second phase is reserved for the adjustment phase. It is longer than the first phase because it concerns the acquisition of independent walking [16,17].

Independent walking is commonly considered as acquired between two and three years of age, but opinions differ on its developmental scale. For Cavagna, Franzetti, and Fuchimoto [18], independent walking is acquired at five or six years of age, whereas for Brenière and Bril [13], this capability requires seven to eight years of practice. Bril et al. [19] explained this by a necessary learning process in walking: "learning to walk is described as an integration process of postural requirements i.e. stabilizing the body to ovoid a fall, and dynamic requirements i.e. building up dynamic conditions to propel the body forward and integrate the available sensory information" [19].

In his system of constraints initially reserved to study the coordination modes, Newell also include the footedness process because it is a relevant factor in locomotion coordination. Difficulties to maintain balance in walking are further accentuated because the weight of the whole body is supported by one leg during the swing phase [16]. This is the largest balance challenge that children meet

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in walking [20]. In jumping movements, Vaivre-Douret and Bloch [21] demonstrated that between the age of two and three, only 27% of children used the right foot for landing, and 83% used both feet. However, in some pedestrian movements, Gabbard [22] demonstrated a mixed-footedness among 3-to-11-year-old children.

Imitating a locomotion movement, the demonstrator and observer would be linked by a matching process. Matching may be direct for only reproducing the end-goal [9,23]. Meltzoff and Moore [24] already showed an early capability to mimic facial and manual gestures (e.g., tongue protrusions, lip pursing, and hand waving) seen on other persons. They concluded that the matching of others' visible movements with one's own movements might be an inborn ability. Wohlschläger et al. [2] demonstrated that 3-to-6-year-old children also reproduced a primary goal of touching a correct body part (e.g. the ear), and attended less to the subsidiary goal of how the touch was to be achieved. Matching may be also complex for including other aspects of movements, such as the precise body part(s) with which the movement is started [23,25,26]. While the left/right hand discrimination had been largely investigated, the left/right foot one is little studied. Deloaoche, Uttal, and Rosengren [27] evoked that, before eight years of age, child had difficulties to represent the segmental state of another person's body, and hence did not copy the precise body part.

The current work expands the previous studies investigating the hierarchy process in imitation. It also tests new aspects by exploring at the same time several imitation conditions with varied observation and reproduction delays for showing the variability of the children's responses. We firstly hypothesized that all children selectively performed the goal's movement rather its aspects or details. We secondly hypothesized that the children would be helped by the adult model to adopt his walking modes only if they had sufficient coordination and footedness.

Method

Participants

Two groups coming from the middle class and belonging to the same state primary school in the region of Poitiers (France) participated in this study. A first experimental group was composed of 85 children and was divided into five age groups: 3.5, 4.5, 5.5, 6.5 and 7.5-year-olds, respectively. Each group comprised 17 children (9 males and 8 females: M = 5.5 year-olds, range = between 3.5 and 7.5-years of age). The children were instructed by a human adult model to imitate a short course of walking movements from gestural demonstrations. A control group was composed of 45 children and also was divided into five age groups: 3.5, 4.5, 5.5, 6.5 and 7.5-year-olds, respectively. Each group comprised nine children (5 males and 4 females: M = 5.5 year-olds, range = between 3.5 and 7.5-years of age). The children received verbal instructions from the same human adult experimenter to perform the same task in a control condition. Gender variable was measured here, neither in the experimental nor in the control group. In order to avoid biases related to number of participants in experimental (85 children) and control (45 children) groups, each child had to perform one trial in each condition, except in deferred imitation (six trials) for raising a possible learning effect. This study was approved by the Ethics Committee of the Paris Descartes University.

Apparatus

Both experimental and control groups of children were videotaped in their school sports room with a JVC SR-VS10 VHS/DV digital video camera (25 images/s) by a cameraman (Figures 1 and 2). Three

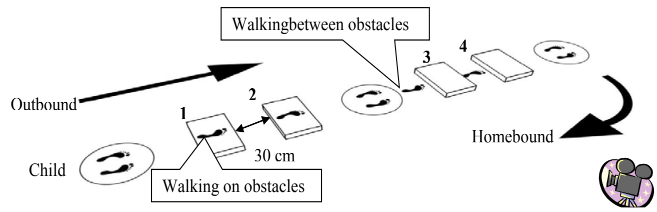

Figure 1: Walkway in Control Condition with Verbal Instructions (CCVI), Immediate Imitation in the Same Walkway (IISW), time Lagged Imitation (TLI) and Deferred Imitation (DI).

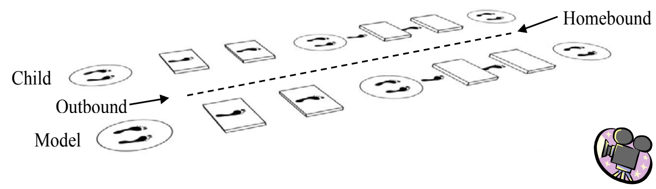

Figure 2: Simultaneous imitation in two parallel walkways (SI//W).

circles (30 cm in diameter) were used for walking: the first circle was positioned at the outset of walkway to materialize the departure, the second circle was positioned at the close of walkway to materialize the arrival, and the third circle was positioned half way through the walkway to materialize the change of the walking strategy (on and between the obstacles). Four obstacles (30 cm×15 cm×10 cm) were also used in this walkway. Each obstacle was placed 30 cm away one from the other. The first two obstacles were positioned ahead of the first circle for walking on the obstacles, and the other two obstacles were positioned ahead of the third middle circle for walking between the obstacles. The total length of the walkway was about 2.50 min each execution direction.

Procedure

In the experimental conditions, the adult model individually instructed each child of each age group to watch and then imitate exactly what he had just done in the two execution directions. At outbound, each child had to start with both feet in the first circle; he/she walked with step-alternating mode on the first two obstacles, starting with the right foot. Then, he/she placed both feet in the middle circle; he/she walked with step-alternating mode between the last two obstacles, also starting with the right foot. At homebound, each child of each age group had to reproduce the same walkway as at outbound.

Experimental conditions

The experimental group imitated the walkway under two separate series of imitation tests. The first series was characterized by the temporal and spatial proximity between the model and the children. It was reserved for the:

Immediate imitation in the same walkway (IISW): Each child of each age group positioned behind the adult model and immediately reproduced one trial in the same walkway. It was supposed that he/she only copied the observed walking movements.

Simultaneous imitation in two parallel walkways (SI//W): The adult model and the child were positioned side by side. The model instructed each child of each group to watch and imitate at the same time and in the same direction, but each in his/her own walkway. Each child had one trial. It was supposed that he/she translated the observed walking movements.

Time Lagged Imitation (TLI): Just after finishing the simultaneous imitation (15-second delay), the adult model invited each child of each age group to perform alone the walking movements for one trial, without accompanying him/her. It was supposed that he/she answered by remembering what he/she had just done.

One week after the three previous imitation conditions, a second series of tests was reserved for the deferred imitation (DI) through six sessions (six trials). During six weeks, each child of each age group was instructed to reproduce alone, in the same walkway, after the model's demonstration (three-minute delay) at the beginning of each session. It was supposed that he/she answered by remembering what he/she had retained following each model's demonstration.

Control condition

After one week to the four latter imitation conditions, each child of each age group was verbally invited by the same adult experimenter to perform the same walking movements as in the experimental conditions. Each child had one trial.

Coding and statistical analysis

The children walking movements both in experimental and control conditions were coded in binary data (1–0). If their walking was reproduced with step-alternating mode (right foot/left foot or left foot/ right foot) without stopping over the obstacles, it was coded as "1" and as "0" if they walked without step-alternating mode (stopping at each obstacle). The children's walking was also separately coded as "1" if they started with the right foot, and as "0" if they started with the left foot.

The statistical process of binary data mobilized specific methods. The binary codes did not share out according to a normality law, and thus did not allow the normality test. It was thus necessary to use a log-transformation of performances to apply an adequate ANOVA. The most frequently used transformation was angular transformation in percentage [28]. The software used for data analysis was Statistica 6.1 (Statsoft, Inc.). A Reduced Distance test was carried out to determine the significant interaction between the experimental variables with more than two levels to determine what the effect should be ascribed to. The statistical significance was set at $p<.05$. A correlation test was also used for analyzing certain morphological parameters of each child of each age group (leg lengths, or obstacle intervals). These parameters (cm) were relevant factors for the balance and propulsion constraints.

We also coded the total scores of each child of each age group in each imitation condition. These scores corresponded to the global number of children for each age group. They were measured with three statistically defined indicators: (i) accordance with the model (AWM) -score ≥ 80%: he/she always performed the walking movements with step-alternating mode and starting with the right foot; (ii) non-accordance with the model (NAWM) -score ≤ 20%: he/she imitated the walking movements using every time different step-alternating modes and footedness; (iii) variability (Varia) -score between 20 and 80%: he/she fluctuated among step-alternating and non-step-alternating modes and left/right footedness. These indicators were important because they determined the accordance degree of each child both in step-alternating modes and footedness and, they also determined in which imitation condition a given age group would be helped by the model to adopt his step-alternating modes and/or footedness. The three dependent variables were the children's success in step-alternating mode, footedness, accordance, non-accordance, variability scores (%). The three independent variables were the five age groups: 3.5 to 7.5-year-olds, the two walking modes: on and between the obstacles, the two execution directions: outbound and home bound. In the control condition, ANOVA and correlation analyses were carried out. For the ANOVA, there were two independent factors: -age group (five levels: 3.5 to7.5-year-olds), and -walking mode (two levels: on and between the obstacles). For the correlation, there were three independent factors: -age group (five levels: 3.5 to7.5-year-olds), -leg lengths (cm) and -obstacle intervals (cm). In the first series of imitations, there was a four-factor analysis of variance and the independent factors were: -age group (five levels: 3.5 to 7.5-year-olds), -imitation conditions (three levels: immediate imitation in the same walkway, simultaneous imitation in two parallel walkways, time lagged imitation), -walking mode (two levels: on and between the obstacles), and -execution direction (two levels: outbound and homebound).

For the second series of deferred imitation, there was a four-factor analysis of variance, the independent factors were -age group (five levels: 3.5 to 7.5-year-olds), -walking mode (two levels: on and between the obstacles), -execution direction (two levels: outbound and homebound), and -trials (six levels of repetitions). To evaluate the whole body postural control, the walking duration of only experimental group was timed (seconds). The duration corresponded to the time from the moment he/she put his foot on the second obstacle, and the moment when he/she left it. The duration was timed separately for the walking on and between the obstacles in each imitation condition. The walking duration was considered as a dependent variable. It was submitted to an analysis of variance ANOVA and to an adequate post hoc test by pairwise comparisons. This test was carried out to determine the significant interactions between the experimental variables with a level set at $p<.05$.

Results

We first present the results of the children's walking scores in the control condition, which is used as a valuation scale of their real motor repertoire compared with imitation ones. Then, we present the children's walking scores in the experimental condition for determining in which imitation condition the children would be influenced by the model to take up his walking modes and/or footedness.

Control condition with verbal instructions

Step-alternating mode: ANOVA showed a significant effect of age: $F(4,+\infty) = 7.27$, $p<.0001$. The Reduced Distance test attributed the difference to the 3.5-year-olds. They accounted lower scores (44% on, and 66% between the obstacles) than the other age groups. Half children of this group put both feet on and between each obstacle after each footstep. The successful of the other age groups was total (100%) in the two walking modes on and between the obstacles.

The correlation between leg length and obstacles' intervals was: r(0.571098), $F(1,43) = 20.813$; $p<.00004$. The correlation between age and obstacles' intervals revealed more important coefficient value: r(0.763251), $F(1.43) = 60.007$; $p<.0001$ than the previous one. The same correlation measured only in the 3.5 and 4.5-year-olds was more significant: r(0.935379), $F(1,16) = 111.93$; $p<.0001$. The younger children were short in body size (3.5-year-olds: 98.66 cm) and leg lengths (48 cm) compared to the body size of the other age groups (4.5: 108.55 cm, 5.5: 113.22 cm, 6.5: 115.77, and 7.5-year-olds: 121.55 cm, respectively) and leg lengths (4.5: 54 cm, 5.5: 60 cm, 6.5: 60 cm, and 7.5-year-olds: 63 cm, respectively) (Table 1).

Footedness: No significant effects of age: $F(4,+\infty) = 1.75$, $p>.05$ and walking modes: $F(4,+\infty) = 0.13$, $p> 0.05$ were found in the footedness of children.

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Age (yrs.)	Leg length (cm)	Interval on obstacles (cm)	Interval between obstacles (cm)
3.5	48 ± 3.42	15 ± 02.53	19 ± 02.38
4.5	54 ± 2.71	28 ± 02.29	24 ± 02.38
5.5	60 ± 2.64	36 ± 01.75	28 ± 01.25
6.5	60 ± 4.13	41 ± 11.61	39 ± 04.09
7.5	63 ± 5.61	42 ± 12.71	55 ± 09.10

Table 1: Mean values (± SD) of biometric data of the legs length and obstacles interval for each control age group.

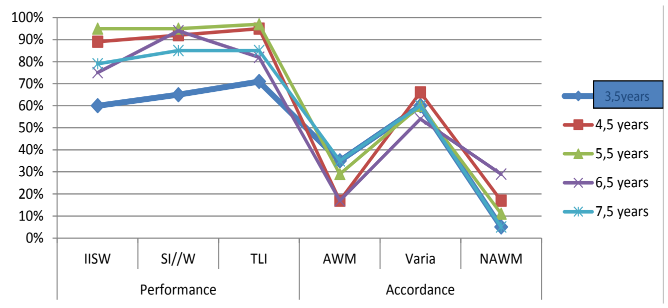

Figure 3: Scores of step-alternating mode (%) in every age group in Immediate Imitation in the Same Walkway (IISW), simultaneous imitation in two parallel walkways (SI//W), Time Lagged Imitation (TLI) (left part), and Accordance With the Model (AWM), variability (Varia) and Non-Accordance With the Model (NAWM) (right part).

The first series of imitation: IISW, SI//W, TLI

Step-alternating mode: ANOVA showed a significant effect of age: F(4,+∞) = 7.21, p<.0001. The Reduced Distance test attributed the difference to the 3.5-year-olds who accounted a lower score (65%) than the other age groups (4.5: 92%, 5.5: 96%, 6.5: 83%, and 7.5-year-olds: 83%, respectively) (Figure 3). The 3.5-year-olds were variable (60%) and fluctuated among step-alternating versus non-step-alternating modes. The 4.5-year-olds showed an important accordance with the model (76%), helped by this one in temporal and spatial proximity imitation. The 5.5-year-olds showed more success (96%) and accordance degree with the model (94%) than the other age groups. The 6.5- and 7.5-year-olds showed an important accordance with the model (70%, 64%), but also some variability (30%).

Footedness: No significant effects of age, F(4,+∞) = 0.47, p>.05, imitation conditions, step-alternating mode, F(4,+∞) = 0.47, p>.05, were found in footedness ability. Only 35% of the 3.5 and 7.5-year-olds adopted the model's footedness, while the other age groups were variable (4.5: 66%, 5.5: 60% and 6.5-year-olds: 54) and fluctuated between the right and left foot (Figure 4).

Walking duration in: IISW, SI//W, TLI: ANOVA showed significant effects of age: F (2,146) = 11.1, p<.0001, step-alternating mode: F(1,73) = 4.5, p<.02, and imitation conditions: F(2,146) = 4.6, p<.01 for all children in walking duration. The time scored in TLI was longer than the one scored in IISW and in SI//W. The planed comparison test attributed the difference to the 3.5 and 4.5-year-olds, who took more time than the other age groups to walk on and between the obstacles (Tables 2 and 3).

The second series of imitation: deferred imitation (DI)

Step-alternating mode: ANOVA showed a significant effect of age: F(4,+∞) = 3.83, p<.001. The Reduced Distance test attributed the difference to the 3.5-year-olds, who accounted a lower score (49%) than the other age groups (4.5: 78%, 5.5: 91%, 6.5: 90%, and 7.5-year-olds: 90%, respectively). No significant interaction effect of sessions: F (4,+∞) = 0.92, p>.05 was found (Figure 5) in step-alternating mode. The 3.5-year-olds were variable (90%) and fluctuated among step-

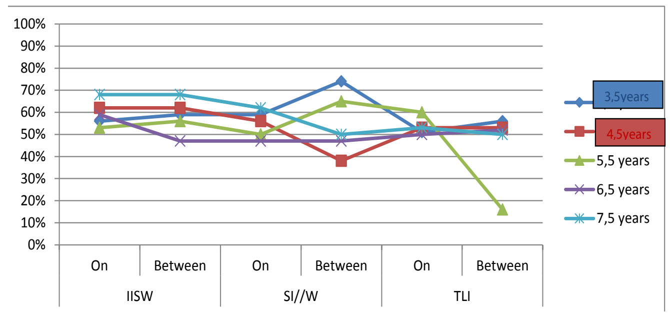

Figure 4 : Scores of footedness (%) on and between the obstacles in every age group in Immediate Imitation in the Same Walkway (IISW), simultaneous imitation in two parallel walkways (SI//W), Time Lagged Imitation (TLI) according to the walking mode on and between the obstacles.

Age (yrs.)	Performed task time		
	IISW (s)	**SI//W (s)**	**TLI (s)**
3.5	2.64 ± 0.07	2.27 ± 0.49	2.46 ± 0.80
4.5	1.74 ± 0.03	1.70 ± 0.03	2.05 ± 0.06
5.5	1.32 ± 0.05	1.44 ± 0.04	1.93 ± 0.01
6.5	1.41 ± 0.08	1.19 ± 0.05	1.72 ± 0.14
7.5	1.11 ± 0.02	1.09 ± 0.09	1.56 ± 0.04

Table 2: Mean values and Standard Deviation (SD) of children's scores (in seconds) for walking duration on the obstacles in Immediate Imitation in the Same Walkway (IISW), Simultaneous Imitation in Two Parallel Walkways (SI//W) and Time Lagged Imitation (TLI).

Age (yrs.)	Performed task time		
	IISW (s)	**SI//W (s)**	**TLI (s)**
3.5	2.80 ± 1.03	2.28 ± 0.07	2.54 ± 0.44
4.5	2.07 ± 0.11	1.77 ± 0.03	1.88 ± 0.10
5.5	1.39 ± 0.03	1.35 ± 0.01	1.61 ± 0.10
6.5	1.62 ± 0.06	1.48 ± 0.01	1.86 ± 0.00
7.5	1.49 ± 0.14	1.32 ± 0.09	1.53 ± 0.03

Table 3: Mean values and Standard Deviation (SD) of Children's scores (in seconds) for walking duration between the obstacles in Immediate Imitation in the Same Walkway (IISW), Simultaneous Imitation in Iwo Parallel Walkways (SI//W) and Time Lagged Imitation (TLI).

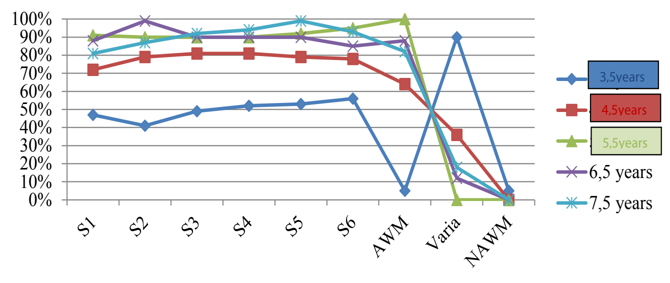

Figure 5: Scores of step-alternating mode (%) in every age group in Deferred Imitation (DI) over six sessions (left part), Accordance With the Model (AWM), variability (Varia) and Non-Accordance With the Model (NAWM) (right part).

alternating versus non-step-alternating modes. The 4.5-year-olds were less variable (36%) than the 3.5-year-olds, and with better accordance with the model (64%). The 5.5-year-olds showed a higher score (91%) and accordance with the model (100%). The 6.5- and the 7.5-year-olds alternated without difficulty (90%, 90%), and with important accordance with the model (88%, 82%).

Footedness: ANOVA showed a significant effect of age: F(4,+∞) = 5.47, p<.001 in the children's footedness. The Reduced Distance test attributed the difference to the 3.5-year-olds. They accounted lower score than the other age groups (Figure 6). Only 23% of the 7.5-year-olds adopted the model's footedness, while the other age groups were variable (3.5: 95%, 4.5: 100% and 5.5: 89% and 6.5-year-olds: 95%) and fluctuated between the right and left foot.

Walking duration in DI: ANOVA showed a significant effect of age: F(4,73) = 4.4, p<.01 in the walking duration. The planed comparison test attributed the difference to the 3.5, 4.5, and 5.5-year-old age groups. They scored longer times than the other age groups (Tables 4 and 5).

Discussion

The main aim of this current work was to study the information that children selected when they observed an adult model demonstrating a series of walking movements in order to reproduce them into different imitation conditions.

We firstly hypothesized that all age groups would accomplish the model's walking movement. As predicted, all children imitated the walking from the first demonstration. They, for example, performed only the walking and no other behaviors (e.g., jumping, running), or differently apparatus using (e.g. grasping the obstacles or circles). Labiadh, Ramanantsoa and Golomer [29] recently demonstrated the same results in jumping movements conducted in the same conditions and with the same age groups. Despite the delay separating the model's demonstration and the children's reproduction (immediate versustime lagged, or deferred imitation), and irrespective to the walkway (one walkway versus two parallel walkways), walking movement was performed by all age groups. This result is consistent with Johansson's [30,31] findings demonstrating the human capability to recognize biological movements from a small number of structured visual cues. This also explains the children's capability to recognize a locomotion movement similar to their own, even when it is produced by an adult with different physical appearance and dynamic skills [32]. The ability to perform by observation and imitation has recently received much attention. A classical finding is that children are faster to execute a movement after observing an actor performing it. Several studies suggested that an important network, underlying imitation and observation, is formed by the mirror neurons [23,33], implying a direct matching [7].

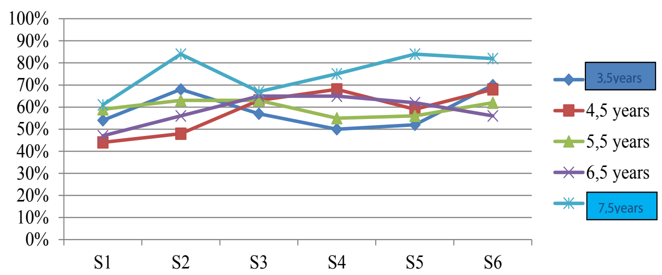

Figure 6: Scores of footedness (%) in every age group in Deferred Imitation (DI) over six sessions.

We second hypothesized that the children would be influenced by the adult model to adopt his step-alternating mode only if they had a sufficient coordination and footedness. All age groups took up the global morphological organization of the model's motor alternation, because they had already acquired an independent walking [18,19,34]. In the same way, the adult model overrode the imitative performance in imitation with temporal and spatial proximity (IISW, SI//W) in the 3.5 (65%) and 4.5-year-old age groups (88%). 35% of 3.5-year-olds were insensitive to the model's walking. They systematically stopped at each footstep (non-step-alternating). This made their walking hesitant and flimsy. Such walking behavior could be explained by the fact that coordination modes are not completely mastered in the children's youngest age groups. For this reason the model's influence disappeared in deferred imitation, when the demonstration and execution delay was longer. Therefore, the preschoolers returned to their step-alternating modes, as in the control condition. This motor behavior may be explained by biometric and kinematic parameters. The youngest children were shorter in body size and leg lengths than the other age groups. This constrained their step alternating [35].

	Deferred Imitation (DI)					
Age (yrs.)	**Session 1 (s)**	**Session 2(s)**	**Session 3 (s)**	**Session 4 (s)**	**Session 5(s)**	**Session 6 (s)**
3.5	0.48 ± 0.07	0.5 ± 0.00	0.53 ± 0.09	0.56 ± 0.07	0.55 ± 0.12	0.5 ± 0.10
4.5	0.43 ± 0.07	0.5 ± 0.00	0.57 ± 0.20	0.57 ± 0.07	0.55 ± 0.05	0.6 ± 0.00
5.5	0.49 ± 0.01	0.5 ± 0.10	0.58 ± 0.10	0.58 ± 0.01	0.57 ± 0.00	0.6 ± 0.00
6.5	0.48 ± 0.20	0.5 ± 0.20	0.55 ± 0.10	0.53 ± 0.03	0.55 ± 0.05	0.6 ± 0.00
7.5	0.46 ± 0.04	0.5 ± 0.00	0.55 ± 0.10	0.52 ± 0.01	0.49 ± 0.06	0.5 ± 0.00

Table 4: Mean values and Standard Deviation (SD) of children's scores (in seconds) for walking duration on the obstacles in Deferred Imitation (DI) over six sessions.

	Deferred Imitation (DI)					
Age (yrs.)	**Session 1 (s)**	**Session 2 (s)**	**Session 3 (s)**	**Session 4 (s)**	**Session 5 (s)**	**Session 6 (s)**
3.5	0.53 ± 0.07	0.60 ± 0.00	0.55 ± 0.09	0.54 ± 0.07	0.56 ± 0.12	0.60 ± 0.10
4.5	0.57 ± 0.07	0.60 ± 0.00	0.55 ± 0.20	0.56 ± 0.07	0.55 ± 0.50	0.50 ± 0.00
5.5	0.58 ± 0.01	0.60 ± 0.10	0.57 ± 0.10	0.58 ± 0.08	0.59 ± 0.00	0.60 ± 0.00
6.5	0.55 ± 0.15	0.50 ± 0.20	0.55 ± 0.10	0.60 ± 0.03	0.62 ± 0.05	0.60 ± 0.00
7.5	0.55 ± 0.04	0.50 ± 0.00	0.49 ± 0.10	0.54 ± 0.01	0.54 ± 0.06	0.60 ± 0.00

Table 5: Mean values and Standard Deviation (SD) of children's scores (in second) for walking duration between the obstacles in Deferred Imitation (DI) over six sessions.

As regard the walking strategies, the preschoolers slowed down the rhythm of their moving, while they observed the model and attempted to imitate his posture [36]. In contrast, the schoolers firstly constructed the postural strategy, and then selected their appropriate postural control. This depended upon their ability to anticipate the consequences of movement to hold up controlled balance [19]. The schooler's behavior was compatible with Assaiante et al.'s [17] finding, suggesting that, the age of 6-7 constitutes a crossroads in postural control.

The non-step-alternating modes would also be explained by the mixed-footedness process [22]. Indeed, our results showed that only few children of the 6.5- and 7.5-year used the left footedness, both in experimental and control conditions. However, their footedness was unstable because they were just starting to acquire it [37]. In deferred imitation, all age groups displayed mixed and variable footedness. Even in immediate imitation in the same walkway, the children did not copy his footedness, because this requires a bodily highbrow reading [25]. For example, it was suggested that the perception and representation of the other's body parts was constrained by an implicit knowledge of movement that the system would be able to produce [38].

The duration of walking also explained the children's strategies to reproduce the walking movements in the imitation conditions. It was found that the preschoolers (3.5 and 4.5-year-olds) took more time than the schoolers (5.5 to 7.5-year-olds). This was compatible with their step-alternating modes. For example, in deferred imitation, the walking duration was less variable for the oldest age groups than for the youngest ones. The improvement of the walking duration found in the last two sessions was not evident as the duration decreased in the non-step-alternating performance of the youngest groups. Furthermore, walking between the obstacles required more balance and propulsion than walking on the obstacles [29]. May be the youngest age groups were less attentive to their own postural stability than the oldest age groups, who may have resolved the balance and propulsion constraints [39]. The anticipatory postural adjustment for the first step started to appear at the age of 4 or 5 [40]. This justifies their longer walking duration. The children's difficulties also seemed to be related to problems in dividing their visual attention between self-focus and perception of the model's movements [41,42]. It is also conceivable that the obstacles themselves, presented higher demands in physical and morphological capacities, which changed across ages [37].

The novelty of this work is that on the one hand, an investigation associating gestural demonstration and verbal instructions is a new issue in imitation paradigm and, on the other hand, the age of exactly five years and five months represents the turning point in the way to imitate a walking movement with a step alternating. The 5.5-year-old children showed a higher accordance with the model (96%). They controlled the balance [18,19] and resolved the bodily correspondence problem by reading the appropriate adult model's body-parts [25,43]. A practical lesson can be gained from the current study, mainly with respect to people who teach imitative tasks to others (e.g. dancing, sport skills). When teachers want to teach using learning by imitation, they must keep in mind that it is probably more useful to demand the achievement of the ends rather than the means from both their healthy and altered pupils. Recent findings recommend this educational strategy for the acquisition of motor skills [44].

Conclusion

In sum, we found evidence that children are unable to select all aspects of demonstrated movements. In fact, all age groups walked, but did not necessarily use the same step-alternating modes or footedness as the model. The model helped the preschoolers to adopt his motor coordination mode, only in imitation with temporal and spatial proximity (IISW, SI//W), when the demonstration and execution delay was short. This help disappeared in deferred imitation with a longer delay. Few children adopted the model's footedness, because it was too difficult for them to represent their body segments, and also read the other's body-parts. The findings of the present study corroborate the admitted concept that, when imitating others, attempts to perform the goal-directed movements are more efficient than attempts to perform the aspects of these movements.

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