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Scale Errors Offer Evidence for a Perception-Action Dissociation Early in Life

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We report a perception-action dissociation in the behavior of normally developing young children. In adults and older children, the perception of an object and the organization of actions on it are seamlessly integrated. However, as documented here, 18- to 30-month-old children sometimes fail to use information about object size and make serious attempts to perform impossible actions on miniature objects. They try, for example, to sit in a dollhouse chair or to get into a small toy car. We interpret scale errors as reflecting problems with inhibitory control and with the integration of visual information for perception and action.

The relation between visual experience and action is a classic and fundamental problem in psychology and neuroscience. We report here the initial investigation and documentation of a new phenomenon—dramatic failures by very young children to use visual information about size when interacting with familiar kinds of objects. The original impetus for this research came from informal observations in our labs and homes of young children attempting to perform actions on objects that were impossible owing to extreme differences between the relative sizes of the child and the object. Examples include children seriously trying to sit in dollhouse chairs, get inside small toy cars, and put doll shoes on their own feet. These errors of scale indicate that the usual integration of perception and action sometimes breaks down in normally developing young children. We propose that scale errors reflect a combination of immaturity in inhibitory control and in the integration of visual information processed by two neurally and functionally distinct systems (*1*–*4*).

To systematically investigate the occurrence of scale errors in a controlled setting, we gave 18- to 30-month-old children experience with large objects, followed by exposure to miniature replicas that were identical to their larger counterparts except for size (*5*). We assumed that very recent experience with the larger objects and very high similarity between the large and small ones would increase the likelihood that scale errors would occur.

Each child was observed in a laboratory play room containing three large play objects—an indoor slide that they could walk up and slide down, a child-sized chair that they could sit in, and a toy car that they could get inside and propel around the room with their feet. The room also contained several other play items (including a doll and doll-related items, books, etc.). The children were allowed to play naturally with whatever they wanted, except that the experimenter made sure that they interacted at least twice with each of the three large target objects. Next, the child was escorted from the room, and the large target objects were replaced with the miniature replicas. The child then returned to the room; if he or she did not spontaneously interact with the replica objects, the experimenter drew the child's attention to them without commenting on their size.

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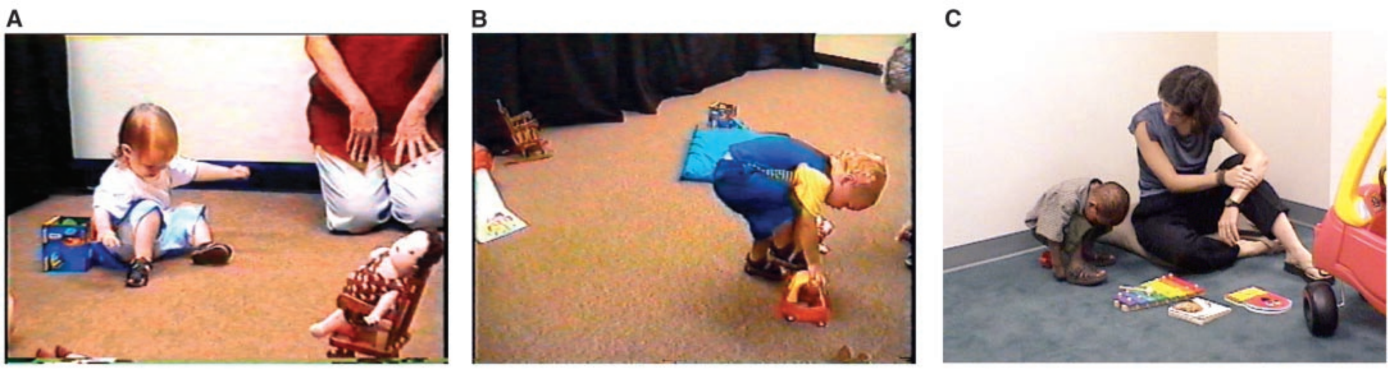

Fig. 1. Three examples of scale errors. (**A**) This 21-month-old child has committed a scale error by attempting to slide down a miniature slide; she has fallen off in this serious effort to carry out an impossible act. (**B**) This 24-month-old child has opened the door to the miniature car and is repeatedly trying to force his foot inside the car. (**C**) This 28-month-old child is looking between his legs to precisely locate the miniature chair that he is in the process of sitting on.

Very conservative criteria were adopted to identify scale errors from videotapes of the children's behavior. The coders counted instances in which children attempted to perform with a miniature object some or all of the same actions they had directed toward its larger counterpart (sitting on the miniature chair, trying to go down the ramp on the slide, or trying to insert a foot into the car). Each instance had to be judged to be a serious (not pretend) effort to carry out the behavior in order to count as a scale error. Particularly clear signs of serious intent were persistence in trying to carry out the impossible action (which occurred especially when the children were trying to squeeze a foot through the car door) and cases in which children fell off the object while trying to perform an action on it (sitting on the tiny chair or going down the slide).

The coding process identified 40 scale errors committed by 25 of the 54 children, giving an average of 0.74 scale errors per child (range = 0 to 4). Figure 1 shows three representative examples. Fourteen of the scale errors (35%) occurred completely spontaneously (i.e., without the experimenter drawing the child's attention to the target object) (*6*). There was no relation between how much time a child had spent with each large object during familiarization and the likelihood of committing a scale error with the miniature version of that object.

As Fig. 2 shows, the incidence of scale errors was an inverted-U–shaped function of age between 18 and 30 months. The number of errors differed significantly by age [$F(2, 51) = 4.40$, $P < 0.02$], with the peak occurring around 2 years. The nature of scale errors is best appreciated by seeing them, so short films of representative examples are available as supporting online material (movies S1 to S4).

Our conclusion that the behaviors we identified as scale errors were in fact serious action errors is supported by two forms of evidence. First, scale errors can be reliably distinguished from pretense. All the tapes of the participants in this study were independently coded to identify instances of conventional pretend play with the three replica objects, and 58 pretend play episodes were identified. The most common form of pretense was pushing the car around on the floor, often accompanied by car noises. When playing with the slide, the children ran their hand down it, apparently designating the act of sliding, or they slid a doll or other toys down it. Notably, there was no overlap at all between the behaviors that had been independently identified as scale errors by one set of coders and those that were identified as pretense by another. Thus, scale errors are distinguishably different from pretend behaviors, both conceptually and empirically (*7*).

An independent control study established that the behaviors identified as scale errors reflect neither a general inability to make appropriate size judgments nor a simple preference for interacting with miniature objects. Each child in a new group of eight children between 19 and 28 months was presented with the pairs of large and small objects simultaneously and asked to perform a target action (e.g., "Come and sit in the chair," "Can you go down the slide," "Drive the car over here"). The children discriminated between the two objects, always choosing the larger object; that is, they chose the object with which it was actually possible to perform the requested action.

What is responsible for the occurrence of scale errors in the behavior of very young children? A noteworthy feature of these errors that must be taken into consideration is that size information was used in the commission of the error. Even though size was not taken into account in the children's decision to interact with a replica object, the size of the object did influence specific aspects of how they attempted to carry out the action. For example, in every case in which children initiated an interaction with the miniature car, they first approached it and bent over or knelt down to get close to it, used a precise grip to open the small door, and aimed their foot for the tiny opening. Sometimes they used their other hand to grasp the top of the car to stabilize it. Having decided to sit in the miniature chair, the children approached the chair and turned around in front of it, bent their knees, and squatted down (much further than had been necessary with the larger chair) until they came into contact with the surface of the very small chair. Thus, in all the scale errors that we observed, the children attempted to carry out the same general action they had done with the larger item (get in the car, sit on the chair), but their actual movements were adjusted to the size of the miniature object.

We propose that scale errors involve a dissociation in young children's use of visual information for planning versus controlling their actions, as well as a failure of inhibitory control. Whenever a child encounters a replica of an object from a highly familiar category, visual information from the replica—its shape, color, texture, and so on—activates the child's representation of the category of larger objects that the replica stands for. Thus, seeing a chair activates the child's representation of the general category of typical chairs. (In the current study, the child's representation of the particular large chair would also be activated.) Included in the activated representation is the motor program for interacting with the full-sized object (e.g., the motor behaviors associated with sitting in chairs). This view is consistent with the current emphasis on the integration of motor representations with cognitive and perceptual representations of experience (*8*–*12*).

What typically happens at this point is that visual registration of the miniature size of the replica leads to inhibition of the activated motor routine associated with its larger counterparts (*13*, *14*). Instead of committing a scale error, the child behaves appropriately, either ignoring the replica or perhaps playing with it as a toy.

Occasionally, however, the available size information does not serve to inhibit the activated motor representation, and the child forms an action plan based on the original object or general category of objects (e.g., the child decides to sit in the chair). Once the plan is initiated, however, visual information about the actual size of the replica object is used to calibrate the movements directed toward it. Thus, the child performs finely tuned actions on a miniature object based on his or her current visual representation of that particular object, but the motor plan instigating those actions is based on the child's representation of a different, larger object.

The nature of scale errors suggests that they stem from immature cortical functioning in normally developing young children. For one thing, these errors clearly involve a failure of inhibitory control; an action appropriate for one object is inappropriately directed toward another. It is well established that infants and young children have great difficulty inhibiting prepotent responses, and sub-

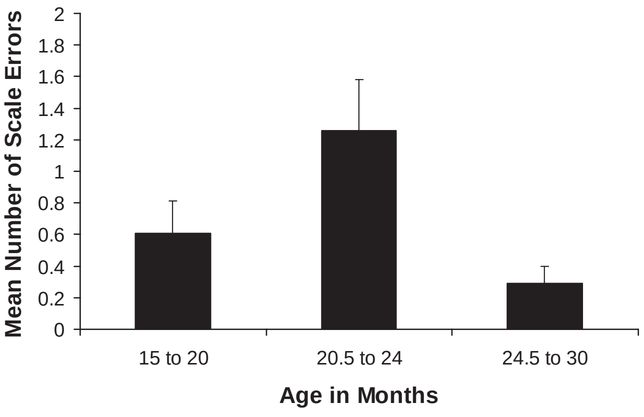

Fig. 2. The incidence of scale errors as a function of age (n = 54; 15 to 20 months, n = 18; 20.5 to 24 months, n = 19; 24.5 to 30 months, n = 17).

stantial evidence implicates immaturity of prefrontal cortex, which undergoes extensive development in the first few years of life (*13*).

Difficulty with inhibitory control does not, however, provide a full account, because scale errors involve more than the repetition of a prepotent action. The dissociation between the use of visual information for planning versus control suggests the relevance of dual process theories of visual processing. This general theoretical framework has recently been fruitfully applied to issues in infant perception and cognition, but not to children of the age studied here (*15–20*).

One of the most influential of such theories (*1*, *2*), and a recent refinement of it (*3*, *4*), posit the existence of two neurally and functionally distinct visual systems underlying perception and action. A ventral stream of projections from primary visual cortex to inferotemporal cortex is involved in the identification of objects and in the formation of action plans. A dorsal stream of projections to the posterior parietal cortex provides online control of the movements required to execute those plans. Dissociations have been shown between these two systems, both in brain-damaged individuals and in normal adults' response to visual illusions (*1–4*).

We propose that the scale errors that young children commit may reflect immaturity in the interaction of the dorsal and ventral streams manifested in occasional breakdowns in the integration of visual information processed by the two systems. A scale error occurs when information about the identity of an object processed by the ventral system is not integrated with information about its size processed by the dorsal system. The precise nature of such breakdowns and factors that influence their occurrence will be the focus of future research.

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Materials and Methods

Movies S1 to S4

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