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Review Article

Fundamental contributions of neuroscience to motor learning in children: a systematic review

Short title: Motorlearning aspects in children

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ABSTRACT

Motor learning generates synaptic neural connections that favour the motor environment and, also, various processes where our cognitive and executive functions intervene. Therefore, it is essential to know the different contributions that come from neuroscience linked to motor learning in a child. This study aimed to determine the fundamental contributions of neuroscience to motor learning in children. The methodology included a qualitative systematic review in the PubMed, Medline and Scopus databases. Of 479 related documents, 24 papers achieved the inclusion criteria (the learning mechanisms of motor skills and the different approaches to achieving meaningful learning). They were selected using the data collection methodology indicated by PRISMA®. The main results indicated that learning occurs based on experiences (cognitive, perceptual, motor, linguistic, neuronal, organic and cultural) and requires processes of adaptation, stabilization, and maturation of brain synchronization of vestibular, perceptual and visual processes. Children who receive motor intervention improve sustained attention, working memory, problem-solving and planning capacity. Motor and cognitive development are favoured by instructions as an essential tool. The implicit instructions present a higher benefit for children with lower motor skills.

KEYWORDS: motor learning; neuroscience; motor control; children.

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INTRODUCTION

The brain is a large mass protected by the skull or cranial vault, formed mainly of gray tissue, giving an important axis to the central nervous system, with millions of connections by nerve cells that are responsible for the control of vital survival functions, of the mind, emotions and feelings, through the reception and interpretation of signals either interoceptive or exteroceptive (Fitzgerald, Gruener, & Mtui, 2012; Hans, 2020). However, specifically the cerebral cortex is hidden in varied grooves and turns or convolutions that have the highest incidence in signal processing, analyzing, synthesizing and integrating it through simultaneous and multidirectional processes (Hans, 2020). To understand the way the brain works, it is crucial to give it a multidisciplinary approach, creating a common language for understanding the nervous system as a whole (Cano-de-la-Cuerda et al., 2015).

Learning is a capacity, that is, something that can be worked on and transformed, which includes a process where behavior varies and is modified in the long term as an adaptation to changes in the environment. This change in behavior is carried out by our higher centers, which do so through perception, cognition and motor organization (Tompsett, Sanders, Taylor, & Cobley, 2017). Learning produces a change in the physical and biochemical structure of the brain, resulting in a brain organization or reorganization that has an impact on the expression of skills and behaviors (Tompsett et al., 2017; Bolger et al., 2018). These changes can be expressed globally in the formation of new synapses or in modifications of established synaptic connections (Cano-de-la-Cuerda et al., 2015). The so-called larger cognitive sensitive period in humans, is where it is considered that more synaptic connections related to learning are created, and it occurs in the early stages of life, from zero to three years, but currently there is evidence that extends up to 10 years (Pherez, Vargas, & Jerez, 2018).

Unlike general learning, motor learning is defined as the set of internal processes associated with practice and experience, which produce relatively permanent changes in the ability to produce motor activities, through a specific skill (Cano-de-la-Cuerda et al., 2015). There are several theories of how the process of motor learning occurs, but undoubtedly all of them evoke that the various motor actions favor synaptic neural connections having multiple benefits, such as the coordinated work of the cerebral hemispheres from their differences and functional specialties (Robinson, Palmer, & Meehan, 2017). The advances that neuroscience gives us about learning in general, more specifically in motor learning, are constantly being

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brought to light. This is how there is a large gap between the knowledge presented by pedagogues, specialists in how to teach, and how they use this information consistently and concretely in educational processes (Barrios-Tao, 2016). Therefore, this research aims to realize a state of the art on the fundamental advances of neuroscience in relation to motor learning in children and, thus, to contribute to all professionals related to motor action in infants, in Special Pedagogy in physical education, so that they have the necessary tools based on current neuroscience to develop more effective teaching methods.

METHODS

The study was conducted according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses [PRISMA®] statement (Moher, Liberati, Tetzlaff, & Altman, 2010).

Data sources

Relevant research and studies were examined, published from January 1, 2005 to April 30, 2019, to form the basis of the study. The articles were selected in the following databases: Pubmed, Medline and Scopus. In addition, the reference lists of the included articles were examined to detect potentially eligible studies for inclusion. The keywords used in different ways and different combinations were: Motor Learning and Neuroscience, Motor Learning and Children, Motor Control and Children, Motor Learning or Neuroscience or Motor Control.

Eligibility criteria

The studies were included in the review if they met the following inclusion criteria: (i) human children, female or male participants, aged four to 12 years without neurological disorders; (ii) reported on motor learning in children; (iii) written in English and Spanish; and (iv) were primary research articles. Two independent reviewers conducted the evaluation and review (M-JT-M and EA-M), and a third reviewer (CH-W) in case of disagreement. Items were first selected for eligibility based on title and summary. Subsequently, the extensive text was reviewed and, after confirming the eligibility to be included, the information was extracted.

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Data collection

Data were extracted from articles that met the inclusion criteria and considered appropriate for a detailed review by two authors, and discussed the differences. The information extracted was as follows: sample characteristic, measurement methods, measurement variables and results.

Risk of bias

A quality assessment of the included studies was carried out using an adjusted format of the Newcastle-Ottawa quality assessment scale (Wells & Shea, 2014). This scale contains eight items categorized into three domains (selection, comparability and exposure). It is possible to grant a maximum of one star for each numbered study in the selection and exposure domains, while for the comparability domain a maximum of two stars.

RESULTS

The search strategy identified 479 articles (Figure 1), of which 9 articles were deleted because they were duplicated. The titles and abstracts of the articles were examined to determine their suitability, which led to the inclusion of 24 full-text articles.

Studies that belonged to some of the following categories were excluded: studies published in abstract form, not written in English or Spanish, which also do not comply with the formality or rigor for the study, with a different methodological design from the one sought in this study, research, interventions not carried out in humans, and that are not related in any way to the subject in question, such as learning without any motor implication, children with cerebral palsy and children who were outside the established age range.

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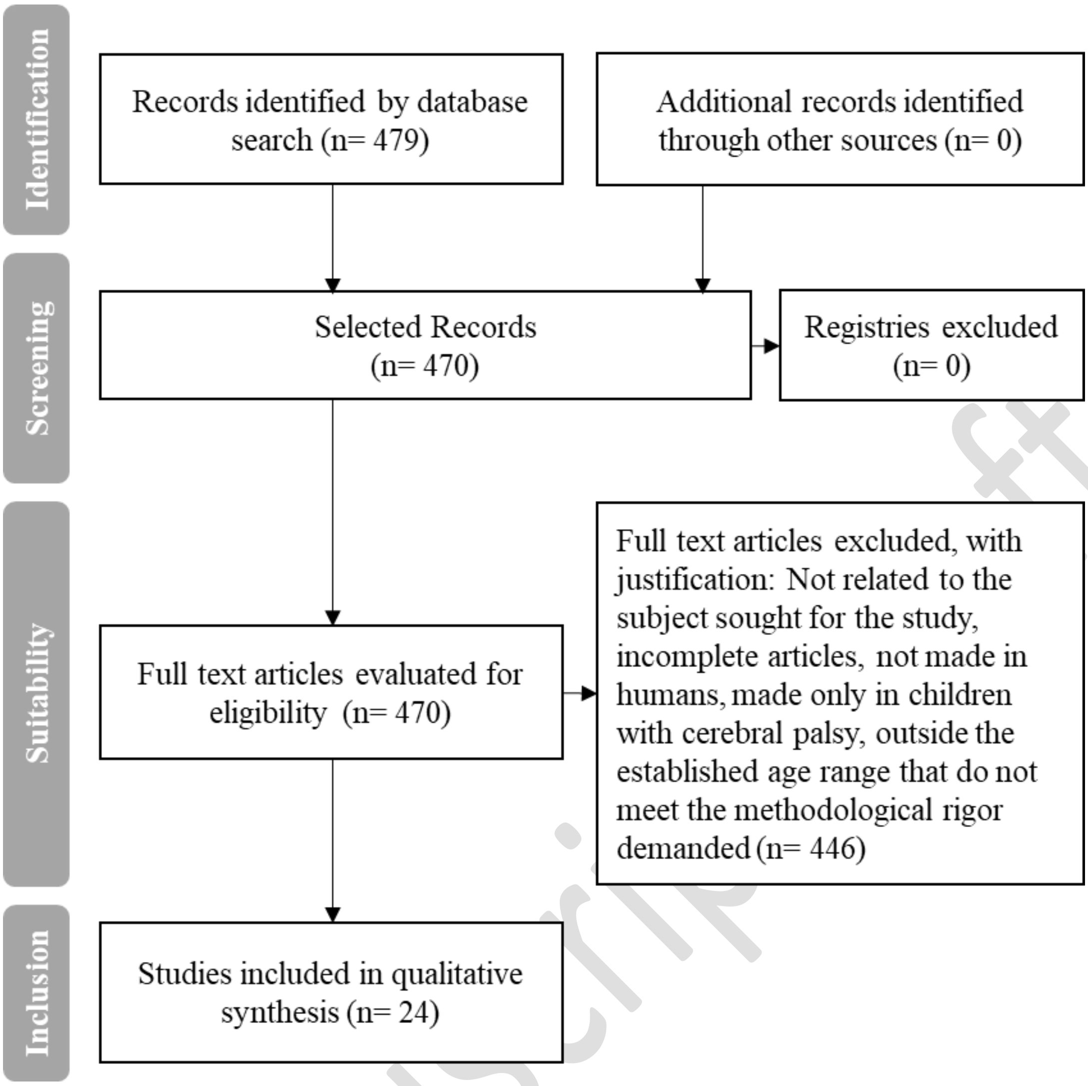

Figure 1. Fluxogram illustrating the different phases of the search and selection of studies included in the review (PRISMA).

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Table 1. Summary of the studies included.

Nº	Author (s)	Sample	Variable	Method	Results
1	(Adi-Japha et al., 2019)	45 children (25 ♀) (71± 2.5 months old). 40 university students (21 ♀) (28.2± 5.5 years).	Fine motor skill test, tracing letters with a pencil.	Performance (sec) and accuracy (exactly reproduced forms).	Both groups had significant improvements in performance time. Children have more learning in blocks after two hours of training, while adults have more learning after two weeks.
2	(Bolger et al., 2018)	301 children; 102 (6.0± 0.4 years) and 101 (9.9± 0.4 years).	Try TGMD-2, in your skill subsets; locomotive and object control.	Locomotive skills (run, gallop, slide, jump, and horizontal jump) and control skills (kick, catch, throw over the head, hit, roll and dribble).	Older children scored significantly higher than younger in locomotive skills and object control (*p*< 0.05). The boys obtained a higher score in object control (*p*< 0.05), and the girls obtained a higher score in the locomotor system (*p*< 0.05).
3	(Bolger et al., 2019)	447 children between 6 and 10 years old; 202 first class (6.5± 0.6 yrs) and 217 fourth class (10.4± 0.6 years).	Test TGMD-2 to assess the competence of FMS locomotive skills and object control skills.	locomotive skills (running, galloping, sliding, jumping and horizontal jumping), control skills, stability, perceived competences.	The children had greater general skills and control of the real. Younger had no differences between locomotive and real perception, while older children had a lower perception.
4	(Bonney et al., 2017)	111 ♂; 6-10 yrs (8.0± 1.0 yrs) with and without developmental coordination disorder.	Ski test on Nintendo® Wii Fit.	Repetitive and variable practice (retention and transfer of motor skills).	Children with and without DCD learn skills in the same way when they are exposed to games, learning and their transfer are similar regardless if it was a repetitive or variable practice.
5	(Bothe et al., 2019)	29 healthy and right-handed adolescents (5 ♀) between 11 and 14 yrs (12.5± 0.8 yrs).	Sessions of stationary bicycle (constant speed 20 W*Kg) and reverse direction bicycle (slalom circuit).	Psychomotor surveillance task. Maximum speed (sec) Heart rate monitor (Hz). Precision.	Both groups improved in driving the reverse bike and reducing their times. The sleep spindle showed changes in the left hemisphere during nighttime learning. Sleep was altered in the night group, associated with learning processing of this gross motor skill.
6	(Cole et al., 2018)	32 children (17 ♀) from 5 to 7 years old (5.8± 0.9 years).	Stimulation of direct current or simulation during each training session.	Manual dexterity with left hand (PPTL).	The tDCS and HD-tDCS showed improvement in learning compared to the mock. The learning effects were also observed in the untrained hand. HD-tDCS was well tolerated and safe without adverse effects
7	(Drews et al., 2013)	120 children (54 ♀) between 6-14 yrs. In three age groups, 6 yrs (6.2± 0.2 yrs), 10 yrs (10.1± 0.3 yrs) and 14 yrs (14.4± 0.3 yrs).	100 g bean bags were thrown at a circular target with its non-dominant arm, wearing opaque lenses, placed at a distance of three meters from the participant.	Launch (hit score).	There are differences between ages, but the goal-oriented motivation is a very strong point when it comes to improving performance and learning. There is greater automaticity in motor control, with positive self-assessments, less nervousness, less thoughts about one's performance and less attention to one's own body movements.
8	(Emami Kashfi et al., 2019)	45 7 (7 yrs) with learning difficulties.	The ABC approach to learning was applied, based on bilateral, unilateral and transversal activity. Eight BOTMP tests were applied.	Thick motor performance (running speed, skill, balance, bilateral coordination and strength), fine motor performance (speed of response, visual-motor control, speed and upper member skills) and both motor performance.	Both experimental groups significantly improved their motor skills and most measures of executive functions. For the control group, improvements to some extent executive functions. The functions in experimental group B were slightly better than in experimental group A. This study supported the learning approach of Blythe ABC that emphasizes ABC, and extended the previous results of the benefits of this approach in children

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Nº	Author (s)	Sample	Variable	Method	Results
9	(Feitoza et al., 2018)	614 children between 5-8 yrs from 4 different countries (231 Brazilians; 129 Australians; 140 Portuguese and 114 Americans).	Kruskal-Wallis tests, separately by age and sex	Locomotive skills and ball skills (hitting a ball, throwing a ball, kicking, catching, throwing over the head and rolling under the hand).	American children have higher PMC, mainly in object control skills. This is likely to be a reflection of a combination of factors, such as preference for different sports in different countries.
10	(Ferrer-Uris et al., 2018)	33 children (12 ♀) between 8-9 yrs, divided into three EXrVMA groups (a) (9.2± 1.1 yrs); rVMA-EX (b) (9.1± 0.8 yrs) and CON (c) (8.8± 0.7 yrs)	Learning task in different rotation conditions (0° and 60°).	Movement time (ms), reaction time (ms) and exit error (cm).	The combat of iE facilitated the motor memory, the consolidation, maximizing its effects when the exercise was presented before the motor adaptation. Despite the positive effects on consolidation, exercise did not improve motor adaptation.
11	(Gashaj et al., 2019)	151 children (81 ♀) of 6 yrs (6.5± 0.4 yrs).	Computerized tasks in relation to: basic numerical skills, executive functions, visuospatial working memory, fine and gross motor skills.	Speed (time) and precision (correct executions).	Motor skills indirectly participate in the development of symbolic skills, fine motor skills with the non-symbolic number line, while gross motor skills with the symbolic number line. Non-symbolic abilities are related to the sensorimotor of nature, while symbolic abilities need to form abstract representations.
12	(Jongbloed-Pereboom et al., 2017)	Children between 6-9 yrs, classified in 3 groups (n= 20 each): preterm children VTP, VPTnmp and VPTmp.	A test was carried out with a square of nine bonuses that lit up.	Reaction time (sec).	There were no differences in the groups with VTP in relation to movement time, number of errors and visual work memory. VTPnmp made fewer mistakes during the test than in the controls, during retention, the groups made the same number of errors (explicit learning).
13	(Jongbloed-Pereboom et al., 2019)	60 children; 39 (5-6 yrs), 21 (7-9 yrs). 28 adult students between 18-21 yrs.	A test was carried out with a square of nine bonuses that lit up.	Visual work (sec), dominant hand and memory (AWMA).	Visual work (sec), dominant hand and memory (AWMA). In implicit learning the curves were similar in all ages. In explicit learning, learning curves differ with age, younger children are slower, but their learning rate was higher than older children.
14	(Kabiri et al., 2017)	73 children from 5-8 yrs without socioeconomic distinction with at least one year of homeschooling.	Motor skills were assessed using the BOT-2 SF motor domain test.	Final motor skills, integration of fine motor skills, manual skills, bilateral coordination, balance, running speed, agility, lower member, upper member coordination and strength.	Home education did not show any detrimental effect on general motor competence among children (5-8 yrs). Participating in three or more hours of organized sports/wk or having an unemployed primary caregiver can improve the overall mastery of motor skills.
15	(Krajenbrink et al., 2018)	169 children (76 ♀) from 8-12 yrs (10.6± 1.2 yrs).	Motor task consisting of launching Slingerball with your skillful hand to a target area with different scores.	Release accuracy (cm), working memory capacity, spatial work memory.	The external focus of attention is only beneficial during practice, but not for learning. The focus of attention on discrete motor tasks in children is short-lived and decreases after one week.
16	(Maxwell et al., 2017)	261 participants (119 ♀) from 9-12 yrs (9.7± 0.7 yrs).	Two tests were performed: low motor skills (speed, agility, manual eye coordination and dynamic and static balance) and high motor skills (golf).	Number of successes and errors.	Children with low motor skills benefit from explicit motor learning, while those with high motor skills benefit from implicit motor learning.

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Nº	Author (s)	Sample	Variable	Method	Results
17	(Robinson et al., 2017)	131 children (61 ♀) of 4 yrs (4.4± 0.5 yrs).	The Test of Gross Motor Development was used. CHAMP was used. They were divided into three groups, with different treatment time: T1= 660, T2= 720 and T3= 900 min.	Locomotive skills (running, galloping, jumping and sliding) and object control (hitting, throwing, catching, kicking, dribbling and rolling underneath).	Significant and similar improvements were observed in the FMS performance of children after CHAMP, regardless of dose, while those in the control group did not experience any improvement. These findings suggest that 30 min of open-air daily play without motor skills instruction is an insufficient movement opportunity to improve FMS performance in preschoolers.
18	(Sullivan et al., 2008)	20 children (8 ♀) (10.7± 2.0 yrs) and 20 adults (8 ♀) (25.6± 2.5 yrs).	A discreet movement was made with the arm, using a lever that only moves in the horizontal plane with specific spacetime.	Time (ms) and trajectory (°).	Adults and children improved accuracy and consistency in practice trials. Children who received reduced feedback (62%) during practice had lower accuracy than those who received 100% feedback. But, during the test, feedback was given to children who received it reduced during the process and they were able to improve their performance compared to those who received 100%.
19.	(Tse et al., 2017)	32 children (17 ♀) aged 5-7 yrs (5.8± 0.9 yrs) who passed the WISC-III test to measure memory capacity.	Jump rope test with standard wooden handle.	Perform as many successful jumps (rubric) as possible in one minute.	The group of children with analog instructions was favored ($p< 0.001$) compared to the group with explicit instructions, it is suggested that analogies be included in explicit instructions to help motor learning in young children.
20.	(Valentini et al., 2016)	2,377 children (1,183 ♀) between 3-10 yrs (7.4± 1.9 yrs).	Test TGMD-2 with 12 items, where locomotion and control skills are apparent.	Locomotion skills (run, gallop, jump, horizontal jump and slide) and control skills (attack, dribble, catch, kick, throw over the head, roll). Score from zero to five.	The performance between boys and girls was significantly different in the sub-tests of locomotion and control, especially in hitting, kicking and throwing, where the boys showed greater skills.
21.	(van Abswoude et al., 2018)	25 children (12 ♀) (10.4± 1.1 yrs).	Golf tasks in an artificial field.	Performance, visual and verbal working memory capacity and conscious control.	In the specific focus of the task, preference was the most important factor for the difference between performance, with an internal and external focus of attention.
22.	(Van Abswoude et al., 2019)	69 children (35 ♀) between 6-11 yrs (9.4± 1.5 yrs). 20 children classified with low motor skills.	The sport of boccia was performed, where they had to throw the ball to a target ball, located 600 cm in front of them.	Motor skills (M-ABC2), working memory capacity (AWMA) and declarative knowledge (open question).	Registered children with low motor skills are likely to improve their performance with explicit practice, but it will not necessarily be motor learning. In working memory capacity, children are more prone to learning implicit tasks, where they did not report keeping more than two rules, but still improved in their performance.
23.	(van Cappellen–van Maldegem et al., 2018)	26 children (3 ♀) between 4-12 yrs (7.0± 1.7 yrs) with motor problems.	The experimental task consisted of Slingerball. They launched on a target area with different circles, scoring according to the radius where the object fell.	Working memory capacity (AWMA) and motor skills (MABC-2).	Children who received an internal focus yielded more precise information than those with an external focus, but nevertheless the improvement was in both groups. A significant effect was observed on the memory of visospatial work in learning. Children who received feedback with an external approach showed an improvement in visuospatial working memory.

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Nº	Author (s)	Sample	Variable	Method	Results
24.	(Zimmer et al., 2016)	36 children between 7-10 yrs; 18 (6 ♀) with DM (9.1± 1.0 yrs) and 18 (6 ♀) without DM (9.1± 1.0 yrs).	Thick motor development test (TGMD-2) to evaluate the fundamental skills.	Locomotive skills and control skills (hitting a stationary ball, stationary dribbling, catching, kicking, throwing over and rolling under). Score for presence (one) or absence (zero) of the ability.	Children with DM demonstrate difficulties in performing a variety of fundamental aspects. Movement skills allow educators to provide more individualized and targeted instruction for these children regarding performance criteria that encompass different skills.

VPT: preterm children with motor problems; VPTmp: preterm children without motor problems; VPTnmp: term children without motor problems; LD: learning difficulties; BOTMP: Bruininks-Oseretsky Test of Motor Proficiency; DCD: developmental coordination disorder; tDCS: transcranial direct current stimulation; HD-tDCS: high-definition transcranial direct current stimulation; LOC: locomotion skills; OC: object control skills; FMS: fundamental motor skills; DM: movement difficulties; Hr: heart rate; REM: rapid eye movement; MABC-2: movement assessment battery for children; AWMA: automated working memory assessment; BOT-2 SF bruininks-oseretsky: short form of the second edition; CHAMP: motor program for children's health activity; TGMD-2: test of gross motor development (2nd ed.); PPT: purdue pegboard test; TMS: transcranial magnetic stimulation; PPTL: purdue pegboard Test left hand; EX-rVMA: rVMA after exercise group; rVMA-EX: rVMA before exercise group; CON: no exercise group.

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DISCUSSION

Learning skills is a basic mechanism, which requires cognitive, perceptual and motor processes (Bolger et al., 2018; Bolger et al., 2019). Motor learning requires adequate processes for skills to be acquired and maintained (Bolger et al., 2019). During the childhood stage, motor learning becomes important since children are constantly internalizing new skills, which, if assimilated by long-term memory, will accompany them throughout their lives (Robinson et al., 2017; Ferrer-Uris, Busquets, & Angulo-Barroso, 2018) and thereby they learn more complex motor skills (Zimmer, Staples, & Harvey, 2016; Bothe et al., 2019) or only the benefits in developing fundamental movement skills, knowledge and understanding of an active and healthy lifestyle (Hulteen, Morgan, Barnett, Stodden, & Lubans, 2018), and also in cognitive skills, specifically in the executive functions and self-regulation skills essential for academic development (Cole et al., 2018; Rudd, O’Callaghan, & Williams, 2019). We support the experiential matter above all others, in which real experiences are essential for the production of learning (Drews, Chiviacowsky, & Wulf, 2013). Therefore, you must have the necessary knowledge about motor learning and its functioning in children so it can stop being one of the lowest priorities in the school curriculum (Bailey, 2018). Based on the study, the findings can be systematized into two fundamental themes that were then developed.

Mechanisms for learning motor skills in children

In general terms, studies show that the human being goes through a stage in which an immense number of skills will last a lifetime, that is, it is during childhood that motor learning becomes really important (Kabiri, Mitchell, Brewer, & Ortiz, 2017; Ferrer-Uris et al., 2018). Newly acquired skills gradually improve depending on multiple learning experiences as cognitive, perceptual, motor, linguistic (Adi-Japha, Berke, Shaya, & Julius, 2019; Gashaj, Oberer, Mast, & Roebers, 2019), neuronal, organic (Emami Kashfi, Sohrabi, Saberi Kakhki, Mashhadi, & Jabbari Nooghabi, 2019) and cultural (Feitoza et al., 2018). It is necessary to find and enhance ways for these skills to influence positive processes of motor learning in children (Ferrer-Uris et al., 2018) since if the strategy, understood as the best way for the student, is not adequate, it can lead to failure.

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The different paradigms of motor learning speak of the fact that this acquisition of skills develops initially very quickly and then slows down as these gains develop. In order for this to happen, the processes have to be adequate in adaptation, stabilization and consolidation (Ferrer-Uris et al., 2018; Adi-Japha et al., 2019). If these skills are developed in the proper way, they can be an enhancer for advanced, cognitive, social motor (Kabiri et al., 2017; Robinson et al., 2017; Bolger et al., 2019) and affective development (Zimmer et al., 2016). However, there are about five to six percent (van Abswoude, Nuijen, van der Kamp, & Steenbergen, 2018) of the population of children with learning disabilities [LD] (Bonney, Jelsma, Ferguson, & Smits-Engelsman, 2017) or developmental coordination disorders [TCD] (Zimmer et al., 2016; van Abswoude et al., 2018), but even with a normal IQ, the development of their skills is well below the average for their age. It is essential to know that the capacity for sustained and self-directed attention is accompanied by the maturation of certain functions, so it is necessary to synchronize vestibular, perceptual and visual processes of each child, independent of their abilities to motor intervention programs (Emami et al., 2019).

Various approaches can be derived from the specific analysis of the studies according to their results, and the learning mechanisms in the groups that received a motor intervention reveal significant differences in favor, unlike the groups that did not receive it (control), between pre and post tests, both in gross motor skills and fine motor skills. The results in the areas of sustained attention, working memory, problem solving and planning capacity of children with learning difficulties are beneficial for the experimental group (Maxwell, Capio, & Masters, 2017; Emami Kashfi et al., 2019). While Ferrer-Uris et al. (2018) in his article "Different post-training processes in children's and adults' motor skill learning" also reveals that there are benefits in groups that, if they receive intervention, the use of that stimulation before learning is mostly consolidated in motor memory through acute exercise, positively affecting motor learning in children. Children with some level of commitment in the movement showed difficulties for various fundamental motor skills compared to healthy children. It is necessary for children to understand, communicate, apply and analyze the different forms of movement, so specialists must provide individualized instructions to children with movement difficulties for the proper development of their motor skills (Zimmer et al., 2016). In addition, skills, by children, influence the learning of motor skills. Children who perceive that their motor skills are high are persevering and constant in improving their skills or new motor skills, while children who perceive that their motor skills are low~~,~~ tend to disconnect from activities and lose interest in the development of their motor skills. As there are also children who

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underestimate their motor skills, which is detrimental to their subsequent development. Correctly identifying the perception that each child has of their motor skills will allow the teacher to guide, stimulate and plan the type of motor sequences that each child requires to maximize their motor development (Bolger et al., 2018; Bolger et al., 2019).

The selected studies focus not only on the mechanisms of learning but also on the conditions that favor their effectiveness. The improvement in children's learning is expressed two hours after training in active groups, significantly improving their performance assessed in time and accuracy of motor tasks (Adi-Japha et al., 2019). According to Cole et al. (2018), motor learning would not only be generated in the short term, but, through brain stimulation, be shown as an enhancer with retained and long-term effects in the primary motor cortex, a key structure for motor learning. Even the basic numerical skills [BNS], executive functions and motor skills are closely related, it was shown that fine motor skills explain the variance in the non-symbolic numerical estimation, while the gross motor skills were explained by the variance of symbolic numerical abilities, indicating that motor skills can indirectly participate in the development of BNS (Gashaj et al., 2019).

Given that the learning process is dynamic and inclusive, and that the development of fine and gross motor skills corresponds to individual potentialities, there has been a discussion about the best environment for its development, that is, home, school, free games or activities (Kabiri et al., 2017). We find in this review diversity of results when it comes to comparing, for example, learning at home or at school. A child educated at home, outside the traditional classroom, is exposed to different opportunities to develop motor skills, unlike children who are educated in schools, since at home there is a tendency to prioritize a greater number of work situations that involve fine motor skills. However, the results of this study are not statistically significant in terms of potential general disadvantages in learning fundamental motor skills (Kabiri et al., 2017). On the other hand, it is specific that free play does not lead to improvements in motor skills, since it is necessary to create high-quality movement opportunities that support the development of their fundamental motor skills according to Robinson et al. (2017), however, it is necessary to determine the minimum dose level, in time, to obtain learning in motor skills. The countries of residence of the boys have great relevance at the time of developing their abilities. One of the most important factors is the sport tendency that the country has, being the boys more benefited than girls, as shown in the results of Feitoza et al. (2018).

One of the main limitations of the studies lies in the sample groups they included. These are relatively small, limiting the results found, but in most cases the evidence, so far, is in total

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relation to the results found (Robinson et al., 2017; Cole et al., 2018; Ferrer-Uris et al., 2018; Adi-Japha et al., 2019; Bolger et al., 2019). The cross section of the sample must include one or more points of comparison, so the sample should not only include children with LD (Emami Kashfi et al., 2019) or only participants of one sex (Bolger et al., 2018; Bothe et al., 2019) or a specific pediatric population as only healthy children (Ferrer-Uris et al., 2018) or only from a geographical area (Bolger et al., 2018). The possible initial evaluations that involve the studies should expand their variety by incorporating different motor skills, such as mastery in different areas, calligraphy (Adi-Japha et al., 2019), environment, past experiences (Cole et al., 2018), numerical tasks (Gashaj et al., 2019), socioeconomic level (Feitoza et al., 2018), and, in the case of presenting some different capacity, by evaluating the degree to which it is presented (Zimmer et al., 2016), allowing more visions and broad findings. Not only the initial evaluations should be varied, but the tasks that are developed should motivate the children, being this novel for all ages (Feitoza et al., 2018; Adi-Japha et al., 2019) and their completion in normal contexts such as physical education or during recess (Zimmer et al., 2016). Finally, evaluators must present the competencies necessary for the administration of the tests (Kabiri et al., 2017).

The limitations of the studies evaluated give us signs on how and what to continue investigating to better enhance the motor, cognitive and social learning of children. For this purpose, studies should involve more representative samples of the cross section, being more representative (Zimmer et al., 2016; Bolger et al., 2018; Emami Kashfi et al., 2019) both in number and in geographical locations (Feitoza et al., 2018), or that the initial findings are confirmed in other investigations, because some are initial studies (Kabiri et al., 2017). The results obtained should be compared with other cognitive processes related to attention (Adi-Japha et al., 2019) or different academic achievements (Emami Kashfi et al., 2019), memory (Bothe et al., 2019), performance (Robinson et al., 2017) or even the comparison with different stimulations related to exercise (Ferrer-Uris et al., 2018), thus achieving a complete motor intervention program (Robinson et al., 2017; Emami Kashfi et al., 2019), with the possibility to examine results not only in the short term but with greater enhancement in the long term (Robinson et al., 2017). Finally, there is a call for the dissemination of the different approaches that can lead to promoting intervention programs not only in the learning of motor skills but also in their rehabilitation (Cole et al., 2018).

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Motor learning and focus according to motor skills in children

Studies show that boys and girls have different motor, cognitive and behavioral abilities, associated with their neurological development, as Jongbloed-Pereboom, Janssen, Steiner, Steenbergen, and Nijhuis-van der Sanden (2017) found when evaluating children with and without history of prematurity, which impacts the learning process. In essence, motor skills do not develop naturally over time, but they need to be practiced and experienced through different experiences, but, for this, instructions are also necessary (Valentini et al., 2016; Bolger et al., 2018) as a tool to achieve their different benefits at motor and cognitive levels (Valentini et al., 2016; Bolger et al., 2019).

The way in which the child receives the information to execute a motor skill can be in two ways, through explicit learning and implicit learning (Jongbloed-Pereboom et al., 2017; Maxwell et al., 2017; van Abswoude et al., 2018; Jongbloed-Pereboom, Nijhuis-van der Sanden, & Steenbergen, 2019; Van Abswoude, Van Der Kamp, & Steenbergen, 2019; van Cappellen–van Maldegem, van Abswoude, Krajenbrink, & Steenbergen, 2018), also called external focus and internal focus (Krajenbrink, van Abswoude, Vermeulen, van Cappellen, & Steenbergen, 2018; van Abswoude et al., 2018) or instructions without analogies and with analogies (Tse, Fong, Wong, & Masters, 2017). Explicit motor learning or without analogies or external focus becomes more relevant for a child when the instructions are accompanied by a theoretical verbalization of the motor action, in which the movement is detailed, hypotheses are formulated and modified, rules can be associated, which requires a greater working memory. Finally, performance is conscious since learning is associated with errors (Maxwell et al., 2017; Tse et al., 2017; Krajenbrink et al., 2018; Jongbloed-Pereboom et al., 2019; van Abswoude et al., 2018; van Cappellen–van Maldegem et al., 2018). On the other hand, implicit motor learning or with analogies or internal focus~~,~~ becomes more relevant for a child when the instructions are accompanied by a lower awareness of how the movement is performed, so the detailed verbal explanations do not have great incidence, but those verbal explanations that are related to everyday things, helping to understand the world around them, and this associativity requiring less working memory (Maxwell et al., 2017; Tse et al., 2017; van Cappellen–van Maldegem et al., 2018; Jongbloed-Pereboom et al., 2019).

The use of explicit instructions facilitates immediate changes in motor learning through the hypotheses, reflected in greater precision in the game, but without retention in time (one week later) or with a very short retention (24 to 48 hours later), unlike the implicit instructions that

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resulted in less efficient motor learning in relation to the motor task of play, but it is retained in time (Krajenbrink et al., 2018). The information approach, for each child, has to be adequate and adapted according to their abilities, in order to enhance the learning of their motor skills (Drews et al., 2013; Bonney et al., 2017; van Abswoude et al., 2018) and that these are beneficial and not harmful (Bolger et al., 2017) in such a way that they are inclusive in both games and outdoor activities (van Cappellen–van Maldegem et al., 2018).

Existing evidence shows that children who have low motor skills development benefit better from implicit motor learning, while children who have high motor skills benefit better from explicit motor learning (Maxwell et al., 2017). Jongbloed-Pereboom et al. (2019) adds that the explicit approach is conditioned by age, being older children (seven and nine years old) highly benefited, unlike implicit motor learning, whose results are similar at all ages, but more significant in young children (five and six years old). Other studies indicate that not only age determines the type of approach, but regardless of the approach used, the motivation and personal preference of the child are the most relevant in the learning process independent of their cognitive abilities, as long as the instructions have the necessary content (Tse et al., 2017; van Abswoude et al., 2018; van Cappellen–van Maldegem et al., 2018; van Abswoude et al., 2019). The physical educator must have the necessary skills to be able to provide both types of approach separately and in turn articulate (Tse et al., 2017).

Although the evidence shows aspects in favor of each focus of learning according to the level of motor skills in children, it is necessary to deepen the different limitations that these studies described at the time of production. The relatively small sample size may influence the level of generalization of the results found (Sullivan, Kantak, & Burtner, 2008; Maxwell et al., 2017; Bolger et al., 2018; van Abswoude et al., 2018), as well as limiting the sample to children who have a homogeneous profile, health status (Tse et al., 2017), age (Sullivan et al., 2008) or who do not perform sports or physical activity after school (Valentini et al., 2016). The level of stimulus needed to preserve children's attention during the study should be appropriate to their tastes, motivating enough (Sullivan et al., 2008; Jongbloed-Pereboom et al., 2017; Jongbloed-Pereboom et al., 2019) and unrestricted tasks, expanding motor executions (van Cappellen–van Maldegem et al., 2018), so the space must also be appropriate (van Abswoude et al., 2018). Finally, many of the studies are preliminary, so it is necessary to continue investigating to corroborate their findings (Bonney et al., 2017; Jongbloed-Pereboom et al., 2017; Maxwell et al., 2017), being that some can potentially present errors of interpretation of the results (Sullivan et al., 2008; Krajenbrink et al., 2018).

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The relationship between the limitations of the studies and the future perspectives of these are really narrow. In order to improve and enhance the studies, it is expected that future measurements not only include motor work, but also visual and verbal work (Jongbloed-Pereboom et al., 2017; Jongbloed-Pereboom et al., 2019), memory (Tse et al., 2017; van Abswoude et al., 2019) and attention (Krajenbrink et al., 2018), considering that motivational impact is a relevant variable when using a method (Sullivan et al., 2008; Drews et al., 2013; van Abswoude et al., 2018), which have a greater tendency to generate successful experiences for the child (Maxwell et al., 2017), optimizing their performance (Valentini et al., 2016). It is also necessary that the sample includes a variety of children not only with different skills and abilities but also representative of various geographical and cultural realities, among others (Tse et al., 2017; Bolger et al., 2019). It is expected that the findings can be used as a guide for the development of motor interventions in different media, such as in educational, sports and rehabilitation processes (Jongbloed-Pereboom et al., 2017; van Abswoude et al., 2018; Jongbloed-Pereboom et al., 2019), being these effective and personalized (van Cappellen–van Maldegem et al., 2018).

CONCLUSIONS

From the analysis of the selected material, it was possible to determine that the findings are mainly related to two subjects (Table 2).

Table 2. Summary of the fundamental contributions of neuroscience in motor learning in children.

Topics	Fundamental Contributions
Mechanisms for learning motor skills in children	• Learning occurs based on experience at different levels: cognitive, perceptual, motor, linguistic, neuronal, organic and cultural; • Learning requires processes of adaptation, stabilization and consolidation, promoting motor, cognitive and social development; • Learning requires the maturation of brain functions, synchronization of vestibular, perceptual and visual processes, to increase the capacity for sustained and self-directed attention; • Children who receive motor intervention improve sustained attention, working memory, problem solving and planning capacity; • Motor learning benefits from planned motor actions and not from free play;
Motor learning and focus according to motor skills in children	• Motor and cognitive development is favored by instructions as an essential tool; • Explicit instructions require theoretical verbalization of motor action and present a greater benefit for children with high motor skills (seven and nine years old); • The implicit instructions present a greater benefit for children with low motor skills (five and six years old); • The child's personal motivation and preferential are a determining factor in the independent learning process of sex, motor ability and level of development.

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The first refers to the mechanisms with which children manage to establish motor learning and the other is related to the approaches that may exist according to the motor skills presented by them. In both aspects there are different ways in which the child can establish a process of learning a motor skill having multiple benefits, not only in the area of fundamental movements but also in other areas of learning. For this reason, it is necessary for the physical educator to have various tools to appreciate and develop different learning options in infants. In this way, the boy and the girl, according to their own characteristics, choose the one that best suits their abilities at that stage of their lives.

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