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Research Article

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Which Relevant Information do Preschoolers and Schoolers Perceive and Select for Imitating a Series of walking Movement?

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Abstract
Imitation is commonly considered as a hierarchically organized mechanism. It is frequently used to explore various scientific fields but few works have studied how locomotion movements are imitated. The current study aims to investigate and expand the findings regarding which information children of different age groups select and integrate for performing a series of locomotion movements. One hundred and thirty children from 3.5 to 7.5 years of age were instructed to walk in step-alternating mode on and between 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 put into percentage. Results showed first, that all children performed the modeled walking movements, but did not necessarily do so with the same step-alternating mode or footedness and second, that the model helped the preschoolers to adopt his step-alternating mode and stabilized the schoolers from the age of 5.5-year-olds. These findings reveal that the age of 5.5 is crucial for imitating a walking task while overcoming the constraints of balance and propulsion.

Keywords: Walking Movements, Matching Process, Step-Alternating Mode, Footedness, Balance and Propulsion, Development.

Introduction
Imitation is an active decomposing-recomposing mechanism that children use for performing motor skills [1,2]. Decomposing-recomposing mechanisms are functionally dependent on perception-action matching [3,4]. There are at least two matching levels that link observers and demonstrators: a direct one, for performing movement's goal and a complex one for accomplishing the other aspects of movements [5-9].

When the demonstrator is an adult person with efficient musculoskeletal and motor control systems, and the observers are children of different ages, body sizes, or leg lengths, imitation requires a complex and different set of mechanisms to match observed coordinated motor skills according to different constraints [10,11]. In Newell's system of constraints any motor coordination results from the characteristics of the task to be performed, the subject who performs the task, and the environment in which it is performed. Yet, to our knowledge, the imitation of locomotion coordination has not been widely investigated in an imitation paradigm. This is why the present study aims to study the step-alternating walking mode as a motor coordination by exploring which pieces of information children of different age groups do select and integrate when they observe an adult's gestural demonstrations of walking movements in order to imitate them in different imitation forms, and how the same age groups perform the same task in a control condition following verbal instructions.

Walking is defined as the ability to move forward with a succession of double and simple supports in alternating mode. According to Bril and colleagues, walking is governed by potential propulsion and balance skills [12-15]. The control of these skills is a complex mechanism because it demands a compromise between the body's propulsion and balance maintenance [16]. To this end, Bril and Brenière have evoked two essential developmental walking phases. The first phase is dedicated to the integration of posture and movement [13]. 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 the adjustment phase. It is longer than the first phase because it deals with the acquisition of independent walking [15].

Although it is commonly considered that independent walking is acquired between two and three years of age, opinions differ. For Cavagna, Franzetti, and Fuchimoto, independent walking is acquired at five or six years of age, whereas for, it requires seven to eight years of practice [12,17]. Bril explains 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" [18].

In his system of constraints, Newell considers motor coordination and footedness as two important motor skills [19]. Difficulties to maintain balance in walking are further enhanced by the fact that the weight of the whole body is supported by one leg during the swing phase [15]. This is the largest balance challenge that children meet in walking [20]. In jumping movements, Vaivre-Douret and Bloch 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 demonstrated a mixed-footedness among 3-to-11-year-old children [21,22].

In an imitation paradigm, the demonstrator and the observer are linked by a matching process. Matching may be direct when imitating only the goal-directed movement [9,23]. Meltzoff and Moore have already shown there is an early capability to mimic facial and manual gestures (e.g., tongue protrusions, lip pursing, and hand waving) seen on other persons [24]. These authors concluded that the matching of others' visible movements with one's own movements might be an inborn ability. Wohlschläger et al. demonstrated that 3-to-6-year-old children also reproduced a primary goal of adequately touching a shown body part (e.g. the ear), and attended less to the subsidiary goal of how the touch was to be achieved [2]. Matching may also be complex when including other aspects of movements, such as the precise body part(s) the movement starts with [23,25,26]. While the left/right hand discrimination has been largely investigated, the left/right foot one has been little studied [27]. Deloaoche, Uttal, and Rosengren evoked that, before eight years of age, children found it difficult to represent the segmental state of another person's body, and hence did not copy the precise body part [28].

The current work expands previous studies investigating the selective and hierarchical imitation process. It also tests new and relevant aspects by exploring at the same time several imitation forms with varied observation and execution delays for demonstrating the variability of the children's responses. We firstly predicted that all age groups would selectively perform the goal-directed movement rather than its aspects or details. We secondly predicted 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 of middle class children attending the same state primary school in the region of Poitiers, France, participated in this study. The 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 gender variable was not measured here. The children were instructed by a live human adult model to imitate a short course of walking movements from gestural demonstrations. The control group was composed of 45 children and also 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. 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, over six sessions 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 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 circles (30 cm in diameter) were used: the first circle was positioned at the outset of the walkway to materialize the departure, the second circle was positioned at the end of the walkway to materialize the arrival, and the third circle was positioned half way through the walkway to materialize the change of strategy in walking on and between the obstacles. Four obstacles (30 cm × 15 cm × 10 cm) were also used. Each obstacle was placed 25 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 length of the walkway was about 2 m.

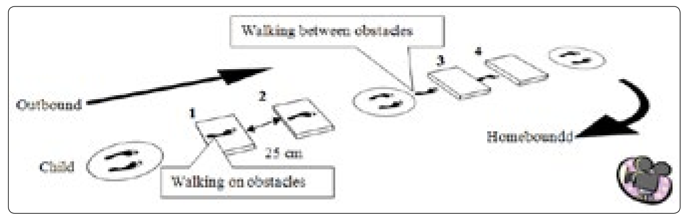

Figure 1: Walkway in control condition with verbal instructions (CCVI), immediate imitation in the same walkway (IISW), lagged imitation (LI) and deferred imitation (DI)

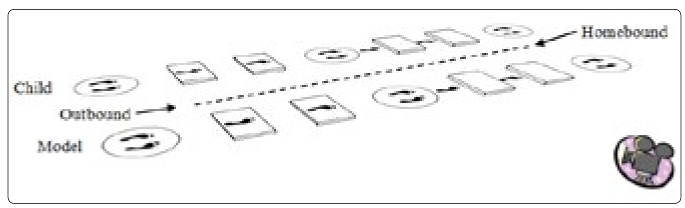

Figure 2: Simultaneous imitation in two parallel walkways (SI//W).

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 walking in two separate series of imitation tests. The first series was characterized by the temporal and spatial proximity between the model and the children. It unfolded as follows:

1. Immediate imitation in the same walkway (IISW): each child of each age group was 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.

2. 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.
3. 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 responded by remembering what he/she had just done.

Then, one week after the three previous imitation forms, a second series of tests was carried out to study the deferred imitation (DI) through six sessions. During six weeks, each child of each age group was instructed to reproduce the model's demonstration only once, by himself, and in the same walkway. The model demonstrated the walk at the beginning of each session and the children had to reproduce it after a delay of three minutes. It was supposed that the children's responses were based on what they had retained of the modeled demonstrations.

Control condition
One week after the four imitation forms described above, each child of each age group was verbally instructed by the same adult experimenter to perform the same walking movements as in the experimental conditions. Each child performed one trial.

Coding and statistical analysis
The children's walking movements, both in experimental and control conditions, were collected and coded in binary mode (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 follow the normality law, and thus the normality test was not possible. Therefore it was necessary to use a log-transform of performances, namely the "angular transformation of percentage" to apply an adequate ANOVA. 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 $p < .05$ [29].

A correlation test was also used for analyzing the biometric parameters of each child of each age group (leg lengths, or obstacle intervals). These parameters (cm) were relevant factors for examining walking balance and propulsion.

We also coded the total scores of each child of each age group in each imitation form. These scores correspond 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%: the child always performed the walking movements with step-alternating mode and starting with the right foot; (ii) non-accordance with the model (NAWM) -score ≤ 20%: every time, the child imitated the walking movements using different step alternating modes and footedness; (iii) variability (Varia) -score between 20 and 80%: the child fluctuated among varied step-alternating and non-step-alternating modes and left/right footedness. These indicators are important because they determine the accordance degree of each child both in step-alternating mode and footedness and, they also determine in which imitation form a given age group would be helped by the model to adopt the latter's step-alternating mode and/or footedness.

The three dependent variables were the children's success in step alternating, footedness, accordance, non-accordance and 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 homebound.

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 forms (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 imitations, 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 the experimental group was also timed (seconds) for each child. The duration corresponded to the time from the moment the child put his/her 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 form. 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. They express their real motor repertoire that will be used as a valuation scale to explain their performance in imitation. Then, we present the children's walking scores in the

experimental condition for determining in which imitation form the children would be influenced by the model to adopt his walking mode and/or footedness.

Control condition with verbal instructions

Step-alternating mode

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

The correlation between leg length and obstacle intervals was: r(0.571098), F(1,43) = 20.813; p < .00004. The correlation between age and obstacle intervals revealed a 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 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).

Table 1: Biometric data of the legs length and obstacles interval for each control age group

	Legs length	interval on obstacles	Interval between obstacles
3.5 years	48 cm ± 3.42	15 cm ± 2.53	19 cm ± 2.38
4.5 years	54 cm ± 2.71	28 cm ± 2.29	24 cm ± 2.38
5.5 years	60 cm ± 2.64	36 cm ± 1.75	28 cm ± 1.25
6.5 years	60 cm ± 4.13	41 cm ± 11.61	39 cm ± 4.09
7.5 years	63 cm ± 5.61	42 cm ± 12.71	55 cm ± 9.1

Footedness

No significant effect of age: F(4,+∞) = 1.75, p > .05 and walking modes: F(4,+∞) = 0.13, p > 0.05 was found in the children's footedness.

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 obtained 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 responses of 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 (76%) with the model: the model helped them in temporal and spatial proximity imitation forms. 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%).

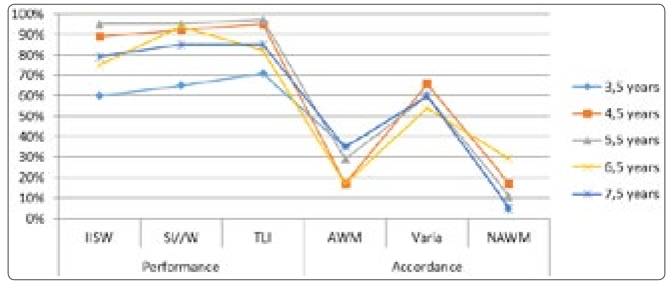

Figure 3: Scores of step-alternating mode (%) in every age group in immediate imitation in the same walkway (IISW), simultaneous imitation in two parallel walkways (SI//W), time lagged imitation (TLI) (left part), and accordance with the model (AWM), variability (Varia) and non-accordance with the model (NAWM) (right part)

Footedness

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

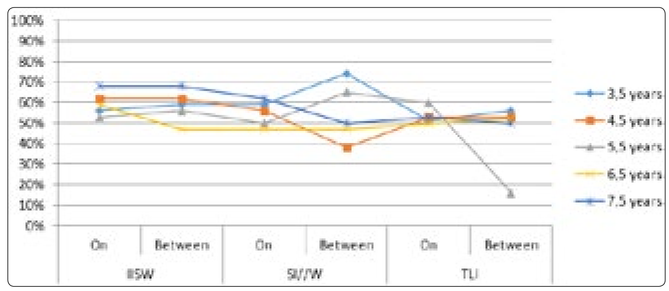

Figure 4: Scores of the dominant foot (%) on and between the obstacles in every age group in immediate imitation in the same walkway (IISW), simultaneous imitation in two parallel walkways (SI//W), time lagged imitation (TLI) according to the walking mode on and between the obstacles

Walking duration in: IISW, SI//W, TLI

ANOVA showed a significant effect of age: F(2,146) = 11.1, p < .0001, step-alternating mode: F(1,73) = 4.5, p < .02, and imitation forms: F(2,146) = 4.6, p < .01 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: they took more time than the other groups to walk on and between the obstacles (Table 2 and 3).

Table 2: Children's scores and standard deviation (second) 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)

3.5 years: **IISW** = 2.64s ± 0.07s, **SI//W** = 2.27s ± 0.49s, **TLI** = 2.46s ± 0.80s,
4.5 years: **IISW** = 1.74s ± 0.03s, **SI//W** = 1.7s ± 0.03s, **TLI** = 2.05s ± 0.057s,
5.5 years: **IISW** = 1.32s ± 0.05s, **SI//W** = 1.44s ± 0.04, **TLI** = 1.93s ± 0.008s,
6.5 years: **IISW** = 1.41s ± 0.08s, **SI//W** = 1.19s ± 0.05s, **TLI** = 1.72s ± 0.14s,
7.5 years: **IISW** = 1.11s ± 0.02s, **SI//W** = 1.09s ± 0.09s, **TLI** = 1.56s ± 0.04s,

Table 3: Children's scores and standard deviation (second) for walking duration between the obstacles in immediate imitation in the same walkway (IISW), simultaneous imitation in two parallel walkways (SI//W) and time lagged imitation (TLI)

3.5 years: **IISW** = 2.80s ± 1.03s, **SI//W** = 2.28s ± 0.07s, **TLI** = 2.54s ± 0.44s,
4.5 years: **IISW** = 2.07s ± 0.11s, **SI//W** = 1.77s ± 0.03s, **TLI** = 1.88s ± 0.10s,
5.5 years: **IISW** = 1.39s ± 0.03s, **SI//W** = 1.35s ± 0.01s, **TLI** = 1.61s ± 0.10s,
6.5 years: **IISW** = 1.62s ± 0.06s, **SI//W** = 1.48s ± 0.01s, **TLI** = 1.86s ± 0.0008s,
7.5 years: **IISW** = 1.49s ± 0.14s, **SI//W** = 1.32s ± 0.09s, **TLI** = 1.53s ± 0.03s,

Second series of imitation: deferred imitation (DI)

Step-alternating mode

ANOVA showed a significant effect of age: $F(4,+\infty) = 3.83$, $p < .001$. The Reduced Distance test attributed the difference to the 3.5-year-olds, who obtained 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: $F(4,+\infty) = 0.92$, $p > .05$ was found (Figure 5) in step-alternating mode. The 3.5-year-olds were variable (90%) fluctuated among step-alternating versus non-step-alternating modes. The responses of the 4.5-year-olds were less variable (36%) than those of 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%).

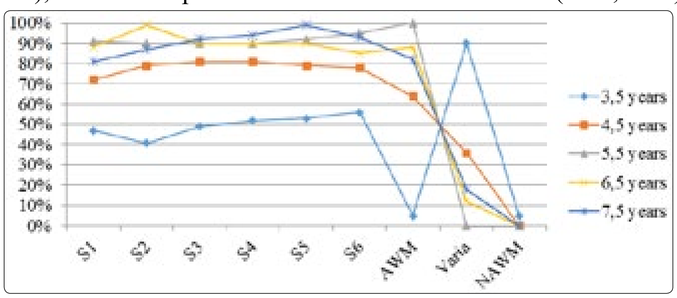

Figure 5: Scores of step-alternating mode (%) in every age group in deferred imitation (DI) in six sessions (left part), accordance with the model (AWM), variability (Varia) and non-accordance with the model (NAWM) (right part)

Footedness

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

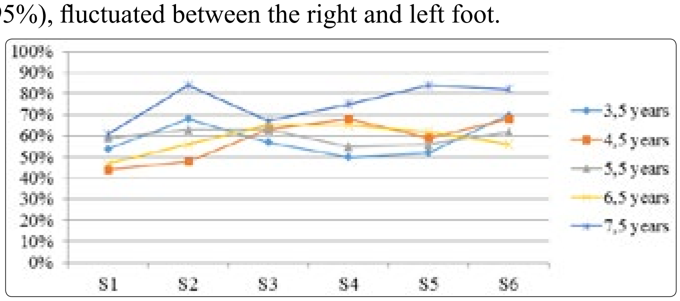

Figure 6: Scores of the dominant foot (%) in every age group in deferred imitation (DI) in six sessions.

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 (Table 4 & 5).

Table 4: Children's scores and standard deviation (second) for walking duration on the obstacles in deferred imitation (DI) in six sessions

	S1	S2	S3	S4	S5	S6
3.5 years	0.48s ± 0.07s	0.5s ± 0s	0.53s ± 0.09s	0.56s ± 0.07s	0.55s ± 0.12s	0.5s ± 0.1s
4.5 years	0.43s ± 0.07s	0.5s ± 0s	0.57s ± 0.2s	0.57s ± 0.07s	0.55s ± 0.05s	0.6s ± 0s
5.5 years	0.49s ± 0.01s	0.5s ± 0.1s	0.58s ± 0.1s	0.58s ± 0.01s	0.57s ± 0s	0.6s ± 0s
6.5 years	0.48s ± 0.2s	0.5 ± 0.2	0.55 ± 0.1	0.53 ± 0.03	0.55 ± 0.05	0.6 ± 0
7.5 years	0.46s ± 0.04s	0.5s ± 0s	0.55s ±0.1s	0.52s ± 0.01s	0.49s ± 0.06s	0.5s ± 0s

Table 5: Children's scores and standard deviation (second) for walking duration between the obstacles in deferred imitation (DI) in six sessions

	S1	S2	S3	S4	S5	S6
3.5 years	0.53s ± 0.07s	0.6s ± 0s	0.55s ± 0.09s	0.54s ± 0.07s	0.56s ± 0.12s	0.6s ± 0.1s
4.5 years	0.57s ± 0.07s	0.6s ± 0s	0.55s ± 0.2s	0.56s ± 0.07s	0.55s ± 0.5s	0.5s ± 0s
5.5 years	0.58s ± 0.01s	0.6s ± 0.1s	0.57s ± 0.1s	0.58s ± 0.08s	0.59s ± 0s	0.6s ± 0s
6.5 years	0.55s ± 0.15s	0.5s ± 0.2s	0.55s ± 0.1s	0.6s ± 0.03s	0.62s ± 0.05s	0.6s ± 0s
7.5 years	0.55 ± 0.04	0.5 ± 0	0.49 ± 0.1	0.54 ± 0.01	0.54 ± 0.06	0.6 ± 0

Discussion

The main aim of this study was to examine and analyze the information that children select when they observe an adult model demonstrating a series of walking movements for reproducing them into different imitation forms.

The first hypothesis predicted 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: they did not perform any other locomotion behaviors (e.g., jumping, running), or used the apparatus differently (e.g. grasping the obstacles or circles). Labiadh, Ramanantsoa and Golomer have recently demonstrated the same results in jumping movements conducted in the same conditions and with the same participants [30]. Despite the delay separating the model's demonstration and the children's reproduction (immediate versus time lagged, or deferred imitation), and irrespective to the walkway (one walkway versus two parallel walkways), the walking movement was performed by all age groups. This result is consistent with Johansson's findings demonstrating the human capability to recognize biological movements from a small number of structured visual cues [31,32]. 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 [33]. The ability to perform by observation and imitation has recently received much attention. A standard finding is that children are faster to execute a movement after observing an actor performing it. Several studies have suggested that an important network, underlying imitation and observation, is formed by the mirror neurons, implying a direct matching [7, 23,34].

The second hypothesis predicted 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 [12,17, 35]. 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 movements. They systematically stopped at each footstep (non-step-alternating mode). 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 mode, 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 mode [36].

As regard the walking strategies, the preschoolers slowed the rhythm of their moving down, while they observed the model and attempted to imitate his posture [37]. In contrast, the schoolers firstly constructed the postural strategy, and then selected their appropriate postural control. This is due to their ability to anticipate the consequences of movement to hold up controlled balance [12]. The schoolers' behavior was compatible with Assaiante et al.'s finding, suggesting that the age of 6-7 constitutes a crossroads in postural control [16].

The non-step-alternating mode would also be explained by the mixed-footedness process [16]. Indeed, our results showed that only some children of the 6.5- and 7.5-year age groups used the left footedness, both in experimental and control conditions. However, their footedness was unstable because they were just starting to acquire it [38]. In deferred imitation, all age groups displayed mixed footedness. Even in immediate imitation in the same walkway, the children did not copy the model's footedness, because this requires a bodily highbrow reading [25]. It has been suggested that the perception and representation of the other's body parts is constrained by an implicit knowledge of movement that the system would be able to produce [27].

The duration of walking also explains the children's strategies to perform the walking movements in imitation forms. 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 mode. 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 [30]. 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 starts 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 [36].

Conclusion

To sum up, we found evidence that children are unable to select all aspects and details of demonstrated movements. In fact, all age groups walked, but did not necessarily use the same step-alternating mode 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.

The novelty of this work is that on the one hand, an investigation associating gestural demonstration and verbal instructions is a new issue in the 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. The 5.5-year-old children showed a higher accordance with the model (96%). They controlled the balance and resolved the bodily correspondence problem by reading the appropriate adult model's body-parts [15,17, 43].

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