

Can size and rigidity of objects influence infant's proximal and distal adjustments of reaching?

Tamanho e rigidez dos objetos influenciam os ajustes proximais e distais do alcance de crianças?

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Abstract

Background: It has been found that objects influence the adjustments to reaching of breastfeeding infants, however, it has not been investigated whether these adjustments change in older infants. **Objectives:** The aim of this study was to determine whether the size and rigidity of objects influence the proximal and distal adjustments to reaching of infants of 6, 7, 8 and 36 months of age. **Methods:** Nine healthy infants were presented with: one large rigid, one small rigid, one large malleable and one small malleable object. The movements were videotaped and later analyzed qualitatively with regard to proximal (unimanual and bimanual reaching) and distal adjustments (horizontal, vertical and oblique hand orientation, opened, half-open and closed hand) and with regard to grasping of these objects (with and without). Friedman test and Dunn multiple comparisons were applied and 0.05 was considered as a significant difference. **Results:** Infants of 36 months of age performed more unimanual reaching than younger infants. Additionally, at all ages, unimanual reaching was particularly performed for small objects. At 36 months of age infants guided the hand horizontally to touch and grasp the objects, while at 6 and 7 months the hand orientation was oblique to touch and vertical to grasp the objects, regardless of the object's properties. Over the months, both at the beginning and at the end of reaching, the hands became more open, especially to touch the large rigid object, and infants increasingly performed reaching with successful grasping, especially for malleable or small objects. **Conclusions:** From 6 to 36 months of age, the reaching became more refined and the infants adjusted to the different properties of the objects which were observed through changes in the proximal and distal adjustments.

Key words: reach; manual adjustments; grasp environment; child; physical properties of objects.

Resumo

Contextualização: Objetos influenciam nos ajustes do alcance de lactentes, no entanto ainda não se investigou se esses ajustes se modificam em crianças com mais idade. **Objetivos:** Verificar se o tamanho e a rigidez dos objetos influenciam os ajustes proximais e distais do alcance dos 6 aos 8 meses e aos 36 meses de idade. **Métodos:** A nove crianças saudáveis foram apresentados: um objeto rígido grande, um rígido pequeno, um maleável grande e um maleável pequeno. Os alcances foram filmados e posteriormente analisados qualitativamente quanto aos ajustes proximais (alcance uni e bimanual) e distais (orientação da mão horizontalizada, verticalizada e oblíqua; mão aberta, semiaberta e fechada) e a apreensão desses objetos (com e sem). Foram aplicados o Teste de Friedman e as comparações múltiplas de Dunn, considerando-se 0,05 como diferença significativa. **Resultados:** Constatou-se que, aos 36 meses, houve mais alcances unimanuais do que nas idades anteriores e, em todas as idades, os alcances unimanuais foram realizados principalmente para os objetos pequenos. Aos 36 meses, as crianças orientaram a mão horizontalizada para tocar e apreender os objetos, enquanto que, aos 6 e 7 meses, a orientação foi oblíqua para tocar e verticalizada para apreendê-los, independentemente das propriedades dos objetos. No decorrer dos meses, tanto no início quanto no final do alcance, as mãos tornaram-se mais abertas, principalmente para tocar o objeto rígido grande, e as crianças realizaram cada vez mais alcances com apreensão, principalmente para os objetos maleáveis ou objetos pequenos. **Conclusões:** De 6 a 36 meses, os alcances tornaram-se mais refinados e ajustados às propriedades mais discrepantes dos objetos apresentados, o que se observou pelas modificações nos ajustes proximais e distais.

Palavras-chave: alcance; ajustes de mão; apreensão; ambiente; criança; propriedades físicas dos objetos.

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Introduction ◻◻◻

Physical properties of objects and the sensation that they cause play an important role in the configuration of motor actions¹⁻³, such as reach, touch and grasp. These actions, in turn, generate perceptual-motor experiences that involve vision and touch, and helps the understanding and knowledge of the environment. With these experiences, it is possible not only to perceive the environment, but also to know how to modify, anticipate and organize future actions when similar situations occur^{4,5}.

Specifically for reaching, studies have shown that age, especially due to the individuals' intrinsic properties (anthropometry such as size of hands, capacity of the motor, sensorial and cognitive systems) and their relationship with the environment, influence the acquisition time⁶, as well as the qualitative changes of arm movements towards the object. Authors have reported that the acquisition of reaching occurs around the 4th and 5th month of age⁷⁻¹³. After its acquisition, there is a refinement processes in both proximal adjustments (unimanual and bimanual reaching) and distal adjustments (hand orientation and opening of fingers) to make contact and grasp the object³. The proximal adjustments carried out by infants of 5-6 months are characterized by symmetrical and synergistical movements in both arms, due to their poor postural control¹⁴. From 8-9 months, these adjustments are characterized by asymmetrical and lateral movements, ie, they are capable of reaching small and large objects with either one or two hands^{2,15}. With regard to distal adjustments, Newell, Scully and McDonald² and Lockman, Ashmead and Bushnell¹⁶ verified that by the 4th and 5th months, infants adjust the positioning of hands when they touch the object, and around the 7th and 9th months, these adjustments are made in anticipation to touching the object.

Changes in proximal and distal adjustments of reaching in infants of 4-9 months of age have been explored in the literature. However, to understand the adaptability of infants, it is also necessary to manipulate the task conditions³.

There is some evidence that young infants, as the ones of 4-6 months of age, are capable of performing proximal and distal adjustments of movements to reaching towards objects of different properties^{2,3,15,17}. However, others studies demonstrate that the ability to effectively use visual and tactile information to plan and make proximal and distal adjustments occurs only around the 8th and 9th months^{4,18} or after the age of 11 and 12 months¹⁹. Thus, it is possible to infer that the differences in ages at which infants are able to make adjustments are due not only to the intrinsic capabilities, but also to the infant's relationship with the objects. Therefore, it is believed that the properties of the objects also offer opportunities in promoting variations

of actions, which characterizes the differences in the adaptive capacities. Based on this inference, as well as on the results of a previous study³ of infants of 4-6 months of age, in which adjustments before the size and rigidity of the objects were observed, there is motivation to investigate whether the same infants in subsequent ages (6-8 months and with 36 months) would continue using similar adjustments or would change their movement patterns.

Based on the theoretical perspective of Dynamical Systems¹², the behavior is self-organized and emerges from the confluence of many subsystems, including the infant's intrinsic properties and extrinsic factors, such as experience on the task and the objects to be manipulated⁴. It is believed that infants at 36 months of age perform proximal and distal adjustments of reaching depending on the physical properties of the objects, differently than they did at 6, 7 and 8 months of age. Such a statement is justified because in the course of months, infants practice diversified tasks and develop their perceptual-motor skills. This will favor more refined and adjusted reaching to the context given that changes occurred in many subsystems, such as improvement of postural control and of visual acuity during the infant's development, which may shift the behaviors to new or reorganized motor patterns¹². It is expected that infants at 36 months of age will not have differences in proximal and distal adjustments in relation to the size and rigidity of the objects due to the complexity of the relationship of the tasks with the properties of the objects and the infant's sensory-motor ability. At this age, infants can better control their movements to reaching as they have had a larger amount of practice and experience and therefore will not require a reorganization of the motor patterns to reaching the objects.

Thus, the assessment of reaching of the same infants at 36 months, the age in which they have complete domain of the motor skills of the upper limbs²⁰, will be important to demonstrate how the adaptability of movements occur while facing the same properties of the objects.

In view of the aforementioned, the aim of the present study was to verify the influence of objects of different sizes and rigidity on the proximal and distal adjustments of reaching of infant at 6, 7 and 8 months and at 36 months of age.

Methods ◻◻◻

Participants

Nine healthy infants were longitudinally assessed at ages of 6 months (M=6 months and 1 day; ± 3 days), 7 months (M=6 months and 28 days; ± 2 days) and 8 months (M=8 months and

2 days; ± 3 days), with tolerance of five days before or after the birthday date, and at 36 months of age ($M=36$ months and 18 days; ± 14 days). These infants had been assessed at 4, 5 and 6 months³ with the objective to verify if the adjustments would change in subsequent ages. This study was approved by the Ethical and Human Research Committee of the Universidade Federal de São Carlos (UFSCar), São Carlos, SP, Brazil (protocol n° 040/03) and the parents or caregivers of infants signed the informed consent term.

Materials and procedures

Infants were placed in a infant chair^{3,7,21} (Figure 1). Four objects were shown to them: a large rigid (LR), a small rigid (SR), a large malleable (LM) and a small malleable (SM)³, for a period of 1 min or until the child performed seven reaches^{3,22}. Intervals of 5 seconds were allowed after the presentation of each object and the total time of the procedure was of approximately 4 minutes and 25 seconds^{3,22}. The procedure was recorded by three digital cameras^{3,21,22}. These images were later opened in the Dvideow system²³ for qualitative analysis of the reaching (for additional information, see Rocha, Silva and Tudella^{3,22}).

System analysis

Continuous arm movements that were initiated and directed to the object which were concluded by the touch of the hand on the object were considered a reach. The initial position of the upper limb was not set, therefore it could have been moving, however not close to the object (path inferior to 10 frames)^{3,22}. When the infant showed no interest, cried, was irritable or was inattentive during the accomplishment of reaching, or when they started with the hand near to the object, the resultant reach was excluded from the analysis (for additional information, see Rocha, Silva and Tudella³).

Description of the dependent variables

Proximal adjustments: unimanual or bimanual reaching, according to the classification used by Rocha, Silva and Tudella³.

Distal adjustments: reaches according to the hand orientation (horizontal, vertical and oblique) and opening of fingers in relation to objects (opened, half-opened and closed hand), classified as described by Rocha, Silva and Tudella³.

Grasping: reaches accomplished with and without grasp. It was considered reaching with grasp when the child could take hold of the object or part of it with one or both hands. Reaching without grasp was determined by movements directed to the object, followed by touch; however, did not result in the infant taking hold of the object.

A study of interrater reliability (three observers) was carried out and showed a raw Correlation Index (CI) of 97.9%, for all variables.

Data analysis

The Levene test of Homogeneity of Variance ($p < 0.05$) and the Kolmogorov-Smirnov test ($p < 0.05$) were used for the analysis of reaching. It was observed that the data was not homogeneous or normal. Thus, the Friedman test was applied to verify differences among the factors age (6, 7, 8 and 36 months) and objects (LR, SR, LM and SM). When the differences between ages or between objects were significant, the data was analyzed using Dunn multiple comparisons. For all the analysis, a level of 0.05 was considered significant. The software SPSS 13.0 and Bioestat 4.0 were used for statistical analysis.

Results

Six hundred and fifty-six movements to reaching were analyzed. One hundred and sixty-seven reaches were for the LR object, 163 for the SR, 165 for the LM and 161 for the SM. Of the 656 movements, 174 were accomplished at 6 months, 160 at 7 months, 162 at 8 months and 160 at 36 months.

Proximal adjustments

There were significant differences between age groups in the reaches were performed unimanual versus bimanual ($F(3)=16.933$; $p=0.0007$) (Figure 2A). It was observed that at 7 ($p < 0.05$) and 8 ($p < 0.01$) months, infants performed more bimanual reaching than at 36 months.



Figure 1. Child placed on the infant chair to reaching.

Among the objects (Figure 2B), there were significant differences in the reaches performed unimanually or bimanually ($Fr(3)=31.043$; $p<0.0001$). It was verified that for the LR object, infants accomplished more bimanual reaching than for the SR object ($p<0.001$) and SM object ($p<0.01$) and that for the LM object, infants accomplished more bimanual reaching than for SR object ($p<0.01$).

Distal adjustments

Between the age groups (Figure 3A), there were significant differences in the moment of touching for the hand orientation: horizontal ($Fr(3)=13.088$; $p=0.0045$) and oblique ($Fr(3)=24.011$; $p<0.0001$). Infants at 6 ($p<0.05$) and 7 months ($p<0.05$) had less horizontal hand orientation than at 36 months and, therefore, at 6 ($p<0.001$) and 7 months ($p<0.001$) they performed more oblique hand orientation than at 36 months.

In regards to grasping the object, (Figure 3B) there were significant differences between the age groups for the vertical ($Fr(3)=21.756$; $p<0.0001$), horizontal ($Fr(3)=26.100$; $p<0.001$) and oblique hand orientations ($Fr(3)=14.084$; $p=0.0028$). The vertical hand orientation was most commonly observed at 7 months than at 8 ($p<0.01$) and 36 ($p<0.0001$) months. The horizontal

hand orientation was most commonly observed at 36 months than at 6 ($p<0.01$), 7 ($p<0.001$) and 8 months ($p<0.05$). The oblique hand orientation was more common at 8 months than at 36 months ($p<0.05$).

In relation to the objects, for both touching (Figure 3C) and grasping, (Figure 3D), there were no significant differences in hand orientation.

Regarding the opening of fingers at the beginning of movement, (Figure 4A), there were significant differences between age groups in the reaches accomplished with opened hand ($Fr(3)=29.866$; $p<0.0001$) and half-opened hand ($Fr(3)=37.089$; $p<0.0001$). Infants at 6 ($p<0.01$) and 7 ($p<0.001$) months started the movements with opened hand less frequently than at 36 months and at 8 months ($p<0.05$). At 6 and 7 months, infants started the movements with half-opened hand more frequently than at 8 ($p<0.05$) and 36 ($p<0.001$) months.

Regarding the opening of fingers at the end of movement, (Figure 4B) there were significant difference between age groups in relation to touching the objects with opened hand ($Fr(3)=36.794$; $p<0.0001$) and half-opened hand ($Fr(3)=36.794$; $p<0.0001$). Infants at 6 months ($p<0.01$) touched the objects with opened hand less frequently than at 36 months and, at 6 ($p<0.001$) and 7 ($p<0.01$), months infants touched the objects with opened hand less frequently than at 8 months. At 6 months, infants touched the objects with half-opened hand more frequently than at 8 ($p<0.001$) and 36 ($p<0.01$) months, and more frequently than at 7 than at 8 months ($p<0.01$).

In relation to the objects, there were no significant differences among opened hand, half-opened and closed hand at the beginning of movement (Figure 4C). At the end of movement (Figure 4D), there were significant difference in the touches with the opened hand ($Fr(3)=14.031$; $p=0.003$) and half-opened hand ($Fr(3)=14.135$; $p=0.003$). The LR object was touched more frequently with opened hand than the SM object ($p<0.05$) which, in turn, was touched more frequently with half-opened hand than the LR object.

Grasping

Between age groups (Figure 5A), there were significant differences in reaching with and without grasping the object ($Fr(3)=25.996$; $p<0.0001$). It was observed that infants at 36 months performed more reaches with grasping than at 7 months ($p<0.001$).

Among the objects (Figure 5B), there were significant differences in the reaches performed with and without grasping the object ($Fr(3)=20.850$; $p<0.0001$). The LM objects ($p<0.01$) and SM ($p<0.05$) were grasped more than the LR objects.

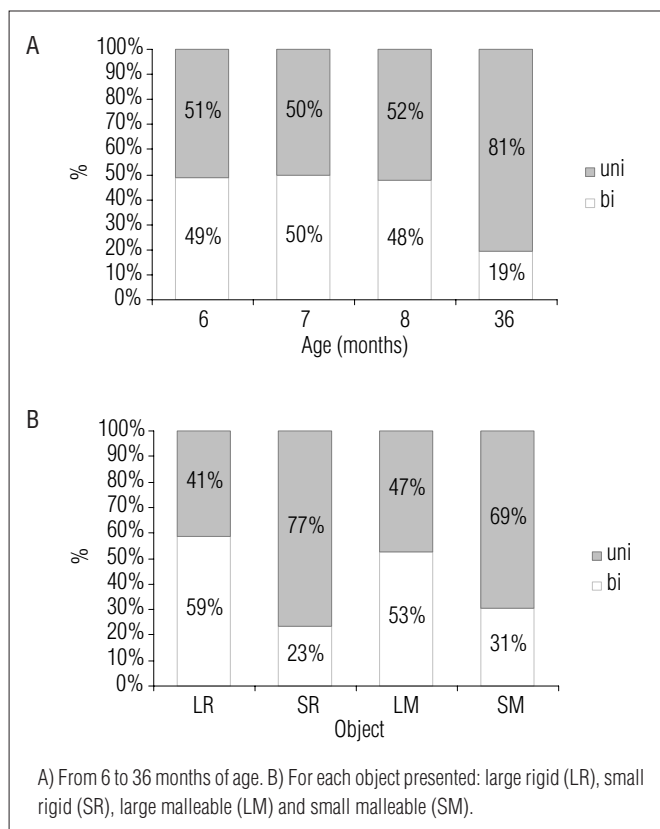


Figure 2. Percentage of unimanual and bimanual reaches performed by infants.

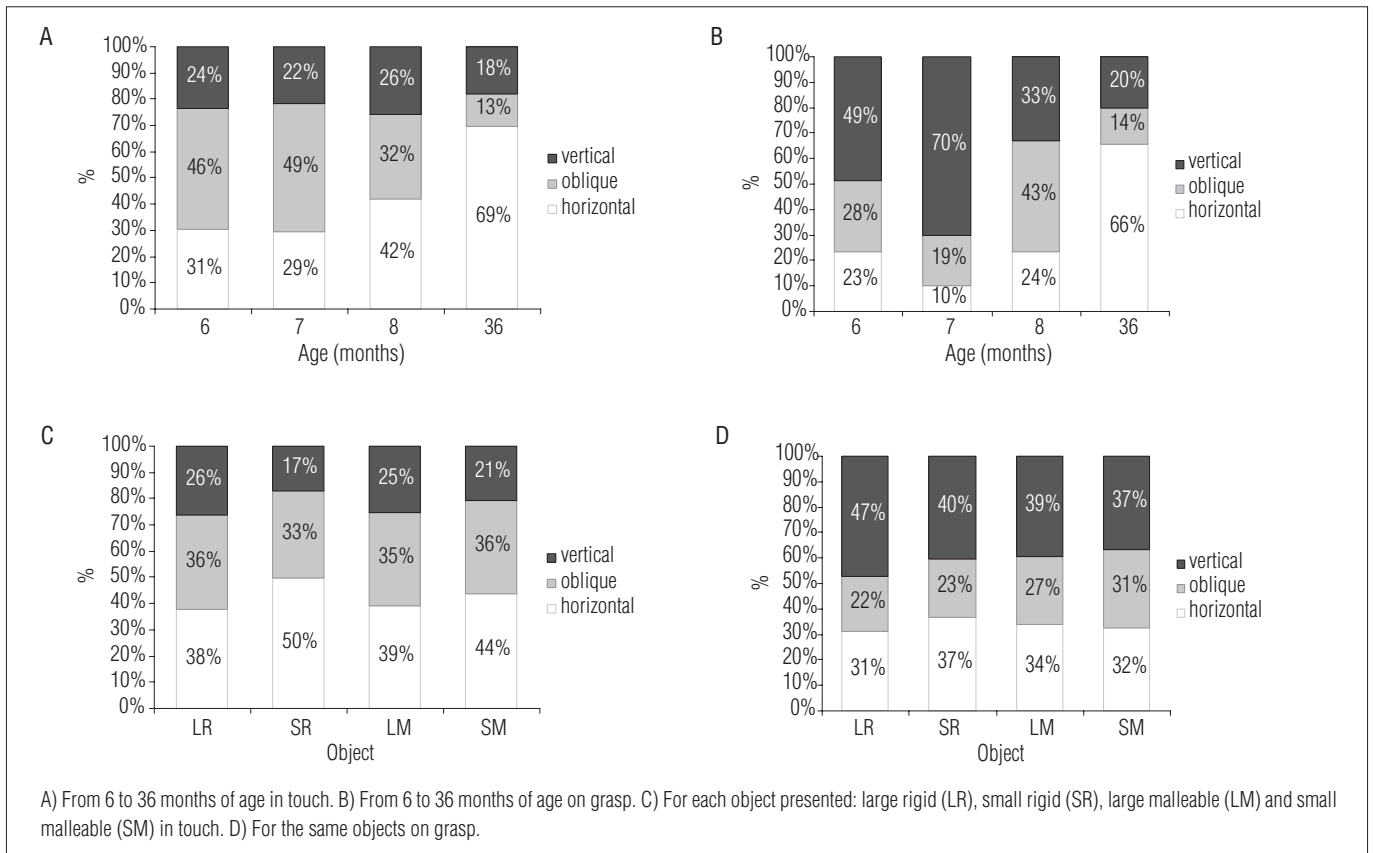


Figure 3. Percentage of reaches with horizontal, vertical and oblique hand orientation performed by infants.

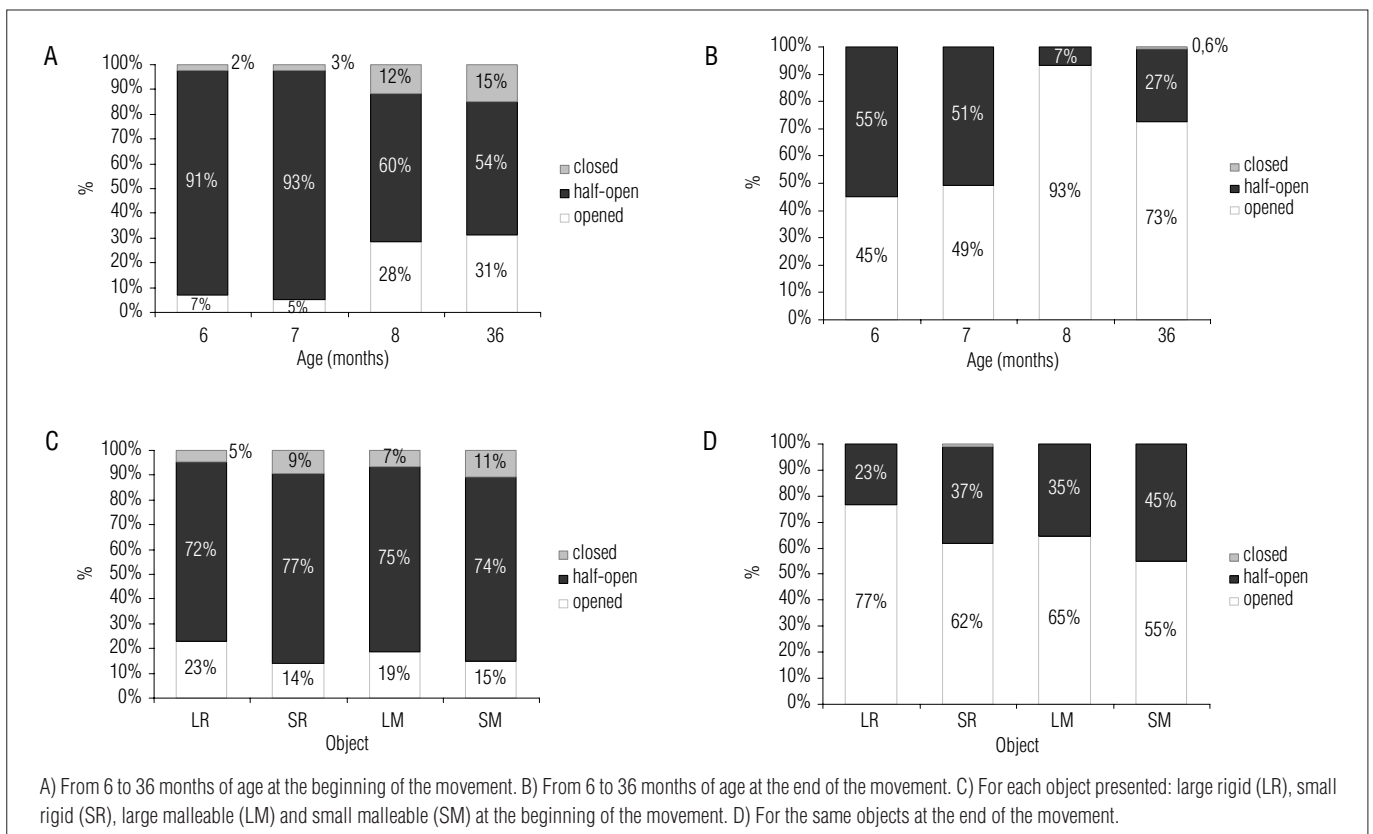


Figure 4. Percentage of reaches performed by infants with opened hand, half-open and closed hand.

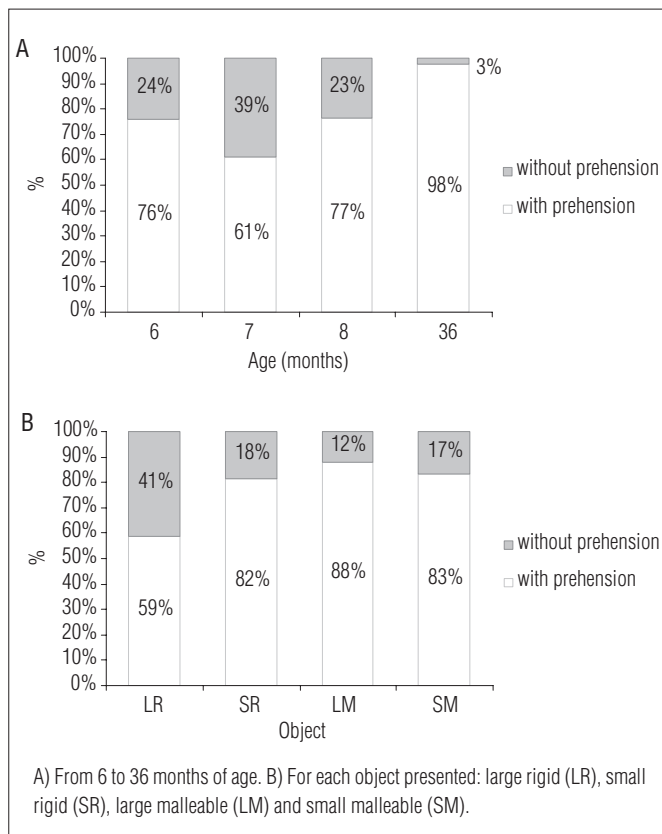


Figure 5. Percentage of reaches with and without grasping the object by infants.

Discussion

The results of the present study lead to two main conclusions regarding the proximal and distal adjustments to reaching of infants at 6-36 months of age: the size of objects is a more relevant than the rigidity for infants up to 8 months of age and that, at 36 months, infants show established and controlled reaching patterns towards different properties of objects.

Regarding proximal adjustments, for infants at 7-8 months, the size of the objects was more important than rigidity, given the accomplishment of more bimanual reaching for larger objects (LR and LM) and more unimanual reaching for smaller objects (SR and SM). In these ages, infant are still in a refinement process, exploring objects²⁴ and acquiring experiences in a variety of actions because at 36 months, as expected, they performed predominantly unimanual reaching, independently of the size and rigidity of the objects. At 36 months, it is suggested that infants are able to process the perceptual-motor information and to note that the objects are not sufficiently large in relation to the size of their hands to be bimanual apprehended. Therefore, it is suggested that infants selected the unimanual reaching based on their

experiences, changes in the biomechanics of the upper limb, postural control and the possible lateral domain that is establishing during this period. This leads them to perform the task with the most skilled member, which favors the grasping of the object with less energy expenditure, according to their biomechanical capabilities and intent on carrying out the task. A similar result was also observed by Corbetta, Thelen and Johnson⁴ and Rocha, Silva and Tudella³, reflecting the ability to perceive the affordances, meaning the capacity to perceive and adjust the relationship between environmental properties and properties of their own action system. Thus, the action system and the environmental conditions can be described in geometric variables, such as the size of object or body dimensions¹⁷.

The results of the present study showed that, with the refinement of the reach, there was an increase in complexity, adaptability and selectivity of the motor responses. Such inferences corroborate the study of Corbetta and Thelen²⁵, in which bimanual reaching are synchronous motor patterns, while unimanual reaching are asynchronous motor patterns, ie, more selective motor responses, which are present in infants with better postural and upper limbs control as demonstrated in this study for infants at 36 months of age.

In relation to the distal adjustments, it is suggested that at the ages of 6-7 months, infants maintained an anticipatory hand orientation determined by the sight of the object and the proprioception of the upper limb²⁶ during its displacement toward the object, as observed by Rocha, Silva and Tudella³. It is noteworthy that, in these ages, after the additional tactile information of the object, there was the need of a new adjustment of the hand orientation from oblique to vertical so that the child could grasp the object, independently of its physical properties. These results reaffirm the idea that, in this period, infants are in process of reaching refinement, because such strategy was not observed at 36 months of age, when infants touched and apprehended the objects with the same hand orientation. It is suggested that, at 36 months of age, infants did not need the additional tactile perception to apprehend the object. Additionally, in this age, infants had better control of movements and underwent extensive global development, ie, they acquired the sitting position without support, independent walk and started specialized manual tasks in different contexts, which favors the strategy of reaching. It is suggested that, at 36 months, the infant's intention was to take hold of the objects to throw them, which justifies the hold with horizontal hand orientation. It is important to detach that such movements were performed for spherical objects, perhaps, if cylindrical bars were showed, there could have been changes in the orientation of the object in the space and

consequently changes in the hand orientation, as observed by von Hofsten and Fazel-Zandy²⁷. This indicates that the information provided by the properties of objects associated to the infant's functional capacities determine differences in the adjusted action to the task.

Regarding the opening of fingers, at both beginning and end of movements, at 6-7 months, the hands were half-opened, while at 8 and 36 months, the hands were opened at the beginning and end of movement. Such results demonstrate that there was development of the distal control, since from 8 months, the distal adjustments occurred in anticipation to the touch of the object. The results corroborate the studies of Thelen, Corbetta and Spencer²⁸, Newell, Scully and McDonald² and Lockman, Ashmead and Bushnell¹⁶, von Hofsten and Rönnqvist¹⁰ and Fagard¹⁹, which affirmed that, between 9-10 months, the hand is actually opened in function to the object shown.

Moreover, the results of the present study demonstrated that the hand was more opened to touch the LR object than the SM object. This result was expected since, to grasp the LR object, a larger opening of the hand is needed. Jakobson and Goodale²⁹ and Rocha, Silva and Tudella³ also verified that larger objects favored the opening of the hand in infants as young as the ones at 4-6 months. Thus, it is suggested that, even with the organic changes, with the experience acquired in varied tasks, with the acquisition and improvement of gross motor skills and specific manipulations, older infants (6-36 months) continue using the same adjustments. Tsiotas, Borghi and Parisi³⁰ indicated that the relationship between the visual and motor systems sustain that an object tends to evoke its *affordances*, reactivates previous experiences and interactions with it. Thus, it is considered that the properties (rigid and large) of the objects showed in the present study can guide similar positioning adjustments of the fingers, independently of the infant's age, ie, their intrinsic conditions.

In relation to grasping, it was verified that, starting from 8 months, most of the reaching was carried out with grasping objects and that the malleable ones were more commonly grasped than the LR object. It is believed that, although there were organic changes in the course of aging, the physical

properties of the objects shown continued provoking similar adjustments as those demonstrated in the younger infant (4-6 months), as observed by Rocha, Silva and Tudella³. It is also believed that this result is due not only to the size, but also to the rigidity of the objects, as malleable objects facilitate the grasping, as well as small objects, even if they are rigid. Since the LR object was grasped the least, it is suggested that infants, by their perceptual-motor ability, prefer to hit it than to grasp it. Besides, in relation to the rigidity, it is suggested that infants prefer to hit the LR object and to grasp the LM object, because the action provoked on the LR is displacement, while on LM is deformation. So, hitting the LR is visually more attractive than the LM. These inferences were also observed by Eppler³¹, who verified that, around eight months of age, infants prefer to hit the rigid objects and to squeeze the malleable ones.

It is worth highlighting, although with limitation on the number of participants, three clinical implications of the results of this study. First, in intervention with infants with special needs with motor difficulties of bilateral integration of upper limbs for which the execution of bimanual reaching are sought, the intervention should be performed repeatedly, mainly for large objects, until the eighth month of age, the period in which bimanual reaches are performed. Second, if it is not possible to intervene before the eighth month, the size of the object must be greater than the large object of the present study (12.5cm of diameter) to favor more bimanual reaching. Third, to favor reaching with opened hand it is necessary to show rigid and large objects; because they encourage the use of this strategy for the object to be grasped.

Finally, the results of the present study demonstrated that the proximal and distal adjustments to reaching are influenced by the size (proximal adjustments and opening of hand) and rigidity (grasp) of the objects in the period of 6-36 months of age, which is comparable to the results of 4-6 months of age³. Thus, this reinforces the idea that for the visually guided activities to be successfully completed, infants should be able to identify the boundaries of action and then select the most efficient movement pattern based on the most important properties of the objects showed to them, leading to adjustments in the manual reaching.

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