DOI: 10.1590/1809-2950/17009426022019

SYSTEMATIC REVIEW

End-state comfort effect in manipulative motor actions of typical and atypical children: a systematic review

Estado de conforto final de ações motoras manipulativas de crianças típicas e atípicas: revisão sistemática

Estado de confort final de acciones motoras manipuladoras de niños típicos y atípicos: revisión sistemática

Karina Pereira[1], Jéssica Cristina Medeiros[2], Laíce Rodrigues Bernardes[3], Luciane Aparecida Pascucci Sande de Souza[4]

ABSTRACT | This study aimed to make a systematic review of scientific articles on the planning of manual motor actions of typical and atypical children. To do so, a search of articles published between 1996 and 2017 was done on PubMed, LILACS, Science Direct, and SciElo databases. Original articles in English and Portuguese evaluating the planning of motor actions in typical and atypical children performing manual tasks were selected. For the analysis, the population age, number of children, type of task, main results, site of study and impact of the journal were considered. From the eighteen articles found, twelve were about typical children (from nine months old to twenty years old) and six about atypical children (from three to fourteen years old) diagnosed with autism, hemiplegic cerebral palsy, and developmental coordination disorders. In nine- to ten-year-old typical children, the planning ability of manual motor actions develops over the time and is similar to that of an adult. The atypical children showed motor planning ability lower than that of the typical children, and determining the age when this planning ability is acquired was not possible.

Keywords | Child; Motor Planning; Child Development; Teenager.

RESUMO | O objetivo desse estudo foi realizar uma revisão sistemática de artigos científicos sobre o planejamento de ações motoras manuais de crianças típicas e atípicas. Para isso, foi feita uma busca de artigos publicados entre 1996 e 2017 nas bases de dados PubMed, Lilacs, Science Direct e SciELO. Foram incluídos artigos originais em língua inglesa e portuguesa, que avaliaram o planejamento de ações motoras em crianças típicas e atípicas por meio de tarefas manuais. Para a análise dos artigos, considerou-se a população, a faixa etária, o número de crianças, o tipo de tarefa, os principais resultados, o local de realização do estudo e o fator de impacto da revista. Ao todo, foram encontrados 18 artigos, sendo 12 com crianças típicas (9 meses a 20 anos de idade), e 6 com crianças atípicas (3 a 14 anos) diagnosticadas com autismo, paralisia cerebral hemiplégica e transtornos de déficit de coordenação. Nas crianças típicas, observa-se que a capacidade de planejamento de ações motoras manuais se desenvolve ao longo do tempo e se assemelha a de um adulto entre os 9 e 10 anos de idade. As crianças atípicas apresentaram capacidade de planejamento motor inferior à das crianças típicas e não foi possível determinar a idade em que essa habilidade de planejamento é estabelecida.

Descritores | Criança; Planejamento Motor; Desenvolvimento Infantil; Adolescente.

RESUMEN | El objetivo de este estudio fue realizar una revisión sistemática de artículos científicos sobre la planificación de acciones motoras manuales de niños típicos y atípicos. Para ello, se realizó una búsqueda de artículos publicados entre 1996 y 2017 en las bases de datos PubMed, Lilacs, Science Direct y SciELO. Se incluyeron artículos originales en inglés

This study is related to the master's research project linked to the Graduate Program in Physical Education, Federal University of Triângulo Mineiro, conducted by the researchers Laboratory of Physical Therapy in Visual Deficiency, in partnership with other institutions and schools that work with people with visual impairment.

[1]Universidade Federal do Triângulo Mineiro (UFTM) – Uberaba (MG), Brazil. E-mail: karina.pereira@uftm.edu.br. Orcid: 0000-0001-7486-1004
[2]Universidade Federal do Triângulo Mineiro (UFTM) – Uberaba (MG), Brazil. E-mail: jessica_medeiros_@hotmail.com. Orcid: 0000-0002-3729-1281
[3]Universidade Federal do Triângulo Mineiro (UFTM) – Uberaba (MG), Brazil. E-mail: laicebernardes@gmail.com. Orcid: 0000-0001-7442-2685
[4]Universidade Federal do Triângulo Mineiro (UFTM) – Uberaba (MG), Brazil. E-mail: luciane.sande@uftm.edu.br. Orcid: 0000-0002-7160-9556

Corresponding address: Karina Pereira – Rua Vigário Carlos, 100, 4º andar, sala 408 – Uberaba (MG), Brazil – Zip Code: 38025-350 – E-mail: karina.pereira@uftm.edu.br –
Financing source: Nothing to declare – Conflict of interests: Nothing to declare – Presentation: Dec. 12th, 2017 – Accepted for publication: Nov. 8th, 2018.

y portugués que evaluaron la planificación de acciones motoras en niños típicos y atípicos a través de tareas manuales. Para el análisis de los artículos, se consideró la población, el grupo de edad, el número de niños, el tipo de tarea, los principales resultados, el lugar de realización del estudio y el factor de impacto de la revista. En total, se encontraron 18 artículos, 12 con niños típicos (9 meses a 20 años) y 6 con niños atípicos (3 a 14 años) diagnosticados con autismo, parálisis cerebral hemipléjica y trastornos de déficit de coordinación. En los niños típicos, se observa que la capacidad de planificación de acciones motoras manuales se desarrolla a lo largo del tiempo y entre los 9 y 10 años se asemeja a la de un adulto. Los niños atípicos presentaron una capacidad de planificación de motores inferior a la de los niños típicos y no fue posible determinar la edad en que se estableció esta capacidad de planificación.

Palabras clave | Niños; Planificación Motora; Desarrollo Infantil; Adolescente.

INTRODUCTION

Planning an action involves a complex process in which the individual selects a sequence of particular movements among infinite possibilities to perform an action[1,2]. More specifically, the best strategy to grasp a particular object needs to be formulated when planning a manipulative action, considering the objective of the task, the current restrictions to perform it and the physical properties of the object grasped, allowing the most efficient production of movements or performance of sequential actions[3,4]. Determining how a movement or a combination of movements in particular is selected involves the degrees of freedom problem described by Bernstein[5]. Among the numerous degrees of freedom to perform the same task, the individual must choose the most harmonic and simple motion strategy possible.

Considering how a movement strategy or motion actions are determined, Rosenbaum et al.[6] observed individuals often adopt awkward postures at the beginning of a movement, so that they end up in a comfortable posture. This tendency to complete the action in a comfortable posture was titled end-state comfort. These awkward postures would be those in which joints stay distant from resting position, i.e., extreme joint angles[1,7].

To observe how individuals plan their action in manipulative tasks, Rosenbaum et al.[6] developed a classical model to study the end-state comfort paradigm. The authors requested their volunteers to grasp a bar placed horizontally and observed how these individuals positioned the hand at the beginning of the movement. The authors noticed that when individuals were asked to fit the bar in a target placed to their right (turning the bar 90º clockwise), they grasped the bar overhand. However, when the task was to grasp the bar and put it in a target on the left side (turning the bar 90º anti-clockwise), the participants grasped the bar underhand. That is, individuals always tended to change the initial position of grasping according to the purpose of the task to achieve a comfortable position of the upper end limb, allowing the most effective fitting of the bar.

A vast number of studies have been conducted to study the motor planning, especially with adults. The main findings report that these individuals always perform a manipulative task according to the end-state comfort. From studies on motor planning with adults, some authors[8-10] have tried to understand whether this ability develops along with sensory motor development and the age at which, more precisely, this ability becomes enhanced.

A recent study with children suggested the ability of this population to plan a manipulative motor action is similar to that of an adult at about nine years old[11]. However, few studies on this topic were conducted with typical children[9,10,12,13].

The fact that studies on the planning of motor actions of typical and atypical children are a recent topic in the scientific literature aroused the interest in gathering and investigating the main findings about this topic in scientific publications. Considering this, this study aimed to make a systematic review by selecting scientific articles on the planning of manual motor actions of children with typical and atypical sensory motor development.

METHODOLOGY

This study is characterized as a systematic review, for which recruitment, selection and rigorous analysis of articles on the planning of manual motor actions of typical and atypical children were performed. A mapping of articles published between January 1996 and February 2017 in PubMed, LILACS, Science Direct, and SciELO databases was done. The following keywords were used in English and in Portuguese: end-state

comfort (*estado de conforto final*), children/childhood (*crianças*), typical (*típica*) and atypical (*atípica*). An inclusion criteria was adopted to select the articles: (1) original articles in English or Portuguese; (2) samples with typical and atypical children; (3) evaluation of the planning of motor actions by manual tasks. Furthermore, the choice was not to exclude the articles according to their sample size, since few studies address the topic in the literature and this would imply the possible exclusion of some of them.

Initially, a selective reading of titles and abstracts of all articles of the search was done. In the cases in which the title and the abstract were not clear enough, the full text was read. The articles that involve the planning of manipulative actions of children and those referred by the articles found were included when they met the criteria proposed, even not being part of the search on the database[14].

The search and initial selection of the articles was conducted by two researchers, who worked independently. The development of the inclusion criteria followed the PICO strategy (Participants, Interventions, Comparisons, Results, and Study), guided by the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA)[15]. Thus, studies were selected if they followed the criteria: (1) participants: typical and atypical children; (2) interventions: evaluation of the end-state of the movement; (3) comparisons: observation of the planning of the action of the movement to perform the task; and (4) results: starting the ability to plan manipulative motor actions and description of skills in typical and atypical children.

The data were tabulated and analyzed according to the main aspects: authors; year of publication; group of children evaluated (typical or atypical); age or age group; number of children evaluated; type of task evaluated; main results; site of the study; and impact factor of the journal in which it was published.

RESULTS AND DISCUSSION

From the search on the databases selected, sixteen articles were found, and fourteen met the inclusion criteria established. Other four articles were added for appearing among the bibliographic references of some studies. Therefore, eighteen articles were included in this systematic review: twelve with typical children and ten with atypical children.

The articles were analyzed and categorized in two tables, according to the type of study population. Thus, the data from typical children is shown in Table 1; and the data from atypical children, in Table 2.

Planning of manual motor actions of typical children

An interesting aspect regarding the publication of articles on the planning of motor actions in typical children is the year of publication. All the articles found were published only from 1999 on (Table 1). Additionally, nine out of ten articles with typical children were published in the last four years, which reinforces that this study area is still recent.

Table 1. Studies on the planning of motor actions in typical children

Author(s)	Year	Age group of the sample	Sample of the study	Type of task	Results	Site of study	Impact Factor
Jovanovic; Schwarzer[16]	2017	3, 5, and 21 years	30 27 30	1- To pick up the bar on the middle shelf and to place it on another shelf (target shelf) on the starting position 2- To pick up the bar on the target shelf and to put it on the starting position	Phase 1: Different heights showed a weak influence in the 3-year-old group when compared with the other groups. Phase 2: The height had greater influence in the groups of 3 and 5 year olds when compared with the group of adults.	Germany	2.333
Jung; Kahrsb; Lockman[17]	2016	16-33 months	30	1- To pick up the wooden rod on the table 2 – To place the rod in a horizontally or vertically oriented slot located in the middle of the table	Older children showed more advanced spatial planning and improvements in coordination.	New Orleans	3.411

(continues)

Table 1. Continuation

Author(s)	Year	Age group of the sample	Sample of the study	Type of task	Results	Site of study	Impact Factor
Jongbloed-Pereboom, et al.[18]	2013	3-10 years	351	To fit a wooden sword	The planning ability was enhanced from 3 to 10 years old, showing a decreased improvement at 9 years old.	Netherlands	2.377
Scharoun; Bryden[11]	2013	3-12 years	92	To manipulate a cup	The end-state comfort appeared at 9 years old.	Canada	2.976
Knudsen et al.[12]	2012	3-8 years	96	1- To manipulate a cup 2- To transport and to fit a wooden bar	1- A 13% increase in the planning ability was observed at 3 years old and a 94% increase at 8 years old. 2- 63% increase in the planning ability at 3 years old and a 100% increase at 8 years old.	Germany	2.8
Jovanovic; Schwarzer[19]	2011	18, 24, and 42 months	81	To transport and to fit a wooden bar vertically	The children already used planning strategies at 18 months of age, with significant increase at 24 months.	Germany	2.137
Stockel; Hughes; Schack[9]	2012	7-9 years	36	To transport and to fit a wooden bar	Planning ability is fully developed at 9 years old.	Germany	2.378
Thibaut; Toussaint[10]	2010	4-10 years	120	To transport and to fit a wooden bar	Planning ability of motor skills develops gradually from 4 to 10 years old, but with a drop in the level of ability at 8 years old.	France	2.377
Weigelt; Schack[20]	2010	3-5 years	51	To transport and to fit a wooden bar	Gradual improvement in planning capacity: 18% at 3 years old, 45% at 4 years old, and 67% at 5 years old.	Germany	4.759
Adalbjornsson; Fischman; Rudisill[8]	2008	2-6 years	40	To manipulate a cup	Only 11 out of 40 children were able to plan their action according to the end-state comfort. No difference between ages was observed.	United States	1.108
Manoel; Moreira[13]	2005	2,5-6 years	40	1- To transport and to fit a cylindrical wooden bar; 2- To transport and to fit a semicylindrical wooden bar	The children did not demonstrate planning ability according to the end-state comfort, even when the task demanded higher precision level (task 2).	Brazil	0.06
McCarty; Clifton; Collard[21]	1999	9, 14, and 19 months	36	To grasp a spoon and to feed himself	At 19 months old, the children altered the hand (right or left) to grasp a spoon according to the start position.	United States	2.976

Studies on motor planning in typical children were done in several countries: Germany (n=5), United States of America (n=3), Canada (n=1), Netherlands (n=1), France (n=1), and Brazil (n=1). These studies were published in top journals in the fields of Physical Education and Psychology, with impact factor between 0.06 and 4.759.

The manual tasks used to assess planning skills were: to transport and to fit a wooden bar (n=6), to manipulate a cup (n=3), to fit a wooden sword (n=1), to transport and to fit a bar upright (n=1), to grasp a spoon and to feed yourself (n=1), to handle a book (n=6), whereas in one study[12] the choice was to apply two tasks with the same children, which were: to transport and to fit a wooden bar and to manipulation of a cup. The choice for the task of manipulation of a cup was justified by the authors[8,11,12] due to the fact that the cup is a common object in the daily

life of children and because of the number of experiences it provided to the child throughout their development. In its turn, the choice by Jongbloed-Pereboom et al.[18] for conducting the study using a wooden sword was made simply because it is a more interesting, attractive, and playful task for children, besides having been previously used in studies with atypical children. The task of grasping a spoon and eating using it, chosen by McCarty et al.[21] was selected for being part of the daily experiences of a child. Just as in this study, the authors chose to evaluate children from 9 years old.

Regarding the age of the children in the studies, it ranged from nine months to twenty years old, and five studies chose to evaluate a broad age range from three to twelve years old. The choice for assessing children of such different age range in the same study is related to the main findings of these studies, as the authors found the planning ability of motor actions of typical children develops over childhood development[10,11,18], reaching, between nine and ten years old, the same levels of an adult. Therefore, choosing to study broader age groups allows showing it quite clearly.

McCarty et al.[21] assessed children aged nine, fourteen and nineteen months old while performing a task that would be common to the routine of a child that age. In the study, a spoon containing food was given to the child, so that the base of the spoon was faced left or right randomly. This procedure meant that children at nine months picked up the spoon uncomfortably, but, at nineteen months, infants adopted the strategy of changing the dominant hand that grabbed the spoon, according to the way it was presented. That is, at this age, they considered the position of the spoon before adopting an action strategy. Unlike previous studies, the task used was customary for the child, making the previous experience influence the planning of such a task. Jovanovic and Schwarzer[19] also found little evidence of planning when assessing children at 18, 24, and 42 months old, although it was noticed that at 42 months some children used strategies such as changing the way of holding the bar to accomplish the task.

Jung et al.[17] found similar results when evaluating children between 16 and 33 months. The task was to take the wooden rod on the table and fit it into a slot on the surface so that the children should carry the rod to the slot. The results showed older children did a more advanced and coordinated spatial planning by making relatively short paths and avoiding unnecessary object rotation.

Regarding other studies with typical children, similarities were observed in relation to ages when the motor planning ability becomes evident. In the studies by Adalbjornsson et al.[8], Manoel and Moreira[13], the authors assessed the planning ability of children between two and a half to six years old, using different tasks. The authors concluded that the children showed little evidence of planning capacity until six years old. Corroborating these studies, Weigelt and Schack[20] assessed children from three to five years old and noticed gradual improvement in planning capacity, although at five years old this ability had not reached the same levels of an adult yet.

The other studies[9,12,18] assessed children over six years old and obtained similar results when planning manual motor actions. In these studies, the authors highlight between eight and ten years old this ability reaches the same levels of adults.

Jovanovic and Schwarzer[16] investigated how children from 3 and 5 years old and adults around 21 years old performed the task of picking up a bar in a levels shelf. The task consisted of two phases: first, the participant should take the bar on the middle shelf and put it on another shelf (target); second, the participant should pick up the bar on the target shelf and put it on the starting position from the previous shelf. In the first phase, weaker influence of the different levels of the shelf were observed on the results of the 3-year-old group when compared with the other age groups. According to the authors, this result is related to the low motor demands. Regarding the second phase, the different levels had greater influence in the groups of 3 and 5 years old, in which the difficulty in returning the object to the starting position was greater.

The emergence of the planning ability of manipulative actions according to the end-state comfort seems, therefore, to be related to the sensory motor development. Some studies show the age period between three and ten years old is considered crucial for the development of motor control as a whole, as it has already been evidenced in literature by both behavioral[22] and neuroimaging studies[23]. In this age group, motor and sensory areas develop first, followed by areas of higher order, such as the prefrontal cortex[23].

Regarding motor control, an important feature to the child's development is the motor planning, for being an aspect that integrates both the motor and cognitive components when choosing a strategy for motor action. Therefore, it would explain why the planning ability of motor actions develops over sensory motor development.

Planning of manual motor actions of atypical children

The six studies found in the literature about planning of motor actions of atypical children are described in Table 2. Similar to the articles of typical children showed in Table 1, the interesting aspect observed is the year of publication of these studies. The first ones (n=2) were published in 1996 and 1997, and the other studies only about thirteen years later, from 2010 on. The three most recent studies assessed children with cerebral palsy (CP), which shows a current interest of the researchers in analyzing the patterns of movements of this population.

Table 2. Studies on the planning of motor actions of atypical children

Author(s)	Year	Sample	Age range	Sample of study	Type of task	Results	Site of study	Impact Factor
Adams et al.[23]	2016	Developmental Coordination Disorder (DCD)	6-10 anos	DCD=30 Typical=90	1 – To grab a wooden sword and to put it into a slot 2 – To grab a bar and place it vertically in a circular holder on the table	1 – Children with DCD plan less for the end-comfort state of the hands compared with those from the control group 2 – No significant differences were found between groups.	South Africa	1.606
Janssen; Steenbergen[24]	2011	Hemiplegic Cerebral Palsy (CP)	7-12 years	CP=16; Typical=24	To transport a bar upright and place it in platforms of different heights: 1 – Unimanually; 2 – Bimanually	There was little evidence of planning in children with CP, and no difference was observed between ages. In the bimanual task, children showed higher planning ability with the most affected limb.	Netherlands	2.483
Crajé et al.[25]	2010	Hemiplegic Cerebral Palsy (CP)	3-6 years	CP=24; Typical=24	To fit a wooden sword	Planning ability of children with CP was lower than that of typical children, and no evidence of improvement over the age was observed in children with CP.	Netherlands	2.483
Van Swieten et al.[26]	2010	Autism Developmental coordination disorder (DCD)	9-14 years 6-13 years	DCD=27; Autists=20; Typical=70	To grasp a bar and to rotate it according to the position indicated	Children with autism showed the same planning ability compared with typical children. Younger children with DCD showed lower ability to perform the task compared with typical children.	United Kingdom	4.759
Smyth; Mason[27]	1997	Developmental coordination disorder	4-8 years	DCD=95; Typical=91	To rotate a disk towards several targets; 2- To transport and to fit a wooden bar	The planning ability did not differ between children with DCD and typical children.	United Kingdom	5.422
Hughes[28]	1996	Autism	Average age – 14 years old	Autists=36; Typical=28	To transport and to fit a wooden bar	Children with autism showed little evidence of planning ability in manipulative tasks.	England	3.723

Note: CP: cerebral palsy; DCD: developmental coordination disorder.

The studies on motor planning of atypical children were carried out in the following countries: Netherlands (n=2), United Kingdom (n=2), South Africa (n=1), and England (n=1). Just as the studies with typical children, these articles were published in top journals in Physical Education and Psychology, showing impact factor between 2.483 and 5.422. Considering the other groups of atypical children, children with autism (n=1) and developmental coordination disorder (DCD) (n=1) were analyzed. Yet, in another study[26], the authors simultaneously assessed children with autism and children with developmental coordination disorder.

The studies by Janssen and Steenbergen[23] and Crajé et al.[25] assessed children with hemiplegic CP and found similar results even evaluating children of different age groups through different tasks. In the first study, the task consisted of grasping and transporting a bar upwards or downwards to a holder. Two conditions were tested: the first one was performed unimanually and the second one, bimanually, that is, transporting a bar in each hand. In the

second study, the task was to fit a sword in a wooden block, where the sword had been previously placed in different positions, requiring, thus, different ways of grasping to perform the task adequately. In both studies, the authors did not find evidences of planning of manipulative motor actions, justifying that the children with CP can present problems to visualize their movements before performing the task. These problems would be related to the construction of internal models of motor imagery, that is, the children with CP would present an impairment in the ability to imagine movements before performing them[23,25]. Moreover, children with hemiplegic CP have an important limitation to control their degrees of freedom, since the presence of spasticity and motor synergies act to make the execution of some movements difficult, such as supination, important to the execution of these manual tasks.

An interesting aspect of the results found in the study by Janssen and Steenbergen[25] is that, when performing the bimanual task, the planning ability of children with CP was greater while performing it with the impaired upper limb. According to the authors, the explanation for this finding would be the children's choice for adopting a strategy more focused on the cognitive, that is, these children focus their attention on the most affected side while performing the task and, consequently, the performance of this limb improves.

In the study by van Swieten et al.[26], both children with autism and children with DCD were evaluated. As in this study, the author compares these two groups separately from typical children, we chose to present and discuss the details of each population separately as well. van Swieten et al.[26] and Hughes[28] assessed the planning of motor actions in children with autism while performing distinct manual tasks, which may have influenced the different results between studies. In the first study, the task was to grab a bar and to rotate it until the final position shown, which required the initial hold to be adopted according to the final position of the bar. In this study, 20 autistic children aged nine to fourteen years old were evaluated, and their performance was similar to that of typical children. Contrarily, the study by Hughes[28] with 36 autistic children, average aged between thirteen and fourteen years old, showed little evidence of planning ability while performing the task of transporting and fitting a wooden bar when compared with typical children. The different results found in these studies may have been consequence of different tasks to assess autistic children.

Similarly, the studies that assessed the planning of motor actions with children with Developmental Coordination Disorder (DCD) had discrepant results. The study by van Swieten et al.[26] assessed 37 children with DCD aged between six and thirteen years old, and a less ability was found in children until eight years old when compared with typical children of the same age. Adams et al.[24] evaluated children with DCD and typical children between six and ten years old. They were evaluated on two tasks: the first was to pick up a sword and to put it in a slot on the box, both on the table. The second task consisted of grabbing a bar in a frame and placing it vertically in a circular holder on the table. The results showed children with DCD planned less for end-state comfort in the task of the sword compared with the control group. However, in the task of grabbing the bar, no significant differences between groups were detected. The study shows children with DCD have motor action planning deficits when compared with typical children and that this deficit is task-related. Smyth and Mason[27] declare that this ability in children with DCD between four and eight years old (n=95) seems to be similar to that of children with typical development of the same age, although until eight years old this ability is not yet completely developed as it is in an adult. Van Swieten, et al.[26] justify that children with DCD seem to consider their difficulties in performing manual task, choosing simpler movements. It was not evident in the study by Smyth and Mason, even assessing a higher number of children. Both studies used similar tasks of rotating a bar placed in a disk according to the final-oriented position; however, in the study by Smyth and Mason[27], the initial grasping was not controlled, allowing children to perform movements clockwise or anti-clockwise, and in the study by van Swieten et al.[26], the direction of rotation of the bar was given by the examiner, being the final position the most distant from the initial grasping.

Studies on the planning of motor action of atypical children are still scarce, therefore, it is little conclusive. A broader approach of studies on this topic are necessary, with higher samples of atypical children and methodological standardization to reach a specific conclusion about the subject.

CONCLUSIONS

The results found evidenced that the planning of motor actions is a characteristic inherent in the child sensory

motor development for aggregating not only motor but also cognitive characteristics, and it is enhanced over this development.

In typical children, a consensus seems to be reached among the studies found that this ability becomes similar to that of an adult only at around nine to ten years old, although younger children already outline some planning strategies. In atypical children, determining a specific age for task execution is not possible because there are few studies and few samples are used.

Thus, more studies are necessary, mainly with atypical children, because they will be the baseline to assess the main difficulties of this population, and consequently, to estipulate proper therapeutic actions to stimulate this capacity. Moreover, one highlights that the methodological standardization of the studies will allow a better comparison between the results.

REFERENCES

1. Chapman KM, Weiss DJ, Rosenbaum, DA. Evolutionary roots of motor planning: the end-state comfort effect in lemurs. J Comp Psychol. 2010;124(2):229-32. doi: 10.1037/a0018025
2. Fischman MG, Stodden DF, Lehman DM. The end-state comfort effect in bimanual grip selection. RQES. 2003;74(1):17-24. doi: 10.1080/02701367.2003.10609060
3. Herbort O, Butz MV. The continuous end-state comfort effect: weighted integration of multiple biases. Psychol Res. 2012;76(3):345-63. doi: 10.1007/s00426-011-0334-7
4. Steenbergen B, Meulenbroek RGJ, Rosenbaum, DA. Constraints on grip selection in hemiparetic cerebral palsy: effects of lesional side, end-point accuracy, and context. Brain Res Cogn Brain Res. 2004;19:145-59. doi:10.1016/j.cogbrainres.2003.11.008
5. Bernstein N. The co-ordination and regulation of movements. Oxford: Pergamon Press; 1967.
6. Rosenbaum DA, Marchak F, Barnes HJ, Vaughan J, Slotta JD, Jorgensen MJ. Constraints for action selection: overhand versus underhand grips. In: Jeannerod M, editor. Attention and performance XIII: motor representation and control. Abingdon: Psychology Press; 1990. p. 321-42.
7. Moreira CRP, Manoel EJ. Planejamento na aquisição de habilidades motoras de manipulação. In: Tani G, editor. Comportamento motor: aprendizagem e desenvolvimento. Rio de Janeiro: Guanabara Koogan; 2008. p. 251-8.
8. Adalbjornsson CF, Fischman MG, Rudisill ME. The end-state comfort effect in young children. Res Q Exerc Sport. 2008;79(1):36-41. doi: 10.1080/02701367.2008.10599458
9. Stockel T, Hughes C, Schack T. Representation of grasp postures and anticipatory motor planning in children. Psychol Res. 2012;76(6):768-76. doi: 10.1007/s00426-011-0387-7
10. Thibaut JP, Toussaint L. Developing motor planning over ages. J Exp Child Psychol. 2010;105(1-2):116-29. doi: 10.1016/j.jecp.2009.10.003
11. Scharoun SM, Bryden PJ. The development of end- and beginning-state comfort in a cup manipulation task. Dev Psychobiol. 2014;56(3):407-20. doi: 10.1002/dev.21108
12. Knudsen B, Henning A, Wunsch K, Weigelt M, Aschersleben G. The end-state comfort effect in 3- to 8-year-old children in two object manipulation tasks. Front Psychol. 2012;3:1-10. doi: 10.3389/fpsyg.2012.00445
13. Manoel EJ, Moreira CRP. Planning manipulative hand movements: do young children show the end-state comfort effect? J Hum Mov Stud. 2005;49:93-114.
14. Sampaio RF, Mancini MC. Estudos de revisão sistemática: um guia para síntese criteriosa da evidência científica. Braz J Phys Ther. 2007;11(1):83-9.
15. Moher D, Liberati A, Tetzlaff J, Altman DG, PRISMA. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. Ann Intern Med. 2009;151(4):264-9. doi: 10.1371/journal.pmed.1000097
16. Jovanovic B, Schwarzer G. The development of the grasp height effect as a measure of efficient action planning in children. J Exp Child Psychol. 2017;153:74-82. doi: 10.1016/j.jecp.2016.09.002
17. Jung W, Kahrsb BA, Lockman JJ. Manual action, fitting, and spatial planning: relating objects by young children. Cognition. 2016;134:128-39. doi: 10.1016/j.cognition.2014.09.004
18. Jongbloed-Pereboom M, Nijhuis-van der Sanden MWG, Saraber-Schiphorst N, Crajé C, Steenbergen B. Anticipatory action planning increases from 3 to 10 years of age in typically developing children. J Exp Child Psychol. 2013;114(2):295-305. doi: 10.1016/j.jecp.2012.08.008
19. Jovanovic B, Schwarzer G. Learning to grasp efficiently: the development of motor planning and the role of observational learning. Vision Res. 2011;51:945-54. doi: 10.1016/j.visres.2010.12.003
20. Weigelt M, Schack T. The development of end-state comfort planning in preschool children. J. Exp. Psychol. 2010;57(6):476-782. doi: 10.1027/1618-3169/a000059
21. McCarty ME, Clifton RK, Collard RR. Problem solving in infancy: the emergence of an action plan. Dev Psychol. 1999;35(4):1091-101. doi: 10.1037/0012-1649.35.4.1091
22. Hay L, Bard C, Ferrel C, Olivier I, Fleury M. Role of proprioceptive information in movement programming and control in 5–11 year-old children. Hum Mov Sci. 2005:24:139-54. doi: 10.1016/j.humov.2005.05.002
24. Adams ILJ, Ferguson GDF, Lust JML, Steenbergen B, Smits-Engelsman BCM. Action planning and position sense in children with developmental coordination disorder. Hum Mov Sci. 2016;46:196-208. doi: 10.1016/j.humov.2016.01.006
23. Janssen L, Steenbergen B. Typical and atypical (cerebral palsy) development of unimanual and bimanual grasp planning. Res Dev Disabil. 2011;32(3):963-71. doi: 10.1016/j.ridd.2011.02.002
25. Crajé C, Aarts P, Nijhuis-van der Sanden M, Steenbergen, B. Action planning in typically and atypically developing children (unilateral cerebral palsy). Res Dev Disabil. 2010;31(5):1039-46. doi: 10.1016/j.ridd.2010.04.007
26. van Swieten LM, Van Bergen E, Williams JHG, Wilson AD, Plumb MS, Kent SW, Mon-Williams MA. A test of motor (not executive) planning in developmental coordination disorder and autism. J Exp Psychol Hum Percept Perform. 2010;36(2):493-9. doi: 10.1037/a0017177
27. Smyth MM, Mason UC. Planning and execution of action in children with and without developmental coordination disorder. J Child Psychol Psychiatry. 1997;38(8):1023-37. doi: 10.1111/j.1469-7610.1997.tb01619.x
28. Hughes C. Brief report: planning problems in autism at the level of motor control. J Autism Dev Disord. 1996;26(1):99-107.