Drawing Development: From Similarity of Features to Direction

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NICHOLLS, ANDREA L., and KENNEDY, JOHN M. *Drawing Development: From Similarity of Features to Direction.* CHILD DEVELOPMENT, 1992, 63, 227–241. Children often are said to pass through a series of stages in learning to represent 3-dimensional objects, such as cubes, on a 2-dimensional picture surface. Drawings of cubes from 1,734 children and adults were collected. They were classified into 10 drawing types (5 distinguished by Willats, and some additional types, one taken from Caron-Pargue). Over 80% of 5-year-olds produced a single square to represent a cube. Also, over 80% of 14- and 15-year-olds and over 80% of adults produced a parallel-projection drawing. However, there are several routes between these two milestones of drawing development, since no other drawing type captured more than 23% of the drawings at any age between 6 and 13. It is instructive that some children produced drawings that *never* were made by any of the adults, while some adults produced drawings of cubes that young children did not. We suggest that these differences between children and adults show that the younger children use a similarity geometry with "feature-based" criteria, while the older children and adults use a vantage-point geometry that includes "direction-based" criteria.

The problem of how children learn to represent three-dimensional objects on a two-dimensional picture plane is one that has received considerable attention (Arnheim, 1974; Caron-Pargue, 1985; Cox, 1986; Freeman, 1980; Goodnow, 1977; Kellogg, 1969; Kennedy, 1984; Mitchelmore, 1978; Piaget & Inhelder, 1956; Willats, 1984, 1985, 1987). Many authors describe general stages in learning to draw. Here we will reexamine this position and claim that children adopt a wide variety of solutions as they progress from initial to later stages. We have two main questions. First, how prevalent are drawings that typify the various "stages"? We will present data from close to 1,000 children and close to 1,000 adults making drawings of cubes. We will claim some "stages" are much more in evidence than others. Second, what guides drawing development? We will look to "anomalous" drawings that children produce and adults do not, especially drawings that do not fit neatly into the main stages, as indicators of the underlying criteria guiding development, much as departures from standard usage in language sometimes suggest the rules children follow. We will suggest that, with age, children produce drawings revealing influences from projective geometry using a vantage point.

One approach to drawing development and lists of stages is evident in the argument that a developmental sequence is only useful for general classification purposes, and each "stage" may be an independent solution to a specific problem in spatial representation in two dimensions. Mitchelmore (1987) emphasized the need to examine the drawing devices used to solve specific problems of representation. For example, he was concerned with the child's use of parallel lines to represent parallel edges in the cube (Mitchelmore, 1985, 1987). Duthie (1985), Freeman (1987), and Phillips, Inall, and Lauder (1985) all followed this approach. Freeman (1987) suggested that the use of obliques, which Mitchelmore (1978) and others found begins to develop at about age 9, may be generated as "an entirely local solution to the problem of getting two discrete faces to join at an edge" (Freeman, 1987, p. 320) rather than an attempt to show directions from a vantage point. Freeman's point is that viewer-centered depictions can emerge unintended from solving problems given by an object-centered approach.

An alternative and very sophisticated thesis about relations between perception, drawing development, and perspective is of-

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fered by John Willats (1984, 1985, 1987). He argued that children's drawing development is strongly influenced at several junctures by whether the drawing "looks right."

He proposed that drawings that "look right" would provide stages that would be long lasting compared to other stages. We will test this claim, and find it needs qualification. Willats based his analysis on two studies, one on drawings of tables and one on drawings of cubic objects. His analysis of drawings of cubes amplified and modified conclusions from the drawings of tables. He proposed six drawing stages (with types shown by some of the drawings in Fig. 1). The first is an enclosure (Fig. 1, top left). The second is a single aspect—"one-square," we will term it (Fig. 1, top middle)—which Willats points out "looks right." The third involves multiple aspects (Fig. 1, top right). Kennedy (1984) describes this as revealing the aspects shown attached and "folded out." The fourth involves two aspects—"two squares" shown attached (Fig. 1, second row, left). Willats notes that this could be produced by a horizontal or vertical projection, and "looks right." The fifth stage involves a base with a T-junction and a central Y junction (Fig. 1, second row, center). The sixth involves a variety of parallel or convergent projections (Fig. 1, second row right and third row). Like the second- and fourth-stage drawings, the sixth-stage drawings "look right."

Lee and Bremner (1987) repeated the Willats drawing-a-table study with a large

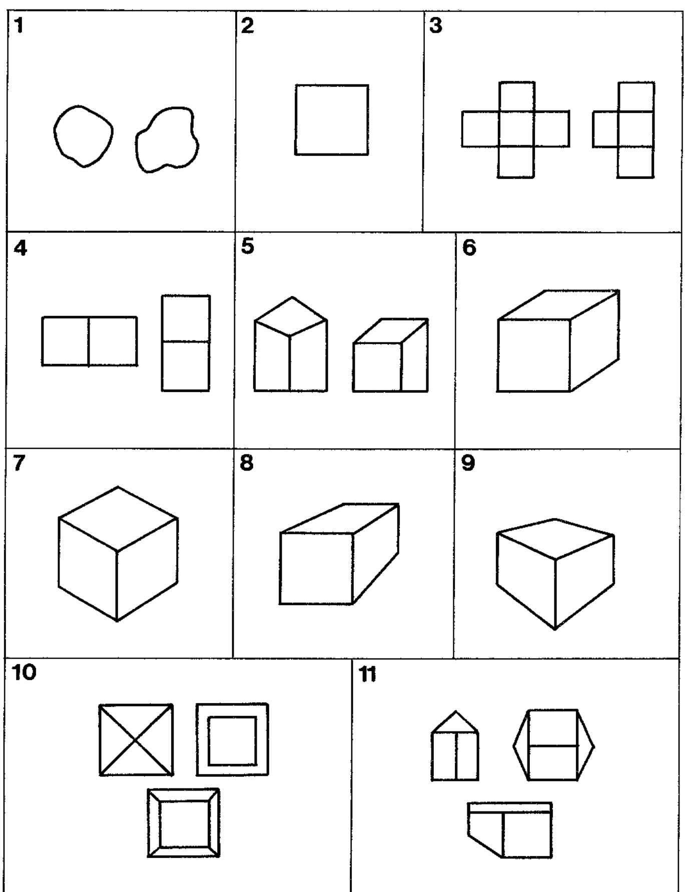

FIG. 1.—Drawing classification categories. Top row, left to right: Enclosure (category 1), One-square (2), Foldout (3); second row: Two-squares (4), Drawings with a frontal vertex shown by a Y-junction, and a vertex at the base shown by a T-junction (5), Square with obliques (6); third row: Edge with obliques (7), Convergent square with obliques (8), Convergent edge with obliques (9); bottom row: Dissection (10), and Other (11).

sample of children (789) aged 4 to 14. They report that their findings "suggest that Willats's conclusion that the representation of depth in drawing goes through a series of discrete stages, each of which can be identified with a projection system, cannot be supported" (p. 495). They argue that the processes involved are best described, as Mitchelmore and Freeman have it, as the finding and remembering of appropriate but rather task-specific graphic descriptions. On the other hand, Lee and Bremner do find an early phase of drawing development in which children draw a table top as a square, a later phase in which convergent perspective is used in inexact fashion, and a third kind of drawing in which the table top is shown by parallel obliques. They argue that oblique projection is qualitatively different from the other systems. The reason for its use by children is unclear, they write. We concur that the use of obliques can be ambiguous. For example, Lee and Bremner's subjects may have produced obliques because they were imagining drawing the object as though sitting at a vantage point slightly to one side of the object (and not directly in front, as per Lee and Bremner's instructions). The subjects may do so because they deem the result to be a better drawing of the table. Or they may be unclear about what it means to draw from a vantage point, such as directly in front, and they may use oblique lines for any edge that recedes in depth rather than simulate projection to a vantage point. Lee and Bremner discuss projection without identifying the role of the picture surface (see esp. their p. 481). They fail to relate the amount of convergence in a drawing of a rectangular table top to the orientation of the projection surface. If the drawing surface between the vantage point and the table is perpendicular to the plane of the table there will be appreciable convergence, as Lee and Bremner note. But if the drawing surface was horizontal, and parallel to the table top, there would be no convergence. Orientations intermediate between perpendicular and parallel change the amount of convergence. Evidently the child's conception of the projection surface's role is important and cannot be entirely left out of account.

At one extreme, children may envisage copying shapes of parts of the object on the picture surface in miniature, with proportions and angles of parts being the relevant factors. At another extreme, children may envisage the projections of the parts of the object to a vantage point and aim to produce a drawing that produces the same projections, as though the picture surface was a plane intervening between the vantage point and the object. With age, children may become more able to use the notion of projection for more and more features of the object (and with more flexibility in the choice of the orientation of the picture plane too). We will use this conception of a developmental change to examine drawings from children and adults.

Some children produce drawings that do not fit easily into the stages outlined by Willats (1977, 1981). Caron-Pargue (1985) presents many such examples from a large study of children's drawings of cubes. Three hundred and forty-six children, ranging in age from 3 to 11, were instructed to draw a cube "the same as the one here" (our translation).

Caron-Pargue (1985) groups the cube drawings into five categories, each of which is divided into two or more types. Here we summarize the main categories. The first category she calls "forms and fillers" ["formes et remplissages"]. It contains cube drawings consisting of single enclosed forms (Stage 1 for Willats), or many enclosed forms "filling up" the page. An analysis of the frequency of drawing categories by age showed that these drawings are primarily produced by 3- and 4-year-olds. (The drawings showing many enclosed forms may be showing multiple aspects but disregarding the connections between sides; see Kennedy [1984].) In her second category, "quadrilaterals," Caron-Pargue places two types: cubes drawn as single squares (Stage 2 for Willats) and cubes drawn as single rectangles. She shows that over 90% of 5-year-olds produced a drawing in this category. This is consistent with Mitchelmore (1978, 1987) and Willats (1984, 1985). The percentages of 6- and 7-year-olds producing "quadrilaterals" are fairly high (85% and 58%, respectively). Fewer children produce this category of drawing as age increases (9% at age 9 and 0 at age 11).

Caron-Pargue's (1985) third category is "compositions with rectangles." She says that "this category includes all cases where two or more rectangles are attached to or inscribed within a simple polygonal outline" (Caron-Pargue, 1985, pp. 62–63, our translation). For example, two or more rectangles are attached to a square in "explosions" ("eclatement"), or fit inside a square in "dissections" (Fig. 1, bottom left). Willats's

(1981, 1985) Stage 4, two attached squares, and Stage 3, "fold-out," both fall into this category, as do other drawing types that the Willats sequence does not accommodate. Caron-Pargue offers five types within this category, and combined, they captured no more than 28% of the drawings at any one age level. Children from ages 4 through 11 produced a drawing that falls into this category (5% or more at each age), and the "peak" age for this type is not clear. Caron-Pargue herself remarks on the diversity within this category.

The fourth category offered by Caron-Pargue (1985) is called "compositions with obliques." Here, some lines in the drawing representing edges of the cube meet at angles other than 90 degrees. In some cases, triangles or pentagons are present. Willats gives no examples of cube drawings containing triangles in his classification. The percentages of children producing these drawings at any age level in Caron-Pargue's study never surpassed 26% (9-year-olds). Most examples were found from 8 through 11 years of age.

Her final category is "perspectives." Here she groups "semi-perspective," which contains vertices shown by T-junctions and Y-junctions, with "the classic" drawing of a cube containing a square together with sides shown in oblique perspective. Willats (1984, 1985) places drawings with T-junctions at the base and Y-junctions as the top, frontal vertex in a separate class (class 5). Caron-Pargue distinguishes between drawings containing a square: "academic perspective" ["perspective scolaire"], and those that show a cube with a vertex and edge facing the viewer: "perspective en triedre." Like other theorists of drawing development, Caron-Pargue places both parallel and convergent perspective drawings in her final stage without differentiating them. If we consider the frequencies for the category without those for the "semi-perspective," Caron-Pargue's data show that 65% of 10½- and 11-year-olds produce a drawing that falls into this category. Caron-Pargue found that the ages of children producing drawings in this category were not significantly different from the ages of children producing the drawings placed in her category 4. This may be a function of her reduced age range.

Alas, the developmental sequences proposed by Caron-Pargue and Willats differ in several respects. The authors are in controversy over the number of stages to include and the drawings to place in the stages. Consider one example—the Willats prototype Stage 5 drawings of cubes that contain a base T- and a middle Y-junction. Caron-Pargue places these drawings in a subclass of her fourth category, while Willats assigns them to a class of their own. (Mitchelmore does not seem to treat them systematically. It is unclear whether he places cubes with base T-junctions in Stage 3a [Mitchelmore, 1987] or Stage 3b [Mitchelmore, 1978].) Further, some developmental sequences accommodate certain types of drawing which others do not.

Notice, of the proponents of stages, only Caron-Pargue (1985) provides considerable frequency data for each of her age groups, but only up to 11 years of age. And none of the frequency data provided in support of the main drawing theories include data for adults. Yet as Cox (1986, p. 342) points out, "children's drawings are usually judged according to the yardstick of adult productions." The "stage" proponents all describe an initial class of drawings in which a cube is shown by a single square, occurring around 5 years of age. Caron-Pargue's (1985) data provide impressive evidence. The proponents of stages also all describe a final stage in which the drawing "looks like a cube," meaning it shows three sides of a cube in correct orientation to each other, suggests some degree of depth, and is drawn using parallel or convergent perspective. In fact, the frequency data presented in support of the drawing theories here do not distinguish between parallel and convergent drawings in the final stages.

We must note that some (Hagen, 1985, 1986; Freeman, 1987; Moore, 1987; Phillips, Hobbs, & Pratt, 1978; Phillips et al., 1985) argue that drawings in this final stage are not attempts to represent how a cube "looks." These authors are critical of the notion that the final goal in drawing development is a drawing of an object in correct perspective, showing convergence due to projection to a vantage point (Hagen, 1985; Moore, 1987; Phillips et al., 1978). Moore (1987), for example, finds that after manipulation of objects, "errors" in copying drawings of the objects increase rather than decline. She explains this as an intent on children's part to draw "in accordance with their own understanding of the object's properties" (Moore, 1987, p. 228). Additional evidence in support of the position that children draw "what they know" rather than "what they see" comes from studies where children draw shapes or parts of objects that are not visible from their vantage point (Davis, 1983; Freeman & Janikoun, 1972; Lee & Bremner, 1987; Light & MacIntosh, 1980). However, other evidence suggests that under certain circumstances young children may indeed take vantage point into account in their drawings (Cox & Martin, 1988; Ingram & Butterworth, 1989; Light, 1985). Cox and Martin (1988) had children and adults draw a cube inside, behind, or in front of an opaque or transparent beaker. They found most children and adults only included what they could see in their drawings. They did not draw the cube inside the opaque beaker, even though they saw the experimenter place it inside. Ingram and Butterworth (1989) showed that when children are asked to depict the spatial relations between objects, they tend to take their own position into account. They will draw a block that is farther away as higher in the picture plane than one that is closer to them.

According to Cox (1986), such evidence for view-specific drawings in young children undermines the assumption that there are "clear-cut stages" of drawing development. However, there is some agreement on two major developmental stages: the initial "one-square" stage, and a later stage composed of drawings with oblique lines extending from a frontal square. What is unclear is the role that viewpoint or vantage point plays in this development. Criteria that children use to deem their drawing successful could be based on (1) projective matters, such as how well their drawing accurately reenacts what is projected from a real object to a specific vantage point, or (2) "feature matching," an object-centered similarity between features in the object and features on the page. Object-centered similarity is used here in the geometrical sense: angles and proportions in the drawing match angles and proportions in the real object, while objective sizes and lengths may differ. Such features on the page, like angles, may be geometrically congruent to, or "match exactly," the corresponding features of the object. Projective criteria concern matters of direction (matching the visual directions of parts of the object from a vantage point with visual directions given by lines on the page) and showing what is facing the observer's vantage point. As a result, they also concern matters of convergence, where lines in a drawing that represent parallel edges of an object converge toward a point to show increasing distance from the observer. Note that feature-based criteria are irrespective of vantage point. A square side of the cube is drawn on the page as a square, regardless of its direction from the observer. A 90-degree angle in the object is represented as a 90-degree angle in the drawing, regardless of its projection to an observer. This distinction between projective or "direction-based" criteria (which some would call visual-field-similarity criteria) and similarity-on-the-page or "feature-based" criteria is related to Marr's (1982) "viewer-centered" and "object-centered" descriptions, used by Willats (1987) and others. When we use the phrase "similar features" it will be to stand for an object-centered kind of copying.

To determine what children's drawings are guided by, drawings of cubes from children and adults were classified in terms of the first five of Willats's (1981) six stages. Some additional categories were added to elaborate on the sixth stage and to include drawings that did not fit easily into Willats's (1981) theory, notably one based on the "dissection" examples presented by Caron-Pargue (1985). Finally, drawings that did not fit into *any* of these categories were given a separate analysis to determine whether they were produced exclusively by children or adults and whether they indicated projection criteria, local features, or both.

Method

Subjects

There were 1,734 participants, ranging in age from 4 years to 77 years. The younger subjects and many of the older subjects were obtained on a voluntary basis at the Ontario Science Centre. Others participated voluntarily as part of optional course activities in introductory sensation and perception courses at the University of Toronto. Seven hundred and eighty-nine subjects were grouped as "children" (under 16 years of age). Four hundred and thirty-nine were girls (mean age = 9.9 years, SD = 3.1) and 350 were boys (mean age = 9.7 years, SD = 3.0). There were at least 50 children at each age level, with the exception of 4-year-olds (not many of whom visit the Centre), where there were only 15. The remaining 945 were adults (mean age 32.4 years), 551 females (mean age = 31.8 years, SD = 14.6) and 394 males (mean age = 33.3 years, SD = 14.9), with the majority in the 16–25 age range.

The 1,734 participants were taken from a larger pool of 2,020 (915 of whom were children). One hundred and sixty adults and 126 children (mean age = 11.2 years, SD =

2.1) were excluded from the data analysis because they produced a wire or "transparent" cube drawing in which all interior lines were visible in response to instructions to draw a solid cube. (We excluded these because we are unsure whether the subjects failed to understand our instructions or understood the task but could not successfully eliminate hidden lines.)

Procedure

Participants were tested individually. Each subject was given a small cube (ca. 3.5 cm^3) to examine. Children aged 4 to 8 years were asked what the object was. Their term (e.g., cube or block) was then used thereafter. The cube was placed on the table in front of the participant. The top and two sides of the cube were visible to the subject. The subject was given a blank piece of white paper and a black pencil or ballpoint pen and asked to make his or her best drawing of the cube—referred to as "this cube" or "this block." Subjects were free to touch the cube. Few did. An occasional subject asked about the orientation of the cube. They were told to make what they thought was their best drawing of a cube. Most subjects made their drawings with little inspection of the cube. Most drawings were made with attention to the drawing, not to the cube. (We did not set the cube at a fixed location and emphasize drawing it with this orientation, for children may not be able to make what they deem to be a "best" drawing under these conditions, e.g., "their best drawing" may be in oblique projection and conflict with an object given to them face-on, as we have suggested may have occurred for some subjects in Lee and Bremner [1987].)

Classification.—The drawings of cubes were classified according to the 11 categories shown in Figure 1. Five of the categories were similar to those used by Willats (1981). In category 1, Enclosures, the cube was depicted as an enclosed shape. One-square drawings, category 2, were single squares or rectangles. The third category, Foldout, consisted of cubes drawn as three or more squares connected together. In category 4, Two-squares (Willats's horizontal or vertical oblique projection), a side or face of the cube was drawn so that it appeared to extend horizontally or vertically from a single square representing the front face. Category 5, Y and base-T, contained drawings in which the front vertex of the cube was represented by a Y- and a base vertex by a T-junction. It is at category 6 where the classification scheme here begins to differ from Willats's (1981). Willats's sixth category includes cubes drawn using convergent perspective as well as ones drawn in parallel perspective. In the present classification scheme, drawings of cubes showing obvious perspective convergence are considered separately. In addition, drawings that contain a square are distinct from those that do not. The sixth classification category, referred to as Square with obliques, contained drawings in which parallel, oblique lines extended back from a frontal square to show depth. A seventh category contained Edge with obliques, drawings in which there were three faces and an edge of the cube showing a Y-vertex appeared to face the viewer. Parallel, oblique lines extended back from a vertical line representing an edge. Two further categories, Convergent square with obliques (8) and Convergent edge with obliques (9), were similar to 6 and 7, but in each case the oblique lines extending back to show depth converged (would meet at a point if extended). Drawings in the tenth category were termed Dissection (after Caron-Pargue, 1985). In this category, drawings were based on a square, but contained divisions inside the square. An eleventh category, Other, consisted of drawings that did not fit easily into any of the previously described categories.

The drawings were classified by one assistant (C. Flynn). However, two others, G. Mack and W. Chapelle, with no previous experience at judging drawings, independently confirmed the reliability of the drawing classifications. Each was given the descriptions of the categories and was allowed to practice on 25 drawings taken randomly from the larger pool of 2,020 (which included at least two examples from each of the 12 categories). Each then classified a second similar set of 25. On the second set, G. Mack had 92% agreement with the assistant and W. Chapelle had 84% agreement.

Results

In keeping with the main aims of our paper, we first present results related to main drawing types. Later we will present data for anomalous drawings that do not fit neatly into the main stages.

Main Drawing Stages

The percentage of adults and the percentage of children at each age level producing each type of cube drawing, from categories 1 to 11, are shown in Table 1. There were few 4-year-old volunteers, and while

TABLE 1

FREQUENCY OF SUBJECTS PRODUCING EACH DRAWING TYPE AT EACH AGE LEVEL

	CATEGORY											
AGE	1	2	3	4	5	6	7	8	9	10	11	*N*
4...........	2	11									2	15
	(13)	(73)									(13)	
5...........		43	3								6	52
		(83)	(6)								(11)	
6...........		46	13	1							13	73
		(63)	(18)	(1)							(18)	
7...........		31	11	7	3	1	2			4	13	71
		(43)	(15)	(10)	(4)	(1)	(3)			(6)	(18)	
8...........		21	15	7	6	5	1			1	17	73
		(29)	(21)	(10)	(8)	(7)	(1)			(1)	(23)	
9...........		11	15	7	12	21	5			2	18	92
		(12)	(16)	(8)	(13)	(23)	(5)			(2)	(20)	
10...........		12	6	2	13	25	5			2	19	84
		(14)	(7)	(2)	(15)	(30)	(6)			(3)	(23)	
11...........		3	2	2	13	32	5	1	1	3	11	74
		(4)	(3)	(3)	(18)	(44)	(7)	(1)	(1)	(4)	(15)	
12...........		3	3	1	15	40	8	1	1	3	12	86
		(4)	(4)	(1)	(17)	(46)	(9)	(1)	(1)	(3)	(14)	
13...........			1	1	8	26	8			1	5	50
			(2)	(2)	(16)	(52)	(16)			(2)	(10)	
14...........		1			1	39	9			2	6	58
		(2)			(2)	(67)	(16)			(3)	(10)	
15...........			1		5	35	14			1	5	61
			(2)		(8)	(57)	(23)			(2)	(8)	
Totals:												
Adult...		15	10	3	35	545	224	20	22	7	64	945
		(1.5)	(1)	(.3)	(4)	(58)	(24)	(2)	(2)	(.7)	(7)	
Child...	2	182	70	28	76	224	57	2	2	19	127	789
	(.3)	(23)	(9)	(4)	(10)	(28)	(7)	(.3)	(.3)	(2)	(16)	

NOTE.—Percentages are in parentheses.

11 produced category 2 (One-square) drawings, only two produced drawings that were classified as category 1 (Enclosures). These two were the sole examples of category 1 drawings in our entire sample across the full age range. We regard this as too low a frequency to support analysis. Hence, this category is not included in subsequent discussion. We have presented information on category 1 drawings only to make complete use of the Willats categories.

Inspection of Table 1 shows a nonrandom distribution. Categories 2 (One-square), 6 (Square with obliques), and 11 (Other) clearly captured a large portion of the children's drawings. Together, these drawings account for 67% of the drawings by children. Eighty-two percent of the total of the drawings by adults were contained by categories 6 (Square with obliques) and 7 (Edge with obliques). Categories 3 (Foldout), 4 (Two-squares), and 5 (Y and base-T), corresponding to Willats's Classes 3, 4, and 5, were less frequent for children (23% of the children's drawings) and also had very low frequencies for adults (accounting for only 5% of the drawings from adults). Category 10 (Dissection) contained somewhat fewer drawings for both children (2%) and adults (0.7%). Convergent drawings, in categories 8 (Convergent Square with obliques) and 9 (Convergent Edge with obliques), were produced by only 0.6% of the children and 4% of the adults.

Since there were so few convergent drawings, category 8 (Convergent Square with obliques) was merged with category 6 (Square with obliques) for analysis. Similarly, category 9 (Convergent Edge with obliques) and category 7 (Edge with obliques) were merged. An age × category test of quasi-independence (Reynolds, 1977) was significant, $\chi^2(68, N = 1{,}732) = 996.07$, $p < .001$, indicating that age and drawing type are related. (In tests of quasi-independence, cells with zero count are eliminated.) This analysis was performed on standardized data (percentages).

Mean ages for children for each category of drawings are given in Table 2. Mean age increased according to Willats's drawing categories. The mean age for category 2 (One-square) was 6.7. Mean age increased across subsequent categories up to 12.1 years for category 6 + 8 (Square with obliques) and 12.4 years for category 7 + 9 (Edge with obliques). The mean ages for the categories not defined by Willats (categories 10 [Dissection], 10.5 years and 11 [Other], 9.3 years) both fell between the mean ages for category 4 (Two-squares, 8.6 years) and category 5 (Y and T, 10.8 years).

Categories 2–7 + 9, which corresponded to Classes 2–5 in Willats's sequence, and a breakdown of Willats's Class 6, were highly correlated with age, $r = 0.77$, $N = 640$, $df = 5$, $p < .001$.

Consideration of the mean age for each drawing category cannot indicate the distribution of a given drawing type across age levels. For example, although the mean age for category 2 drawings was 6.7 years, the highest percentages of these drawings occurred at age 4 and 5, and after age 5 the percentage of subjects producing a single square at each age level steadily decreased. Also, although goodness-of-fit tests for the distribution of percentages in each category show that each distribution is significantly different from chance at the $p < .05$ level or greater, of more pressing interest is the general shape of each distribution across age levels. Three categories show pronounced linear trends. For category 2, there is a negative linear correlation between age and percentage, $r = -.90$, $df = 11$, $p < .01$. For category 6 + 8 (Square with obliques), there is a positive linear correlation with age, $r = +.96$, $df = 11$, $p < .01$. Similarly, category 7 + 9 (Edge with obliques) provides a positive linear correlation $r = +.95$, $df = 11$, $p < .01$.

Peak percentages for categories 3 (Foldout), 4 (Two-squares), 5 (Y and base-T), and 10 (Dissection) occur in the middle of the children's age range. Analysis reveals differences in kurtosis. Category 3 (Foldout) reaches two peaks or maxima (at ages 6 and 8). The percentile coefficient of kurtosis for this category, $\alpha = .44$ ($N = 70$) is higher than the coefficient of kurtosis for a normal distribution ($\alpha = .26$). This suggests that the distribution is leptokurtic (meaning more peaked than normal). The distribution for category 4 (Two-squares) does not depart greatly from normal, $\alpha = .23$ ($N = 28$). It is unimodal at ages 7 to 8. Category 5 (Y and base-T) rises from zero at age 5 to 18% at age 11, but seems to reach a "plateau." It changes little from ages 9 to 13, adjoining ages changing by no more than 3%. It is as frequent at 15 as at 8 years (8%). The percentile coefficient of kurtosis is less than that for a normal distribution, $\alpha = .18$ ($N = 76$), indicating a less peaked (platykurtic) distribution. Likewise, category 10 ranges from 6% at age 7 to 2% at age 15, $\alpha = .20$ ($N = 19$). It should be noted that category 4 (Two-squares) contains only 4% of the children's drawings and 0.3% of the drawings from adults. Similarly, category 10 (Dissection) represented only 2% of the children's drawings and 0.7% of the adults'. These percentages are lower than those found for "other" drawings (category 11, 16% of children, 7% of adults).

Finally, the percentage of drawings in category 11 (Other) gradually increased to age 8 (23% of drawings by 8-year-olds). The same figure was evident at age 10 (23% of drawings by 10-year-olds). Thereafter, percentages declined to 8% (age 15) and 7% (adults).

Since our sample was unique in including a large number of drawings by adults, we wished to determine the ages at which the distribution of drawings for children across categories does not differ from the distribution of drawings for adults. An over-

TABLE 2

MEAN AGES (Years) FOR EACH DRAWING TYPE: CHILDREN

	CATEGORY							
	2	3	4	5	6+8	7+9	10	11
Mean	6.7	8.2	8.6	10.8	12.1	12.4	10.5	9.3
SD	1.9	2.0	1.7	2.0	2.0	2.3	2.6	2.7
N	182	70	28	76	226	59	19	127

all age (children vs. adults) × category chi-square test of independence was significant, $\chi^2(7, 1{,}732) = 71.57, p < .001$. Tests of independence of the distributions of drawings across categories for 15-year-olds versus adults and 14-year-olds versus adults were not significant. At age 13, the distribution does differ from that for the adults, $\chi^2(7, 993) = 18.17, p < .05$. Age × category tests of independence were performed to compare the adults to each of the other age levels, and all were significant at the $p < .05$ level or greater. In the interests of brevity, we will not report them here. Although there are no significant differences when either the 14-year-olds or the 15-year-olds are compared with the adults, we wish to point out a notable trend in the data. The combined percentage for Square with obliques and Edge with obliques drawings is quite high and almost equal for 14-year-olds (83%), 15-year-olds (80%), and adults (82%). However, the 14-year-olds produced a relatively greater number of Square with obliques drawings (67% for the 14-year-olds vs. 57% for the 15-year-olds and 58% for the adults). Conversely, the 15-year-olds and adults produced more Edge with obliques drawings (16% for the 14-year-olds, 23% for the 15-year-olds, and 24% for the adults).

Anomalous Drawings

Now consider Category 11 drawings (Other), which did not fit easily into any of the main categories. The percentage of children producing these drawings at each age level is never higher than 23%. However, given that some of the other drawing categories only attained maximum percentages of 10% (category 4, Two-squares) or 6% (category 10, Dissection), this is a substantial portion. The highest percentages of children producing Other drawings were found from ages 8 (23% of 8-year-olds) through 10 (23% of 10-year-olds). At these same age levels, the most prevalent drawing type produced by the majority of children within an age level shifted from category 2 (One-square), produced by 29% of the 8-year-olds, to category 6 (Square with obliques), produced by 30% of the 10-year-olds. Consequently, in this age range, there is no one type of drawing typifying the majority of children.

A preliminary look at category 11 (Other) suggested that some of the drawings could be grouped together, and with the assistance of C. Flynn the drawings were classified according to six types.

This subclassification captured 56% of the children's and 42% of the adults' drawings in this category. The remaining drawings either consisted of unique drawing types, or were unable to be classified because of "sloppy" lines.

The six types grouped drawings in terms of general principles (Fig. 2). In one type, Square with rectangles, two or more narrow rectangles were added onto the sides of a square. A second group, Two-squares with rectangles, consisted of two squares joined together, as in category 4 drawings, but with one or more narrow rectangles added to the top or sides of the two squares. Two-squares with curve was a third group. It contained drawings in which the outermost corners of the two squares were connected by a slightly curved line. A fourth type, Two-squares with triangles, had either a triangle on one side (or top) joining the two squares together, or a triangle on each side. In Two-squares with obliques, the fifth type, parallel oblique lines were added to the top of a horizontal two-squares drawing, and joined. The sixth type consisted of Square with obliques drawings in which one of the lines showing the receding sides or top was noticeably divergent from the other parallel lines. This type of drawing we call Divergent obliques.

There were some interesting differences in the pattern of subclassifications for children and adults (see Table 3). A number of children produced the Square with rectangles (17 children, mean age = 8.2 years, SD = 3.5), but no examples were found for the adults. In addition, 11 children (mean age = 8.2 years, SD = 1.7) produced Two-squares with rectangles. Six children (mean age = 9.2 years, SD = 1.0) connected the outermost top corners of a two-squares drawing with a single, curved line (Two-squares with curve). Notice that no examples of any of these drawing types were found in the drawings produced by the adults.

Two types of drawings were produced both by children and adults. Nineteen of the children (mean age = 10.3 years, SD = 2.6) and eight of the adults produced Two-squares with triangles. In addition, some children and adults produced Divergent obliques drawings, 16 children (mean age = 10.2 years, SD = 1.2) and 13 adults.

There was one subcategory of drawings that was produced mainly by adults. It consisted of drawings in which parallel, oblique lines were added to the two-square drawing.

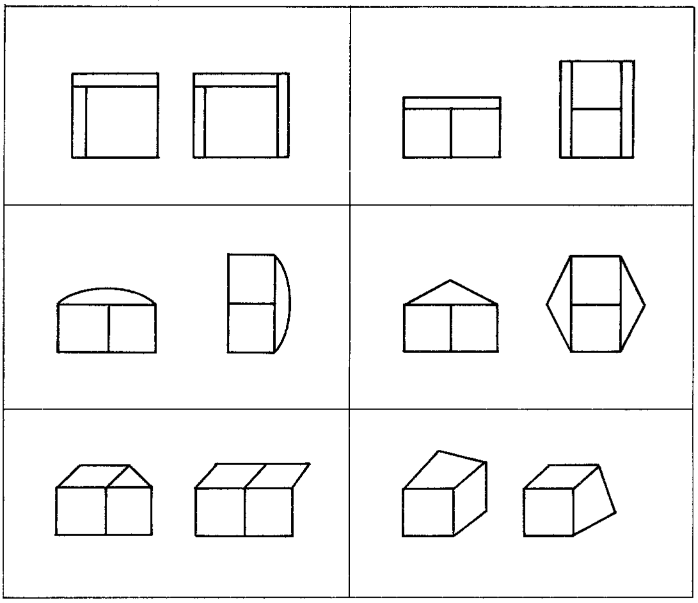

FIG. 2.—Subclassifications for Other drawings. Square with rectangles (top left), Two-squares with rectangles (top right), Two-squares with curve (middle left), Two-squares with triangles (middle right), Two-squares with obliques (bottom left), and Divergent obliques (bottom right).

Six adults and one 11-year-old produced these drawings.

Discussion

Our aim was twofold: first, to assess the frequency of examples of various putative drawing stages, and second, to consider principles that might underlie drawing development. The first task we can accomplish straightforwardly and the second must be speculative.

Our data help to reconcile the conflicting claims of Willats and his critics. If the data are analyzed by mean age or modal age for conformity to the Willats stages, they support the sequence suggested by Willats. However, if the data are analyzed for relative frequency, only some of the stages appear to be important, clear milestones.

Our results provide substantial evidence for two major stages of development in drawing cubes. One is an early stage, One-square (category 2), peaking around 5 years of age. A cube is drawn as a single square. The second is a later stage, peaking at 14 years of age, in which a cube is drawn as a single square with parallel oblique lines extending back to show depth, Square with obliques (category 6). At the intermediate ages, 8 to 10, there is no single drawing category capturing a large proportion of the drawings. Rather, drawings were distributed across several categories. Indeed, at 7–10 years of age, the second highest percentage of drawings was found in the Other category

TABLE 3

SUBCLASSIFICATIONS OF OTHER DRAWINGS: FREQUENCY FOR ADULTS AND CHILDREN

	Children	Adults
Square with rectangles	17	0
Two-squares with rectangles	11	0
Two-squares with curve	6	0
Two-squares with triangles	19	8
Two-squares with obliques	1	6
Divergent obliques	16	13

(11). It seems that while there is an age-related progression, there is no well-defined path between One-square and Square with obliques drawings. Children may take different routes to attain the Square with obliques stage found commonly in the drawings of older children and adults.

We stress that some of the stages that have been proposed by Caron-Pargue (1985) and Willats (1984, 1985) did not contain large percentages of drawings. The Two-squares drawing (category 4), called horizontal and vertical oblique by Willats, never contained more than 10% of the drawings at any age level, with its maximum occurring at ages 7 and 8. Caron-Pargue's Dissection drawings (category 10) were even less prevalent, reaching their peak of 6% at age 7. These categories also contained very few of the adults' drawings.

For adults, the only category approaching the frequency of the Square with obliques drawings was category 7, Edge with obliques (24%). Considered in terms of principles for production of drawings, both Square with obliques and Edge with obliques can be considered to be parallel projection drawings. However, there are age-related grounds for distinguishing the two types. The frequency of the two types of parallel projection drawings combined, roughly 80%, remains stable for 14- and 15-year-olds and adults, suggesting at least one stable underlying principle. But the proportions of Square with obliques and Edge with obliques drawings change, suggesting that there is a second factor. We will return to this later.

At first blush, these findings support a theory of drawing development based on knowledge about similar features, rather than matters of vantage points. The hallmark of vantage-point drawings, convergent projections, is used rarely by children and adults. Even among older subjects, over 80% of 14- and 15-year-olds and over 80% of adults produced parallel projection drawings. The subjects, it might be said, do not appear to be trying to produce a drawing that affects the visual system in the same way as would the structure of the light coming from a real cube. If the aim is, as Willats (1984) puts it, to get a drawing to "look right," this does not seem to mean getting a drawing to accurately mimic optical, geometrical patterns.

According to Willats (1984), drawings that "look right," based on laws of light projection, constitute long-lasting stages, compared to others in which drawings "look wrong" and do not correspond to these laws. But our data betray this claim. Drawings with a centre-Y and base-T vertex (category 5) do not follow light-projection laws. They should, according to Willats (1984), constitute a shorter stage and "look wrong." Yet they are fairly common across a range of ages. That is, their distribution is platykurtic, compared to Two-squares drawings (category 4), which do follow the laws and, in Willats's terms, "look right." Foldout drawings (category 3) which show more sides than project to a vantage point have a leptokurtic distribution, as Willats contends. However, they are much more frequent than Two-squares drawings at all ages.

Additionally, the wide variation in drawings between ages 8 and 10 complicates any position suggesting that children progress through developmental stages by learning to modify features in the drawing to match features in the cube in a systematic order. One possibility, as Mitchelmore (1987) and Freeman (1987) suggested, is that the drawings reflect on-the-spot solutions to the problem of modifying the single square drawing to connect parts showing other cube faces. For example, Freeman (1987) suggested that the use of an oblique line is merely a solution to the problem of showing the relation between two sides of the cube. Our data show that all of the categories found in children's drawings (with the exception of category 1) contain at least a few examples of adults' drawings as well. But what tells the person making the drawing that one "local" solution is better than another? It could be argued that if "looking right" is not relevant, each solution is equally acceptable, which is why each persists into adulthood. Yet there are wide differences in the frequencies of each of the solutions used by children and adults. Further, some younger children produce drawings that adults do not. This suggests that there may be a different basis for the problem-solving attempts by younger children and adults, which might be reflected in the two main stages.

We propose that there is an age-related shift in criteria for successful drawings of cubes. Younger children, from 5 to 8 years, may rely on geometrical similarities between features in the drawing as a set of lines on the page and features of the cube. Children match features of the object, such as a square side, with features in the drawing, such as squares on the paper. Thus, a square represents a cube because of a similarity in shape. This is also a projectively correct drawing, and so it "looks right." However, the fact that the drawing looks right is actually incidental at this age, we suggest. It is the older children who are trying to ensure that the drawing will look right. But while this may be their goal, how do they proceed?

We suggest that around 8 years of age children experience a criterion shift. They are no longer as concerned with geometrical similarity between object features and features on the page. They employ "projective" or "direction-based" criteria, applying them to parts of the object rather than the whole, first to faces and then to angles rather than the whole cube. Consequently, faces can be foreshortened and angles can be drawn more acute or obtuse than they are in the object. That is, children begin to be concerned with the orientation of parts of the cube in vision and the way lines in the drawing recreate those visual directions, not how they lie on the page with respect to one another. In the feature-matching phase, a right angle in the cube can be matched only with a right angle on the paper. In the projective "direction" matching phase, a right angle on the cube is known to project onto the picture as lines that lie in many directions, composing angles that vary from 90 degrees to become highly acute or highly obtuse. Hence angles can be drawn highly acute or highly obtuse, but match the visual directions provided by the cube's right angle. Likewise, squares at a tilt to the observer can be foreshortened.

A consideration of the Other drawings produced by the children supports our notion of a criterion shift. Younger children first begin with a single shape, such as a square. Then they start to add parts that correspond to parts of the real object, but the anomalous drawings show that similarity of shape is not essential. For example, around age 8 or 9, several children drew a single square and then added rectangles to the top or side (17 children, mean age 8.2 years). The child is likely satisfied with the square as congruent with the frontal side of the cube, and is working on the top or side to arrive at something that "looks right." There is congruence between 90-degree angles in the object and 90 degree angles on the page. But the sides are no longer drawn to match the square sides of the cube. They are foreshortened. Our explanation is that the child, while mainly concerned with similarity between features for the front, is beginning to attend to foreshortening and other projective matters for the sides. A similar argument may be made for Two-squares with rectangles drawings.

Notice that no examples of squares with added rectangles were found in the drawings of adults. Evidently some projective criterion in addition to foreshortening may be influencing adults. We suggest that it is a matter of angles. The use of triangles (as depictions of squares) attached to two squares is found both in the drawings of adults (eight of the adults) and in the drawings of older children (19, mean age 10.2 years). Caron-Pargue (1985) also found many examples, which she termed "explosions." Here it is clear that the 90-degree angles of the sides of a real cube are not congruent to the matching angles in the drawing. The triangle could result from following the directions that are set once two angles are drawn with oblique lines. But the child (and occasional adult) does not know how to complete the figure. He or she joins the obliques together, and the result is a triangle. It is important to notice that no standard parallel or polar projective system will produce a triangle to depict a square. Hence, both the children and adults must be using a pictorial rule that involves a less general rule than either of these kinds of projections which apply to the whole object or whole faces. We suggest that this narrow rule could be "use lines to show the directions of two edges of the face (side or top)," which produces converging lines, and an additional rule, "close the figure," which results in the two lines meeting and completing a triangle.

Some adults, and one 11-year-old, added oblique lines to the Two-squares drawing. In most instances, the oblique lines were then joined, by a line parallel to the one showing the top edge of the front of the cube, to make a top face (depicted by a rhomboid). Notice that the obliques did not make a 90-degree angle with a side of one of the two squares (which would be indicative of congruent "feature matching" with the real object). It is clear that some right angles in the object are not being matched with right angles in the drawing. Here, we propose, they seem concerned with how parts of the object lie with respect to a vantage point. The top of the cube is taken to be receding in depth from the vantage point, and this is shown by the use of obliques.

There is an Other drawing type that inconveniences our proposed criterion shift. Around age 9, some children drew two squares to show a front and a side (or top) face of the cube, and a curved line to join up the outermost upper corners of the squares (six children, mean age 9.2 years). At first, this does not suggest a concern for similarity between features, nor a concern for matters of projection. We confess we are challenged by this depiction. But we are not willing to simply discount it. We have found it in raised-line drawings of cubic objects by the blind (Kennedy, 1984). We speculate that an insight into this figure may come from an explanation by a blind woman, Tracy, now in her twenties and totally blind since 24 months, following a cancerous condition of the eyes. She described her raised-line drawing as follows: The curved line stands for a curved path from one top corner (to the extreme left) of the cube, to another top corner (to the extreme right). She traced out this path with her finger. She rejected explicitly the suggestion that the line stood for the rear edge of the top face. Evidently, the line stands for part of the top face, and shows a path *connecting* two corners. If so, similarity with the top edges is rejected, and some congruence with a path that makes connections is stressed.

The majority of older children and adults produced the Square with obliques drawing. There are several reasons for our claim that this display may incorporate an attempt to depict the effects of a vantage point. First, it shows only the visible sides of a cube. Second, angles in the drawing are not congruent with angles in the object, but show their visual directions. If development were simply a matter of finding solutions to the problem of joining up sides, with no reference to the visual effects of the object, there would be no need to progress to the Square with obliques stage. Some other drawing, such as Two-squares with triangles or a Dissection, might do just as well. Finally, the decreasing proportion of Square with obliques drawings for 15-year-olds and adults could reflect a concern for projective matters. This change could arise from a projective problem: there may be dissatisfaction with showing the frontal square and the sides simultaneously. With age, an increasing number of observers may recognize a possible contradiction between showing the front of a cube as a square while simultaneously showing the sides. They may feel that if the sides are to be shown, the front should not be depicted by a square but by a shape like the one for the sides.

We have left until the end two important problems, one which our data force us to note, but alas, do not give us enough to go on to solve, and one which is a crucial matter of method. If showing directions from a vantage point is important, why are there so few drawings showing convergence? A drawing produced according to linear perspective rules, in which there is a specific vantage point implied, would seem to be the *best* way of satisfying a "direction criterion." For perception, convergent drawings should be preferred representations since they are faithful to optical projection. That is, a drawing of a cube that uses convergence is closest to the projection of a real cube seen from a certain vantage point. A parallel projection, such as the Square with obliques, can, on the basis of geometry, only be equivalent to an actual cube seen at a very great distance and magnified! (A parallel projection of an extended object is *never* seen by the visual system: light from a point only reaches the eye as parallels at an infinitely great distance from the source point, and there the object would be too small to perceive.) Yet here a parallel projection drawing is highly favored by subjects as a successful representation of a cube.

We have not enough data on hand to prove our case, but we suggest that the lesson, though somewhat of a paradox, is as follows. Parallel projection drawings emerge, we think, from a concern with projective, direction-matching criteria, not from similarity and feature matching. This means every test relevant to optical, polar projection is in fact applied to parallel projection by perception. Parallel projection meets these tests pretty well, but not perfectly, in cube drawings. For example, parallel projection is perfectly capable of showing foreshortening effects. A tilted square can be foreshortened just as much by parallel projection as by polar projection. Thus, the endpoint we find here is not the final and most satisfactory endpoint of drawing. It is simply a plateau where most people stop and rest. Further refinements are possible, without any change of the basic motivating criteria. Direction-based, projective criteria can lead the observer to "more-advanced" or "better" drawings that meet the criteria more precisely. But the Square with obliques or Edge with obliques drawings meet the tests applied by perception relevant to polar projection well enough.

Now to a crucial question of method. Can our method find "the" course of development of drawing? Our subjects examine a cube and draw it while the cube is in front of them, though without instructions to draw it at a fixed distance or in a particular orientation. We did not ask subjects to draw it as it looked. Note that subjects can be given a method that facilitates drawing orientation correctly, for example, viewing through a transparent screen, from a peephole, and drawing the outline of the object on the screen. Conversely, drawing can be done "from memory," which makes it more difficult to get a particular orientation correct. Chen and Holman (1989) presented pairs of objects with a carefully chosen contrasting feature, relevant to overlap. Children as young as 5 years of age use aspects of projection in these conditions, and with some objects more than others. Evidently, we could rank tasks on the extent to which they facilitate attention to aspects of projection. Some tasks encourage very young children to use projective matters. Thus we must be modest about our method. We suggest that our results indicate a good deal about how children come to draw projectively when they are given an object and are asked to draw it. We think children can be facilitated (or hindered) in drawing projectively by task demands. We stress, however, that our task is an important one, a common experience in the lives of children. The task demands we arranged are not so explicit about projection as to be unusual, or so loose as to be murky. That is, we expect that our findings and our interpretations reflect how children function in everyday and significant circumstances.

We have no warrant for a lengthy survey of influences on drawing development. But we note that Deregowski (1986) reports findings from Bartel, asking 53 illiterate adults in Poland, prior to 1939, to draw a box. Whether drawing from memory or from a model, the single most common drawing was a rectangle (our category 2). Bartel also found, as we did, that schoolchildren aged 9–11 drew cubes chiefly as three faces with a variety of configurations. Interestingly, some 9-year-olds who were thought to be at a disadvantage educationally drew chiefly only single rectangles or rectangles within rectangles (Caron-Pargue's "Dissections"). It seems that developmental progress in drawing likely hinges on opportunities usually accompanying education. This deserves research attention.

In sum, we present several implications for stage accounts of drawing development. First, there are only two well-defined stages, One-square and Square with obliques. Between these two stages, children's drawings may follow many routes, one of which is John Willats's. Second, some drawing stages proposed by several theorists do not occur very often. Convergent drawings also were rare. Theories of everyday drawing development may be justified in grouping parallel and convergent drawings in the same final stage. Finally, the diversity of drawings produced between the One-square and Square with obliques stages, and differences between drawings from children and adults, suggest that it may be useful to consider drawing development as a shift in criteria, from similarity of features (parts of the object being geometrically similar to arrangements of lines on the drawing surface) to matching directions from a vantage point.

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Manuscripts Accepted for Publication

Inhibition in Toddlerhood and the Dynamics of the Child's Interaction with an Unfamiliar Peer at Age Five, Grazyna Kochanska (Department of Psychology, University of Iowa, Iowa City, IA 52242) and Marian Radke-Yarrow.

Thresholds of Quality: Implications for the Social Development of Children in Center-based Child Care, Carollee Howes (Graduate School of Education, University of California at Los Angeles, Los Angeles, CA 90024-1521), Deborah A. Phillips, and Marcy Whitebook.

Display Rules for Anger and Aggression in School-aged Children, Marion K. Underwood (Department of Psychology, Reed College, Portland, OR 97202), John D. Coie, and Cheryl R. Herbsman.

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Long-Term Memory for Context-Specific Category Information at Six Months, Pamela J. Shields and Carolyn Rovee-Collier (Department of Psychology, Rutgers University, Busch Campus, New Brunswick, NJ 08903).

Expertise, Aptitude, and Strategic Remembering, Wolfgang Schneider (Department of Psychology, University of Wittelsbacherplatz 1, D-8700 Wurzburg, Germany) and David F. Bjorklund.

Infant Auditory Temporal Acuity: Gap Detection, Lynne A. Werner (CDMRC, University of Washington, WJ-10, Box 47, Seattle, WA 98195), G. Cameron Marean, Christopher F. Halpin, Nancy Benson Spetner, and Jay M. Gillenwater.