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Adults' perception of children's height and reaching capability

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ABSTRACT

This study investigated the influence of some characteristics of the task, the model, and the observer, in the estimation errors of adults while judging children's affordances. One hundred and eighteen adults, divided in 4 height groups, estimated height and vertical reaching capability of 3 girls (3.55-, 4.74- and 7.06-years old), in the presence and in the absence of the model. Constant errors (CE) (estimation–real value), absolute percent errors (APE) ($|1-\text{estimation/real value}|\times 100$), and error tendency (underestimations, right judgments, or overestimations) were calculated. A model and a condition effect were verified on APE. APE for the younger model were greater than for the other models ($p<0.001$), and APE in the absence of the model were greater than in her presence ($p<0.05$). Generally, adults underestimated height (51.8% of underestimations vs. 32.3% of overestimations) and overestimated reachability (51.3% of overestimations vs. 37.7% of underestimations). The overestimation of reachability was more notorious for the younger model, which might reflect adults' difficulty to consider the specificity of younger children's body proportions. Actually, the overestimation bias may suggest that adults perceive young children as on the basis of adult's geometrical proportions.

1. Introduction

The visual estimation of other people's dimensions and capabilities is recurrent in daily life situations (e.g., height or weight estimation to buy clothes for children), and in many professional settings (e.g., height and weight estimation in intensive care units to adjust drugs dosage). Although people feel that perception is usually precise (Bridgeman & Hoover, 2008), studies suggest that the estimation of body dimensions (Bloomfield, Steel, MacLennan, & Noble, 2006; Hendershot, Robinson, Roland, Vaziri, Rizzo, & Fakhry, 2006), or movement boundaries of others (Fischer, 2003; Rochat, 1995) are often inaccurate.

The estimation of functional measures for other people may be framed in the broader question of the perception of affordances (Gibson, 1979), and more specifically the perception of other people's affordances (Mark, 2007; Rochat, 1995; Stoffregen, Gorday, Sheng, & Flynn, 1999). Gibson (1979) introduced the concept of affordance to describe the opportunities for action provided by the environment for an animal. Affordances are properties of the animal–environment system, since they represent a relation between the abilities of the animal and the features of the environment (Chemero, 2003; Stoffregen, 2003). To perceive an affordance means perceiving the environment in terms of one's action capabilities. Affordances perception might be related to one's dimensions in relation to a property of the environment (e.g., if an object is within our arm's reach we consider it "reachable"), this type of affordances has been called body-scaled affordances; or it might be related to one's behaviour in relation to the environment (e.g., if we can run fast enough to catch a fly ball we consider it "catchable"), this type of affordances has been called action-scaled affordances (Fajen, Riley, & Turvey, 2009). However, not all affordances fit neatly in one of these two categories, and some affordances, such as reaching by jumping are determined by one's dimensions and capabilities (Fajen et al., 2009).

One interesting feature is that the information that specifies affordances, mainly body-scaled affordances, is public, so it might be available not only to the actor but also to an observer. As Gibson points out, the assertion "I can put myself in your position" (Gibson, 1979, p.200) is not a mere figure of speech, meaning that an observer can perceive the information available to another person, without having to occupy his/her point of observation. The question of whether an observer can use this public information to perceive another person's affordances has already been addressed by previous studies (Mark, 2007; Rochat, 1995; Stoffregen et al., 1999). These studies focused on the perception of adults' affordances on several different tasks and suggested that observers are able to use an egocentric framework while evaluating their own action capabilities, shifting to an allocentric framework when evaluating other people's capabilities (Mark, 2007; Rochat, 1995; Stoffregen et al., 1999). Even though the information about affordances seems to be public and

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perceivable, it is not always accurate. Some studies report errors of approximately 10% (Stoffregen et al., 1999) in the perception of other adult's action capabilities.

Errors in the perception of other people's affordances depend on task conditions. Task conditions such as the observer's perspective during evaluation (Gabbard, Ammar, & Rodrigues, 2005; Wagman & Malek, 2008; Wraga, 1999), the viewing conditions (Shim, Hecht, Lee, Yook, & Kim, 2009), the postural and kinetic constraints during task performance (Gabbard, Cordova, & Lee, 2007; Wagman & Malek, 2007, 2009), the exploratory activity (Mark, Jiang, King, & Paasche, 1999), and the action capabilities of the observer during estimation (Ramenzoni, Riley, Shockley, & Davis, 2008a), play a fundamental role in the estimation accuracy and the nature of bias effects. Other task conditions, such as the nature of the variable to be estimated or the information that is available during estimation deserve further investigation.

Regarding the nature of the estimated variable, the estimation accuracy for direct linear body dimensions, like body height, is more accurate than the estimation of inference based characteristics, such as body weight (Bloomfield et al., 2006; Determann, Wolthuis, Spronk, Kuiper, Korevaar, & Vroom, 2007). The estimation of simple morpho-functional variables, such as reaching capability, seems to be more accurate than the estimation of functional active variables that involve actions of higher complexity, such as a reach-and-jump task (Pepping & Li, 2005). The estimation of morphological variables has been addressed in medical settings (Bloomfield et al., 2006; Determann et al., 2007), but not in the scope of affordances perception. The relationship between the estimation of simple morphological variables (e.g., height) and estimations of morpho-functional variables (e.g., reachability) has not been previously investigated.

The information available during estimation is another important task constraint. Stoffregen et al. (1999) using real life situations and artificial kinematic displays verified that observers could perceive affordances for other as long as the actor–environment relations that define those affordances were preserved. The experimental designs have generally considered the visual presence of the model whose dimensions or affordances were estimated. A study on the estimation of head size (Bianchi, Savardi, & Bertamini, 2008) concluded that when visual information is provided, the overestimation of one's own head or of another person's head is reduced. The estimation of other person's capabilities in the absence of the model has not been addressed by previous studies. However, it is an appealing problem since in the absence of the model the direct perceptual confrontation of the model with the environment is not possible, and observers will probably have to rely on an indirect process of perception, based on their visual memory of the model's dimensions.

The characteristics of the model are also important for the perception of other people's affordances. Studies on the perception of body dimensions of passive subjects in medical settings (Kahn, Oman, Rudkin, Anderson, & Sultani, 2007; Uesugi, Okada, Sakai, Nishina, Mikawa, & Shiga, 2002) suggest that the estimation errors for less familiar models are more likely to occur. The estimation errors of infants and children with a small physical size also to be more frequent and of a greater magnitude (Uesugi et al., 2002). Adult's estimates also become significantly less accurate in underweight and obese patients (Kahn et al., 2007). The existing literature provides some information concerning the estimation of body dimensions, but the perception of affordances is a different topic; the relationship between the perception of body dimensions and the perception of affordances that rely on physical characteristics has not been thoroughly discussed.

The adult's estimation of a child's limits of action is a common example of affordances' detection, since parents and caregivers share the responsibility to manage the environments the children move in. The role of parents and educators in the management of environmental conditions has been widely reported in the literature about child safety and prevention of childhood injuries (Morrongiello, 2005), and the anticipation of action possibilities of the children is an important part of this task. In what concerns reachability, a wrong judgement of whether an object is within vertical reach of a child, might lead adults to place dangerous objects in places accessible to children. A few studies have addressed the issue of adult's perception of children's reachability (Cordovil & Barreiros, 2009, 2008), indicating that adults with no experience dealing with children have a greater tendency to underestimate children's reachability (Cordovil & Barreiros, 2008), and that the youngest children's reachability seems to be more frequently overestimated (Cordovil & Barreiros, 2009). It is not clear if the overestimation of the youngest children's reachability is only valid for functional variables, or if it is a consequence of an overestimation of morphological variables, such as height, because height estimations have not been considered in those investigations.

The height of the observer is an individual constraint that should also be taken into consideration. The relationship between other people's affordances and the viewing perspective of the observer was previously investigated in a study of vertical reaching perception for one's self and for others (Ramenzoni, Riley, Shockley, & Davis, 2008b). The results suggested that eye-height scaled optical information was used to evaluate affordances for others, and that taller observers exhibited larger errors when estimating the affordances for shorter models.

This study aims to analyze the influence of: the type of variable to be evaluated (i.e., morphological or morpho-functional); the condition of evaluation (i.e., present or absent); and the model's and observer's dimensions in the adults' estimations of children's height and reaching capability. Concerning the observer's accuracy, we expected that: a) the estimation errors for reachability would be greater than for height; b) the estimation errors in the absent condition would be greater than in the present condition; c) the estimation errors would be greater for the youngest and shortest model (child 1), and would be smaller for the eldest and tallest model (child 3); d) shorter adults' estimations would be more accurate than taller adults' estimations.

2. Method

2.1. Participants

One hundred and eighteen adults (60 males and 58 females), with ages between 18.20 years and 40.07 years ($M=23.21$, $SD=5.23$), heights between 150 cm and 198 cm ($M=171.9$, $SD=9.05$), and with normal or corrected-to-normal vision, participated in this study as observers. Participants were divided into four groups according to their height: group 1 — participants with heights between 150 and 165 cm ($N=32$; $M=161.22$, $SD=3.73$); group 2 — participants with heights between 166 and 171 cm ($N=29$; $M=169.21$, $SD=1.42$); group 3 — participants with heights between 172 and 179 cm ($N=29$; $M=174.52$, $SD=2.54$); and group 4 — participants with heights between 180 and 198 cm ($N=28$; $M=184.29$, $SD=4.56$).

Previously to the data collection informed consent from the parents of the children and the observers that participated in the study were obtained.

2.2. Models

The models were three girls between 3 and 7 years old. The anthropometric and functional characteristics of the models are presented in Table 1.

The older model was 30% taller than the younger, with an identical variation of the maximum reachability. The ratio of sitting height to stature, which is a good indicator of the children's body proportions

Table 1
Anthropometric and functional characteristics of the models.

Child	Age (yrs)	Stature (cm)	Sitting height (cm)	Arm span (cm)	Maximum reachability (cm)
1	3.55	92	52	91	117.8
2	4.74	113.5	59.5	110	146.6
3	7.06	121	64	115	156.2

(Bogin & Varela-Silva, 2010), was 56.52% in child 1, 52.42% in child 2 and 52.89% in child 3, indicating that child 1 was the most disproportionate when compared to adults, a natural consequence of her age.

2.3. Apparatus

A shelf that could be raised or lowered in 1.6 cm intervals (from 25 cm to 188.2 cm) was placed in a well-illuminated room. A cylindrical toy (diameter — 3.5 cm; height — 6 cm) was placed on the shelf, and observers stood 6 m away from it. During observers' estimations the shelf was at the minimum height (i.e., 25 cm). The observers were instructed to mark with an erasable pen, on an aluminium beam behind them, the estimated height and maximum reachability of each child, in the presence and in the absence of the model.

2.4. Procedures

Height and maximum vertical reachability were determined for each model. Maximum vertical reachability was defined as the greatest height at which the model could take the toy out of the shelf, being allowed to stand on tip-toes and touch the shelf, but not to climb or jump to complete the task. To determine a maximum vertical reachability for each model, the shelf was adjusted starting from the vertical distance of the model with her arm extended, being raised 1.6 cm after each successful attempt and lowered 1.6 cm after each failure.

After filling in an individual form (indicating gender, birth date and height), observers were conducted to the experimental room. The model entered the room, stood near the shelf with her arms at the sides, and turned around for approximately 8 s so that the observer could see her walking and standing from the front, from behind and from both sides. The observers were instructed to look at the model, maintaining their standing position, and mark her height and maximum vertical reachability in that specific situation, as previously defined (i.e., they were informed that the child was allowed to stand on tip-toes and touch the shelf, but not to climb or jump to reach the toy). Each model was judged under two conditions: present and absent. In the present condition, the observer marked the model's height and maximum vertical reachability with the model still standing 50 cm aside the shelf. In the absent condition, the model left the room before the evaluation moment, and the observers were allowed to register their estimations 5 s after losing visual contact with the model. The marks on the aluminium beam were erased after each height and reachability estimation. Every observer evaluated all the 3 models' height and reaching capability in both conditions. The order of presentation of the models and of the conditions (i.e., present and absent) was randomized.

2.5. Data collection and analysis

Constant errors (CE) (estimation–actual measure), absolute percent errors (APE) ($|1-\text{estimation/actual measure}|\times 100$), and error tendency (i.e., frequency of underestimations, accurate estimations, or overestimations) were calculated. Constant error is a signed error, negative values expressing underestimations and positive values expressing overestimations. The analysis of the group's CE gives an indication of the overall bias. Absolute percent error (APE) is the amount of error in percentage of the real reachability of the model. This variable is a good indicator of perceivers' accuracy since, it is scaled to the model, and as it is expressed in absolute value, underestimations do not compensate overestimations when considering the mean group's value. Smaller values of APE indicate a greater perceiver's accuracy. For the calculation of error tendency, estimations were considered accurate if estimation error was equal to or less than 1.6 cm (i.e., the minimal interval between two possible heights of the shelf). Estimation errors greater than that value were considered underestimations (estimation–real value < -1.6 cm) or overestimations (estimation–real value > 1.6 cm).

A repeated measures ANOVA was conducted for the data analysis of perceivers' accuracy (APE). Model (3 levels), type of variable (2 levels), and condition (2 levels) were entered as within-subjects variables; and the observer's height group (4 levels) was entered as a between-subjects factor. Bonferroni's post hoc tests were applied when necessary. The Greenhouse–Geisser correction was used in case of violations of sphericity. Descriptive statistics of CE and APE were presented and frequency distributions and chi-squares tests (χ^2) were adopted to analyze error tendency. Statistical significance was set at $p<0.05$ level.

3. Results

3.1. Constant error

Constant error, which represents the group's overall accuracy and bias varied between −38.00 cm and 43.20 cm ($M=-0.0005$, $SD=10.50$). Results of CE for height and for reachability according to model and condition are presented in Fig. 1.

Mean values of CE in Fig. 1 should be analyzed with caution since they represent the overall group's accuracy. A CE of about 0 cm, as it happened in the height estimations of child 1 in present condition ($M=0.07$, $SD=8.22$), does not mean the perceivers were accurate, as it is confirmed by the standard deviation value. In this case what probably happened was that the percentage of observers that underestimated the height of child 1 was similar to the percentage that overestimated it, and the magnitude of the overestimations and the underestimations was probably also similar.

3.2. Absolute percent error

Absolute percent error, which represents perceivers' accuracy, varied between 0% and 36.7% ($M=6.68\%$, $SD=5.36$). Results of APE according to child, type of variable and condition are depicted in Fig. 2.

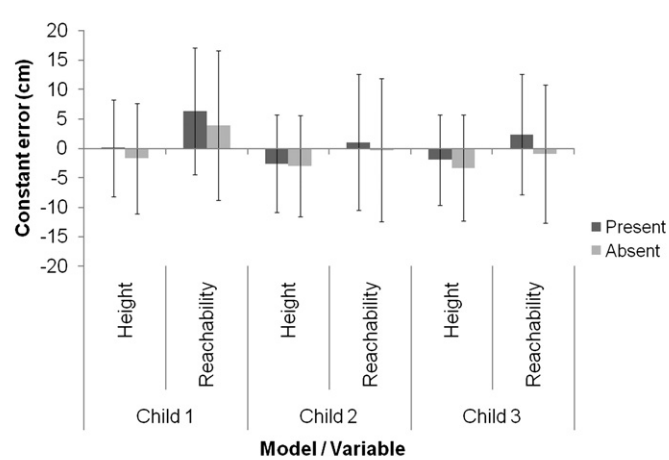

Fig. 1. Mean constant errors for height and reachability of each model, in present and absent conditions. Error bars indicate standard deviations.

The repeated measures ANOVA revealed significant main effects of child ($F(2, 195)=21.324$, $p<0.001$, $\eta^2_p=0.158$) and condition ($F(1, 114)=5.870$, $p=0.017$, $\eta^2_p=0.049$).

Bonferroni's post hoc results indicated that APE for child 1 ($M=8.14$, $SD=6.30$) was significantly greater than for child 2 ($M=6.32$, $SD=4.80$) ($p<0.001$) and than for child 3 ($M=5.58$, $SD=4.50$) ($p<0.001$). APE for child 2 was greater than for child 3, but results just failed to reach significance ($p=0.057$). APE in the absent condition ($M=7.04$, $SD=5.57$) was greater than in the present condition ($M=6.33$, $SD=5.13$) ($p=0.018$).

The effect of type of variable ($F(1, 117)=1.41$, $p=0.237$, $\eta^2_p=0.012$) and all the interactions were not significant. Observer's height group did not influence APE ($F(3, 114)=1.717$, $p=0.167$, $\eta^2_p=0.043$).

3.3. Error tendency

Error tendency for height was significantly different than error tendency for reachability ($\chi^2(2)=52.19$, $p<0.001$). Height was generally underestimated (51.8% of underestimations, 15.8% of accurate estimations and 32.3% of overestimations) and reachability was generally overestimated (37.7% of underestimations, 11.0% of accurate estimations and 51.3% of overestimations).

The condition of evaluation also influenced error tendency ($\chi^2(2)=10.67$, $p=0.005$). There were more overestimations in the present condition than in the absent condition (present condition: 40.5% of underestimations, 15.0% of accurate estimations and 44.5% of overestimations; absent condition: 49.0% of underestimations, 11.9% of accurate estimations and 39.1% of overestimations).

Results of error tendency for the height and reachability of each model in present and absent conditions are depicted in Fig. 3.

Error tendency for judging height was similar for the 3 models (i.e., a greater percentage of underestimations, even though that tendency is not clear for the height of child 1 in the present condition). Reachability was generally overestimated, except for the estimations of models 2 and 3 in the absent condition, where an underestimation tendency occurred. There was a notorious tendency to overestimate the reachability of the shorter model, in both conditions.

The relationship between height and reachability and between the prediction of height and of reachability is presented in Table 2.

Data from Table 2 emphasizes the adults' tendency to overestimate children's reachability, especially for the smallest child. Although child 1 could only reach 25.8 cm (i.e., plus 28%) above her height, adults' mean predictions varied between 31.37 cm in the absent condition and 32.04 cm in the present condition, which represent an increase of 35% of her height. The differences between real and estimated values tended to decrease as the height of the child increased and as the child's proportions became more similar to the adult's.

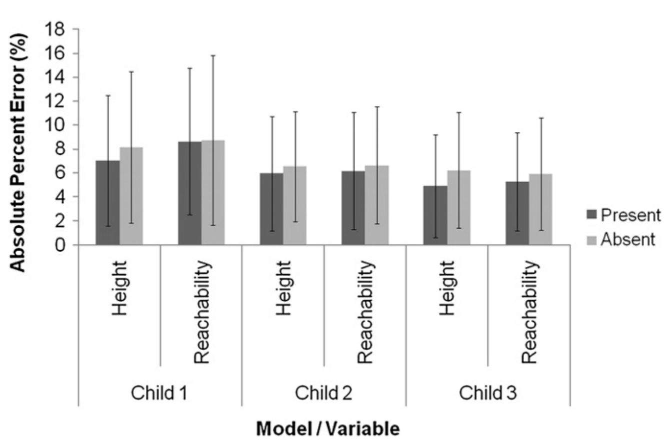

Fig. 2. Mean absolute percent errors for height and reachability of each model, in present and absent conditions. Error bars indicate standard deviations.

4. Discussion

The results of observer's accuracy (depicted by APE) in our study showed that participants were generally capable of perceiving children's action capabilities, confirming that information about affordances for other people is public (Gibson, 1979) and perceivable (Mark, 2007; Stoffregen et al., 1999), even when people evaluate models with physical dimensions and action capabilities quite distinct from their own.

However, as we hypothesised, adult's accuracy in predicting children's dimensions and capabilities depends on some task constraints and on the dimensions of the model.

Contrary to our initial expectations estimation errors for reachability were not significantly greater than for height. Previous studies indicated that morpho-functional variables were easier to predict than functional active variables of higher complexity, such as a reach-and-jump task (Pepping & Li, 2005). The comparison between estimations of simple morphological variables, such as height, and estimations of simple morpho-functional variables, such as reaching without jumping, had not been previously studied. The results of the present study indicate that adult's are equally accurate in predicting these two types of variables, probably because reaching without jumping is a clearly body-scaled affordance, which implies that most of the information that specifies the reaching affordance is available for the observer when he/she looks at the child and at the shelf. Even though there were no differences in absolute percent errors for height and reachability estimations, error tendency was clearly different, since height was generally underestimated while reachability was generally overestimated. These opposite tendencies were also noticeable in the results of CE. Overestimation of reachability has been reported in previous literature (Carello, Grosofsky, Reichel, Solomon, & Turvey, 1989; Fischer, 2003, 2005; Gabbard, Cacola, & Cordova, 2008; Pepping & Li, 2000; Rochat & Wraga, 1997). Results of this study indicate that, when estimating children's capabilities, this bias is probably related to an overestimation of the model's arm, and not related to a general overestimation of the model's dimensions, because height was generally underestimated. To our understanding, the more frequent overestimation of reachability might reveal an inability to consider children's specific body proportions when evaluating functional measures. The ratio reachability/height is smaller in children than in adults. The adults' tendency to overestimate this ratio, considering children's arms to be longer than they actually are, might be described in Leonardo da Vinci's words: "For this is reckoned a common fault in painters, to delight in the imitation of themselves" (da Vinci, 1651/2002, p. 185).

As hypothesised, and despite the small value of the effect size, estimation errors in the absent condition were greater than in the present condition. These results support the idea that affordances' estimation is easier when the relevant actor–environment relations are preserved (Stoffregen et al., 1999), and is an argument in favor of Gibson's theory of direct perception. When observers had to rely on their visual memory of the model's dimensions (i.e., absent condition), their perception was less accurate than when they could directly perceive the actor–environment relationship (i.e, present condition). Theoretically, these results do not exclude the possible indirect perception alternative approach. The reduced accuracy that was observed in the absent condition might be explained by arguing that memory reconstruction processes are not as accurate as the direct estimation of children's dimensions. Error tendency was also affected by the estimation condition. Overestimations were greater in the present condition as reported by previous literature (Bianchi et al., 2008). In the absent condition most adults underestimated the reachability of models 2 and 3. This underestimation tendency might

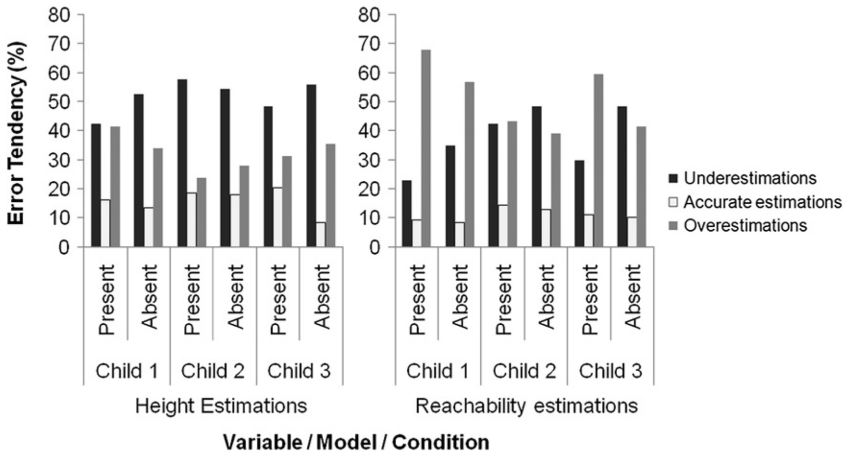

Fig. 3. Error tendency for the height estimations (left) and for the reachability estimations (right) of each model in present and absent conditions.

be a problem in terms of child safety, since adults might place dangerous objects at what they consider to be unreachable heights for children, which are actually reachable.

Concerning the dimensions of the model, we had predicted that estimation errors would be greater for the child 1 and smaller child 3. In fact, the APE for height and for reachability seemed to decrease with the height of the model. The main effect of child also had a small effect size. However, values of APE for the shorter model were significantly greater than for the taller children. APE values for the taller model were also smaller than for child 2 but they failed to reach significance ($p = 0.057$). The differences in APE between child 2 and child 3 might have not been as notorious as the differences between child 1 and the other models due to the children's dimensions. In fact, differences in height and range of reach were about three times greater between model 1 and 2 as compared to model 2 and 3. This might be considered a limitation of the present study. Previous studies on the perception of body dimensions (Kahn et al., 2007; Uesugi et al., 2002) referred that the estimation accuracy diminishes when judging atypical models. In this study, adults were more precise when evaluating the taller children, which might indicate that their judgment is based on an internal reference to evaluate other people's affordances.

A previous study with the same vertical reachability task performed by adults (Cordovil & Barreiros, 2009) revealed that an average adult of 166.1 cm has a reachability of 218.5 cm, being able to reach objects 52.4 cm above his/her height (on tip-toes but without climbing or jumping). The corresponding value for child 1 in this study was about 25.8 cm, which is half of the observed value for an average adult. These data reflect the differential growth rates of specific body parts that result in changes in the body's appearance as a whole. Therefore, children have different proportions from adults, with larger heads and shorter limbs relatively to their body size. The tendency to overestimate younger children's reachability might reflect a difficulty for the adults to consider children's inherent body proportions, considering them as “small adults” based on a proportional frame of reference for adults. Perceptual re-scaling of children may be based upon an adult's body proportions model. This adult-like model was also noticeable in the first paintings of children: “When Christ first appeared in painting as an infant the posture and body-scaled proportions are more adult-like” (Fogel, 2004, p. 737).

The proportionality hypothesis is probably part of the explanation for the least accurate estimations when evaluating the younger model. However, other explanations, such as the sheer difference in height between the 3 models, might also have influenced the adults' estimations. During growth height and reachability co-vary, and for that reason it is nearly impossible to determine whether estimation errors are a function of absolute height or of body proportions. This issue could be further explored in future studies, maybe in virtual environments, where the manipulation of human proportions does not have to reflect natural biological limitations of living organisms.

Finally, in what concerns the observer's dimensions our initial hypothesis was not verified since shorter adults were not more accurate than taller adults when predicting children's height and reachability. The fact that the observer's height had no effect in APE contradicts some results of the previous literature (Ramenzoni et al., 2008b). However, the height differences between observers and models in Ramenzoni et al.'s study were not as notorious as in the present study since both models and observers were adults. The great discrepancy between the adults' and the children's heights seems to have equally affected shorter and taller adults in our study. Other individual constraints, such as the observer's experience in dealing with children (Cordovil & Barreiros, 2008) seem to have a greater influence in the observer's accuracy than the observer's height.

The evaluation of children's action capabilities by adults is of fundamental importance and has received little attention so far. Our study indicates that some constraints, such as the characteristics of the model or the evaluation conditions, might be essential when adults organize the environments where children move in.

Table 2
Real values and mean and standard deviations of reachability–height (R–H) estimations, for the 3 models, in present and absent conditions.

Model	Condition	R–H (cm)	
		Estimation *M* (*SD*)	Real value
Child 1	Present	32.04 (7.86)	25.8
	Absent	31.37 (8.40)	
Child 2	Present	36.69 (8.83)	33.1
	Absent	35.83 (9.08)	
Child 3	Present	39.49 (8.24)	35.2
	Absent	37.57 (9.56)	

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