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Perceiving children's affordances: Recalibrating estimation following single-trial observation of three different tasks

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A B S T R A C T

The adults' ability to perceive affordances for children was investigated in three different tasks. Forty adults made two estimations of the maximum reachability of a 5-year-old boy from a standing position, during a reach-and-jump task and in making a maximum step. A laser light point was displayed on a wall for the estimations of the standing reach and reach-and-jump tasks, or on the floor for the estimations of the step length task. The participants in the experimental group observed the child performing the task between a first and a second estimation, but the participants in the control group did not. In general, the observers were less accurate in estimating the child's maximum step length than in the other tasks. The observation of a single trial was enough to adjust perceivers' estimations, reducing error magnitude to about 50% of the initial error, but only in tasks with a poor first estimation. An absolute error of 5 cm persisted after one-trial observation. The magnitude of the adjustment in the estimation of affordances for others is task-dependent, and is more pronounced in tasks that imply greater action scaling than in tasks that require direct body scaling.

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1. Introduction

The ability to perceive children's capabilities and limits for action is fundamental to help secure their safe development. Caregivers must be able to perceive the child's possibilities for action in different environments in order to adjust their supervising strategies and to structure the environment in a safe way. For example, parents must know their children's gait velocity to assist them in crossing the crosswalk safely, and must know their children's reaching limits to avoid leaving dangerous objects (e.g., hot cookware) accessible to them. Adults recalibrate their estimations about what a child can and cannot do following a single observation. Parents and educators do it after occasional observation in daily life situations such as helping to reach inaccessible objects, giving support to help climbing a stair, and many other common situations (Heft, 1988).

The perception of the possibilities for action in a given environment is known as the perception of affordances (Gibson, 1979). Affordances are invariant properties of the environment taken with reference to the individual, and are determines by the fit between the properties of the environment and the action capabilities of the actor (Turvey, 1992). The characteristics of the environment offer different things to different actors, resulting in specific individual perception of possibilities for action. The affordances in a given environment for a child are frequently very different of the affordances of that same environment for an adult: an object that is within arm's reach for an adult might be unreachable for a child, but it might be reachable for another child that can climb on a chair. Children's body dimensions and motor competence influence the way they perceive and act in the world (Adolph, 1997).

Affordances for others can be perceived by an observer because they are specified by public information that is available not only to the actor but also to other people (Mark, 2007). However, the discrepancy between body dimensions and motor behavior of children and adults makes the perception of children's action capabilities an important challenge for adults.

The debate about adult's perception of children's affordances is quite recent in the literature (Chang, Wade, & Stoffregen, 2009; Cordovil & Barreiros, 2010a,2010b, 2011; Cordovil, Santos, & Barreiros, 2012). Studies on the perception of affordances for the child-adult dyad (Chang et al., 2009), and on the perception of affordances for children (e.g., Cordovil & Barreiros, 2010a; Cordovil, Santos, & Barreiros, 2012) indicated that even though the information about children's affordances seems to be available and detectable, its perception is not always accurate. The characteristics of the child, the nature of the task, environmental singularities, and the characteristics of the observer may be responsible for some variation in the accuracy of the estimation. For example, younger children's affordances are more difficult to estimate than older children's affordances (Cordovil & Barreiros, 2010a, 2011), and the experience in dealing with children seems to improve the accuracy of the estimation of reachability (Cordovil & Barreiros, 2010b; Cordovil et al., 2012).

The increased accuracy in judging affordances implies devoting more attention to relevant cues in the environment. This process involves different timescales and it has been referred to as education of attention (Gibson, 1979) or attunement (Fajen & Devaney, 2006; Wagman, Shockley, Riley, & Turvey, 2001; Weast, Shockley, & Riley, 2011). The improvement of the perception of affordances is achieved through practice, and the effects of practice are facilitated by feedback information (Wagman et al., 2001). Besides being attuned to the relevant cues, observers need to be correctly scaled to the detected information, which is a process of calibration (Bingham & Pagano, 1998; Fajen, Riley, & Turvey, 2009; Jacobs & Michaels, 2006; Mark, 1987; Mark, Balliett, Craver, Douglas, & Fox, 1990; Withagen & Michaels, 2005). Mark (1987) showed that observers were able to calibrate specific accurate action boundaries, under conditions of artificially changed body dimensions, following a very small amount of practice. Action is crucial for the perceptual tuning of actor and environment, but it is possible that a minimal amount of practice is enough to calibrate the perception of the affordances for others.

Furthermore, the amount of practice might be dependent on the nature of the task to be perceived and the magnitude and direction of perceptual error. Some affordances may be more difficult to predict than others. The estimation of functional simple variables, such as reaching capability, is more precise than the estimation of functional active variables that involve actions of higher complexity, such as a reach-and-jump task (Pepping & Li, 2005; Ramenzoni, Riley, Davis, Shockley, & Armstrong, 2008).

Two major types of affordances have been studied in previous literature: body-scaled and action-scaled (Fajen et al., 2009). In body-scaled affordances the individual's dimensions in relation to a property of the environment determine whether an action is possible (e.g., if an object is within our arm's reach we consider it "reachable"). In action-scaled affordances it is one's behavior in relation to the environment that determines whether an action is possible (e.g., if we can run fast enough to catch a fly ball we consider it "catchable"). Some affordances do not fit neatly into one of these two categories. For instance, maximum reach-and-jump and maximum step length are determined by one's dimensions and capabilities. When considering the evaluation of other person's affordances, body-scaled affordances seem easy to predict because they can be estimated based on the actor's dimensions, which are visible to the observer. On the other hand, action-scaled affordances pose an extra challenge since the actor's capabilities are not directly visible to the observer and have to be inferred based on other types of information, such as the actor's proportions and other morphological characteristics. However, practice seems to improve the perception of affordances for others even in action-scaled tasks (Weast et al., 2011). The perception of the affordances of others implies that the actor is perceived in relation to his/her physical body dimensions and as a functional agent.

In this study the adult's perception of a child's affordances was investigated, in a standing reach task, a reach-and-jump task, and a step length task. The effect of one-trial observation was analyzed in the three tasks. We hypothesized that (1) observers would be more accurate in predicting body-scaled affordances (i.e., the child's standing reachability) than affordances dependent on action and body-scale (i.e., the child's reach-and-jump and step length) since information for the later is not directly available but has to be inferred, and (2) that after one trial observation the perceivers' accuracy would increase in the three tasks.

2. Methods

2.1. Participants

Forty adults (19 males and 21 females) between 18- and 28-years-old ($M = 21.47$ yrs, $SD = 2.49$) and with normal or corrected-to-normal vision, participated in this study as observers. Participants were randomly assigned to the experimental ($n = 20$; 10 males and 10 females) or control ($n = 20$; 9 males and 11 females) groups. Ethical approval was obtained for the study and all participants provided informed consent.

2.2. Model

One boy, 5.74-years-old, with a standing reachability of 140 cm, a reach-and-jump reachability that varied between 156 and 162 cm ($M = 160.12$, $SD = 1.40$), and a step length that varied between 61 and 82 cm ($M = 73.20$, $SD = 5.14$).

2.3. Procedure

Maximum standing reachability was defined as the greatest height at which the child's tip of the middle finger would touch the wall by a frontal one-arm overhead reach with both heels on the ground. Maximum jump-and-reach reachability was defined as the greatest height at which the child's tip of the middle finger would touch the wall by a jump up with a frontal one-arm overhead reach. Maximum step length was defined as the greatest distance at which the child's heel would touch the ground in a step that would afford continuing walking.

Estimations for the vertical reaching tasks were made with participants (one at a time) standing at their own foot's distance from the wall, next to the child (who stood at his foot's distance from the wall). For the step length task, participants stood side-by-side with the children. Participants made estimations about how high the child could reach a laser light point that was displayed on a wall for the standing reach and reach-and-jump tasks, or on the floor for the step length task (see Fig. 1).

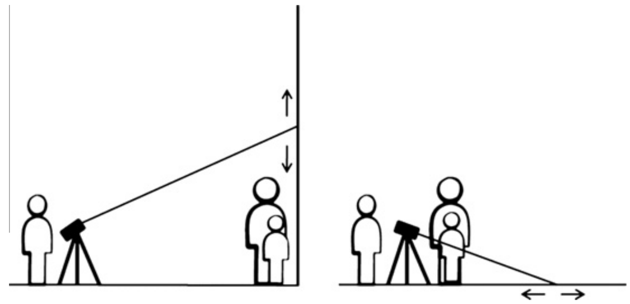

Fig. 1. Illustration of the display for the estimations of the child's standing reach and reach-and-jump tasks (left), and for the estimation of the child's step length task (right). A point light created by a laser pointer attached to an adjustable tripod was moved (up or down/forward or back) for the reachability estimations.

The light point was created by a laser pointer attached to an adjustable tripod in such a way that one of the experimenters could easily heighten it (i.e., move it up in the vertical reaching tasks and move it forward in the step length task) or lower it (i.e., move it down in the vertical reaching tasks and move it back in the step length task). The experimenter would raise or lower the point light until the participant told her to stop. The ascending/descending order was counterbalanced over all participants and they were allowed to adjust their responses until satisfied. The mean value between the ascending and the descending estimations was considered for analysis. The participants kept their eyes closed during the measurement of estimation error. The wall that the participants were facing in the standing reach and jump-and-reach tasks, and the floor and walls in the step length task, were covered with homogeneous white paper to remove any visual references on the surface.

After the estimations the child's tip of the middle finger or the child's tennis shoe's heel were painted with ink and the real values of reachability for each task were determined. For the reach-and-jump and for the step length tasks, the child was instructed to perform the task twice and the highest value was taken into consideration in the analysis. After each measure the marks were erased from the plastic paper so that no visual cues were left for the next estimation (i.e., estimation after the trial). Participants in the experimental group were allowed to look at the child's action and at the marks the child made on the wall or on the floor before they were erased. After the trial, participants were asked to indicate how high or how far the child had reached in each task. Participants in the control group also estimated the child's affordances twice, but were not allowed to observe the child's actions or marks between observations. Task order was counterbalanced among participants. In total, the experiment took approximately 15 minutes for each participant, and the data were collected on four different days so that it was possible to keep the child motivated.

2.4. Data collection and analysis

Absolute percent errors (APE) ($|1\text{-estimation/actual measure}| \times 100$), and error tendency (i.e., frequency of underestimations, accurate judgments, and overestimations) were calculated. Absolute percent error is the amount of error expressed as percentage of the real reachability of the actor. This variable is a good indicator of perceivers' accuracy but not of the under-over estimation bias. For the calculation of error tendency, estimations were considered accurate if estimation error was $\leqslant 1$ cm, underestimations if estimation – real value <-1 cm, and overestimations if estimation – real value >1 cm.

To compare differences in APE and analyze possible interactions, a repeated measures ANOVA was conducted. Task (standing reachability, reach-and-jump reachability and stepping reachability) and estimation (first, second) were entered as within-subjects factors, and group (experimental, control) as a between-subjects factor. Bonferroni's post hoc tests were applied when necessary. The Huynh-Feldt correction was applied in case of violations of sphericity. To analyze error tendency, frequency distributions and chi-squares tests (χ^2) were adopted. Statistical significance was set at $p < .05$ level.

3. Results

APE mean values and standard deviations in the three tasks, for the experimental and the control groups, in first and second estimations are depicted in Fig. 2.

The analysis of variance revealed significant task and estimation main effects on APE. There were also Estimation × Group, Task × Estimation, and Task × Estimation × Group significant interactions. The group effect and the Task × Group interaction were not significant.

The main effect of task, $F(1,57) = 60.55$, $p < .001$, $\eta_p^2 = .614$, indicates that APE in the step length task ($M = 12.71\%$, $SD = 8.21$) was significantly greater than in the standing reachability ($M = 3.67\%$, $SD = 2.74$) ($p < .001$) and than in the reach-and-jump ($M = 4.56\%$, $SD = 3.69$) ($p < .001$) tasks. Differences in APE between the standing reachability and the reach-and-jump tasks were not significant ($p = .361$). The effect of task was identical in the experimental and the control groups since the Task × Group interaction was not significant, $F(1,57) = .68$, $p = .472$, $\eta_p^2 = .017$.

The main effect of estimation, $F(1,38) = 7.79$, $p = .008$, $\eta_p^2 = .170$, indicated that APE was greater in the first estimation ($M = 7.58\%$, $SD = 7.06$) than in the second estimation ($M = 6.38\%$, $SD = 6.43$). However, this main effect should be interpreted with caution because it is group dependent. The Estimation × Group interaction, $F(1,38) = 23.47$, $p < .001$, $\eta_p^2 = .382$, indicated that APE in the experimental group was worse in the first estimation ($M = 7.78\%$, $SD = 7.48$) than in the second estimation ($M = 4.50\%$, $SD = 4.04$). This was not the case in the control group.

The Task × Estimation interaction, $F(2,63) = 6.30$, $p = .002$, $\eta_p^2 = .203$, revealed that differences in APE between the first and the second estimation were greater in the step length task (first estimation: $M = 14.52\%$; $SD = 7.62$/second estimation: $M = 10.90\%$, $SD = 8.47$), than in the standing reachability task (first estimation: $M = 3.43\%$; $SD = 2.57$/second estimation: $M = 3.92\%$, $SD = 2.92$) or in the reach-an-jump task (first estimation: M = 4.79%; SD = 3.54/second estimation: $M = 4.33\%$, $SD = 3.85$).

The interaction Task × Estimation × Group, $F(2,63) = 7.70$, $p = .002$, $\eta_p^2 = .169$, indicated that differences in APE between the experimental and control groups were greater in the second estimation of the reach-and-jump and of the step length tasks (see Fig. 1). Actually, post-analysis revealed significant differences in APE between the second estimation of the two groups, for the reach-and-jump ($t(30) = -2.80$, $p = .009$) and step length ($t(28) = -3.07$, $p = .005$) tasks. In these tasks, APE in the experimental group had a reduction of about 50% between the first and the second estimation (reach-and-jump: 4.70% to 2.76%; step length: 15.51% to 7.17%), whereas APE in the control group augmented (reach-and-jump: 4.89% to 5.90%; step length: 13.53% to 14.62%). Experimental and control groups had similar accuracy levels in the first estimation for the 3 tasks and in the second estimation of the standing reachability. These results indicate that observing the child's action led to estimation adjustments only in the tasks with a low initial accuracy. The initial estimation of the standing reachability task was quite accurate (APE: $M = 3.14\%$, $SD = 2.14$), so the one trial observation did not improve that accuracy (APE: $M = 3.57\%$, $SD = 2.58$).

In what concerns error tendency, results are presented in Table 1.

Observers in our study had a slight tendency to underestimate the child's capabilities in the standing reachability and the reach-and-jump tasks (see Table 1). However, the observation of one

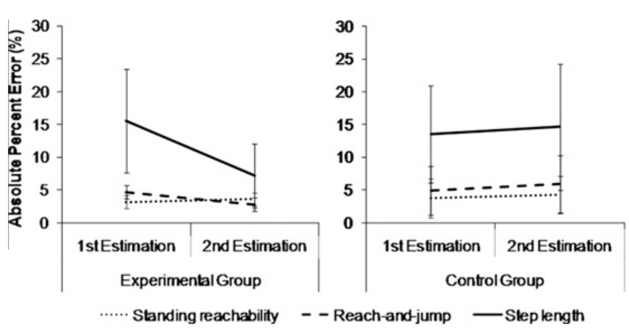

Fig. 2. Absolute Percent Error in first and second estimations for the 3 tasks (standing reachability, reach-and-jump, and step length) in the experimental and control groups. Participants in the experimental group saw the child's actions before second estimation. Error bars indicate standard deviation.

Table 1
Percentages of underestimations (Under.), accurate estimations (Ac.) and overestimations (Over.), in the three reachability tasks, for the experimental and the control groups, in first (1st) and second (2nd) estimations.

Group	Estimation	Task/Error Tendency (%)								
		Standing reachability			Reach-and-jump			Step lenght		
		Under.	Ac.	Over.	Under.	Ac.	Over.	Under.	Ac.	Over.
Experimental	1st	50	15	35	60	15	25	55	5	40
	2nd	50	25	25	45	30	25	40	15	45
Control	1st	55	20	25	70	15	15	35	5	60
	2nd	35	20	45	85	10	5	35	5	60

trial with knowledge of results decreased the amount of underestimations (from 55% to 35% in the standing reach task, and from 60% to 45% in the reach-and-jump task). In the experimental group, the one-trial observation improved the frequency of accurate estimations (from 15% to 25% in the standing reach task, and from 15% to 30% in the reach-and-jump task). Despite the slight adjustments in the error tendency between the first and the second trial in the standing reachability task, the differences in error tendency between groups were not significantly different for first ($\chi^2(2, N = 40) = .52$, $p = .770$) and second estimations ($\chi^2(2, N = 40) = 1.78$, $p = .410$). The adjustments in the reach-and-jump task had a greater effect since differences in error tendency between groups were not significant in the first estimation ($\chi^2(2, N = 40) = .65$, $p = .721$), but they were significant in the second estimation ($\chi^2(2, N = 40) = 7.13$, $p = .028$).

There was not a clear error tendency in the first estimation of the child's step length, since the experimental group had a slight underestimation tendency (55% underestimations) and the control group had a slight overestimation tendency (60% overestimations) (Table 1). The error tendency results in the control group did not change between first and second estimations. In the experimental group, the effects of one-trial observation in error tendency were similar to the ones observed in the two vertical reaching tasks: there was a decrease in the underestimation tendency (from 55% to 40%) and an increase in the frequency of accurate estimations (from 5% to 15%). In the step length task, the differences in error tendency between groups were not significantly different for first estimation ($\chi^2(2, N = 40) = 1.69$, $p = .430$) or second estimations ($\chi^2(2, N = 40) = 1.50$, $p = .473$). Differences between the two groups in the second estimation of this task were noticeable in error magnitude but not in error tendency.

4. Discussion

The findings of this investigation support the idea that one trial observation is enough to significantly adjust perceiver's estimations in some tasks.

In accordance with previous studies (Bloomfield, Steel, MacLennan, & Noble, 2006; Determann et al., 2007; Pepping & Li, 2005) some affordances were more difficult to perceive than others. However, the initial hypothesis that observers would be more accurate in predicting body-scaled affordances than affordances dependent on action and body-scale was only partially verified. Unlike previous studies (Pepping & Li, 2005; Ramenzoni, Riley, Davis, et al., 2008), participants in our study judged the child's action boundaries for the standing reach and for the reach-and-jump task with similar levels of accuracy. These differences in results might be explained by methodological differences between the three studies: (i) Pepping and Li (2005) analyzed self-affordances, whereas we analyzed the perception of a child's affordances; (ii) although Pepping and Li (2005) and Ramenzoni, Riley, Davis et al. (2008) analyzed reaching as a proportion of each individual's actual reach, they did not analyze values of absolute percent errors as we did; (iii) Ramenzoni, Riley, Davis et al. (2008) verified that adults could estimate other adult's reach-and-jump with only slightly less accuracy than they could perceive his standing-reachability. In our study, the adults estimated a child's affordances. The question whether reach-and-jump affordances are easier to perceive in children than in adults might be investigated further. However, this possibility contradicts previous findings that indicate decreased accuracy when the observer and the model have a greater discrepancy in their action capabilities (Cordovil & Barreiros, 2010a; Rochat, 1995). In fact, some studies verified an influence of the observer's action capabilities in the estimation of other people's affordances (Ramenzoni, Riley, Shockley et al., 2008).

As regards error tendency, the slight underestimation tendency of the child's capabilities in the standing reachability and the reach-and-jump tasks verified in this study is a concern in terms of child safety, since it might lead adults to place dangerous objects within reach of the child without realizing it. However, this tendency decreased after one-trial observation. These results support previous studies that mention a greater underestimation tendency of inexperienced observers in the evaluation of children's affordances when compared to experienced observers (i.e., professional caregivers or parents) (Cordovil & Barreiros, 2010b). The underestimation tendency in the reach-and-jump task is also in accordance with previous studies that mention a quite conservative tendency in judging self ability to reach-and-jump (Pepping & Li, 2005, 2008; Ramenzoni, Riley, Davis, et al., 2008) and other's ability to reach-and-jump (Ramenzoni, Riley, Davis, et al., 2008), on the basis of visual information.

In the present study, estimations of step length were significantly less accurate than estimations of both measures of vertical reachability. The greater difficulty in estimating the step length of the child might be related to the nature of the task proposed. To estimate the greatest distance at which the child's heel would touch the ground, in a step that would afford continuing walking, implies knowledge about the child's body dimensions and flexibility in a task that is not actually maximal, because the step should afford continuing walking. The reach-and-jump task was also a dynamical task, which implied body dimensions and strength, but the child was told to jump as high as he could. The fact that step length task was the least common of the three tasks seems to have impaired the capacity of the observers to perceive informational variables that specify this type of affordance, leading to a more difficult estimation of the child's action capability. When children want to cross gaps that are close to their maximum action capabilities they usually jump instead of stepping over and continue walking.

In the standing reachability task, a simple functional variable mostly dependent upon the child's body dimensions, the initial estimation was quite accurate, so the adjustments after one-trial observation were very small. Therefore, our second hypothesis, which predicted that after one single observation the perceivers' accuracy would increase in the three tasks, was also only partially true. In the tasks more dependent in the action of the model (i.e., the reach-and-jump task and the step-reachability task), one-trial observation significantly reduced error magnitude in about 50%. However, mean absolute errors (i.e., |estimation-actual measure|) of about 5 cm persisted in the experimental group after one trial observation (i.e., 5.00 cm for the standing reach task, 4.40 cm for the reach-and-jump task, and 4.98 cm for the step length task). Due to the design of this study, the persistence of the adjustment in perceivers' estimations was not investigated. However, the observation of one trial seems to have attuned the participants to the relevant properties in the environment that specified the child's affordances, allowing them also to recalibrate that information according to the child's body dimensions and action capabilities. The question whether this momentary improvement leads to a more permanent process of perceptual learning should be investigated in future studies.

The optical variables that adults attended to in the three tasks were not explored in this study, but the visual feedback provided by the task observation seemed to have an informational function (c.f., Withagen & Michaels, 2005), informing the perceiver about whether reattunement and/or recalibration was needed to improve the accuracy of the perceptual judgment. The finding that estimations in the standing reachability task did not improve significantly after the one-trial observation might indicate that in this task the observers were already exploiting useful variables during their first estimation, meaning that the feedback provided informed them not to change. On the other hand, the greater improvement in the step length estimations indicates that after visual feedback, observers probably converged on the more useful optical variables and adjusted their second estimations. Theoretically, changes in variable use contradict the assumption that individuals always rely on the same optical variable under the same circumstances (Jacobs & Michaels, 2006). The fact that less change in variable use is found in apparently more natural tasks was underlined by Jacobs and Michaels (2006), but to our knowledge this effect has not been found previously in the estimations of other person's affordances.

5. Conclusion

The results of this study underline the importance of experience in perceiving affordances for children. The affordance that was most common and mostly determined by the child's morphology (i.e., standing reachability) was perceived with minimal amounts of error from the beginning. The ability to estimate affordances that are less common and more dependent on the child's action capabilities improves with a minimal amount of practice, indicating that observers probably converged on the more useful optical variables to adjust their second estimation. The magnitude of the adjustment in the estimation of affordances for others seems to be task dependent.

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