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Cross-Cultural and Developmental Trends in Graphic Productions

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How does space come to be used to represent nonspatial relations, as in graphs? Approximately 1200 children and adults from three language cultures, English, Hebrew, and Arabic, produced graphic representations of spatial, temporal, quantitative, and preference relations. Children placed stickers on square pieces of paper to represent, for example, a disliked food, a liked food, and a favorite food. Two major analyses of these data were performed. The analysis of directionality of the represented relation showed effects of direction of written language only for representations of temporal concepts, where left-to-right was dominant for speakers of English and right-to-left for speakers of Arabic, with Hebrew speakers in between. For quantity and preference, all canonical directions except top-to-bottom were used approximately equally by all cultures and ages. The analysis of information represented in the graphic representations showed an age trend; more of the older children represented ordinal and some interval information in their mappings. There was a small effect of abstractness of concept on information represented, with more interval information represented by children for the more concrete concepts, space, time, quantity, and preference in that order. Directionality findings were related to language-specific left-to-right or right-to-left directionality and to universal association of *more* or *better* with upward. The difficulties in externally representing interval information were related to prevalent difficulties in expressing comparative information. Children's graphic productions were compared to other invented notation systems, by children and by cultures, particularly for numbers and language.

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The earliest forms of written communication were pictorial: cave drawings, petroglyphs, maps, tallies, pictographic forms of writing (Gelb, 1963). The invention of the phonetic alphabet revolutionized written communication, yet, in many ways, it limited communication as well. Alphabetic communication is language specific; in contrast, many pictorial communiqués are produced similarly by and can be comprehended by speakers of different languages with little or no training. Simple line drawings of common objects, for example, were identified immediately by a child raised virtually without pictures (Hochberg & Brooks, 1962). Similarly, no matter what one's language and with little training, depictions of movements and emotion can be "read" from wordless comics, and information and instructions are transparent or readily learned from the common set of pictograms found in airports and highways throughout the world.

Although maps and tallies have been produced by numerous cultures throughout the history of civilization, far earlier than written language (e.g., Brown, 1949; Hughes, 1986; Wilford, 1982), graphs did not appear in any number until the late eighteenth century (e.g., Beniger & Robyn, 1978; Tufte, 1983) when an Englishman, Playfair, and a Swiss, Lambert, began to use them primarily to display economic and political data. Even so, they did not become widely used until the following century. Both maps and graphs use Euclidean space to represent relations among a set of objects; however, maps do this literally and graphs metaphorically. Interpreting simple graphs, that is, X–Y coordinates with a relation represented, like reading phonetic writing, does not seem to be immediate, but rather based on conventions that are learned.

Several aspects of graphic representation may be distinguished. The first consideration is the level of *information* in the conceptual relation that is *represented* by the graphic mapping. Typically, four scale types are distinguished (Krantz, Luce, Suppes, & Tversky, Chap. 1, 1971; Stevens, 1946): nominal, ordinal, interval, and ratio (the last case is not considered here). These scale types are inclusive: an interval representation is also an ordinal and a nominal one, and an ordinal representation is also a nominal one. Because nominal mappings are simpler—in the sense of requiring less information to be represented—than ordinal, and ordinal is simpler than interval, it is natural to expect children to produce nominal relations earlier than ordinal and ordinal relations earlier than interval. Specifically, in the task used here, children place stickers on pieces of paper to indicate three levels of a conceptual relation. To be counted as a nominal representation, stickers merely have to be spatially separate; to be counted as an ordinal representation, the stickers must be separate and also properly ordered (in any direction) and more or less on a line; to be counted as an interval representation, in addition to separation and order, the distance between the two stickers representing a larger conceptual distance must be spatially larger than the distance between the two stickers representing a smaller conceptual distance. Thus, the greater the amount of information to be represented the greater the complexity of the graphing task.

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The second aspect of graphic representation to be investigated is the *direction of increases* used by children. By convention, increases go from left to right and/or from bottom to top. In the case of bottom-to-top, the correspondence to increases may reside in what might be called a cognitive universal. Much of the evidence for this lies in common linguistic expressions, to be discussed below. This case cannot be made for left and right, where there does not seem to be a cognitive association to increases. Rather, the direction of writing may affect the direction of increases. To investigate this, children from three writing cultures participated in the experiments: English-speaking American children, who write from left to right; Arabic-speaking Israeli children, who write both numbers and letters from right to left; and Hebrew-speaking Israeli children, who write letters from right to left, but numbers from left to right. The final aspect of graphic representation to be considered is *content independence*. By convention, graphic form does not usually depend on the particular content of the relation to be graphed. There are some conventions relating to content, for example, plotting the independent variable on the X axis and the dependent variable on the Y axis. However, there are no conventions of form for the three types of conceptual relations investigated here: temporal, quantitative, and preference. These three aspects of graphic representation, information represented, directionality, and content independence, will be investigated in a developmental and cross-linguistic study of spontaneous graphic productions. We turn first to directionality.

DIRECTIONALITY

Languages are permeated with concrete, frequently visual, frozen metaphors for the most ordinary of expressions (e.g., Bierwisch, 1967; Clark, 1973; Clark, 1974; Cooper & Ross, 1975; Lakoff & Johnson, 1980). The universality and transparency of such expressions may reveal pervasive cognitive biases and tendencies not only in comprehension and production of literal and metaphoric extensions of the visual world, but also in the very way the visual world is conceived (e.g., Clark, 1973; Clark & Clark, 1977; Franklin & Tversky, 1990; Shepard & Hurwitz, 1984). A large set of such expressions correspond to the vertical spatial dimension, up and down, high and low, and top and bottom: "What's up?" "He's feeling down today." "She's high on something." "That's a low thing to do." "She's at the top of the class." "He's hit the bottom." In general, *more, better,* and *good* are associated with *up, high,* and *top,* and *less, worse,* and *bad* are associated with *low, down,* and *bottom.* Like the metaphoric expressions based on it, the vertical dimension is asymmetric with the *down* side literally grounded and the *up* side unbounded. Also asymmetric and perfectly correlated with verticality are gravity and the canonical orientation of people. If these metaphoric expressions are indicative of a cognitive universal or general cognitive bias, then in pictorial representations as well, *good* and *more* should be mapped toward the top of a page and *bad* and *less* toward the bottom of a page. In fact, graphic conventions conform to this; increases generally go from down to up, although they may also go from left to right.

In contrast to the up/down dimension, the left/right dimension is not correlated with global physical and biological characteristics. In fact, part of the trouble people have with left and right derives from general symmetry about the left/right axis. Not only do humans have global left–right symmetry, but so do many other members of the biological world, from termites to trees, as well as many manufactured goods designed to serve the biological world, from bicycles to buildings. Despite terms such as "sinister" and "dexterity," derived from the Latin for left and right, respectively, there does not seem to be strong universal cognitive associations of quantity or quality to left or right.[1] In the absence of compelling universal perceptual or cognitive reasons for giving precedence to either left or right, other reasons prevail, for example, handedness, or perceptual/motor habits derived from writing. Like many others, Ladavas (1988) found that people in general judge *up* or *above* faster than *down* or *below* (Braine, Plastow, & Greene, 1987; Corballis & Beale, 1976; Clark & Chase, 1972; Farrell, 1979; Maki, Grandy, & Hauge, 1979; Seymour, 1969, 1974; Sholl & Egeth, 1981); however, she found that left-handers are faster at *left* judgments than *right,* but that right-handers are faster at *right* than *left.* Ambidextrous subjects showed no bias. Because most of the population is right-handed (or left-brain dominant) it is possible that a rightward bias may appear in some tasks.

[1] Anyone in doubt should consult politicians on both the left and the right.

In both perceptual exploration tasks and drawing tasks, the direction of written language plays a large role in whether the left–right or right–left direction is preferred. In a perceptual exploration task, pictures of objects are displayed in an unstructured array or in various structured arrays, such as in rows or in a square or in a triangle; children are asked to call out the names of the objects. Of interest is the order in which they name the objects. American children have an especially strong tendency to call out names of objects from left to right in their early years of reading (e.g., Elkind & Weiss, 1967; Elkind, 1969). In contrast to American children, Hebrew-speaking children have a tendency to call out objects from right to left that is particularly strong during the early years of reading Hebrew. When English is introduced in school, a left–right tendency appears (Kugelmass & Lieblich, 1970, 1979). Interestingly, right–left perceptual exploration is much stronger in Arabic-speaking children than in Hebrew-speaking children (Goodnow, 1977; Kugelmass & Lieblich, 1979; Nachshon, 1985).

Although both Hebrew and Arabic are read and written from right to left, Hebrew-speaking Israeli children are more likely to have extensive exposure to European languages than Arabic-speaking Israelis. In addition, young Hebrew-speaking children are taught to write numbers and perform arithmetic operations from left to right, just as in European languages, but young Arabic-speaking children are taught to perform arithmetic operations from right to left. Finally, although both Hebrew and Arabic are written from right to left, Arabic script is connected and Hebrew script is not, and each character in Arabic is formed right-to-left, while most characters in Hebrew are formed left-to-right. This difference in language culture is evident in a motor task testing directionality (Goodnow, 1977; Goodnow, Friedman, Bernbaum, & Lehman, 1973), where both English and Hebrew readers copied geometric forms from left to right. In a follow-up study, Lieblich, Ninio, and Kugelmass (1975) asked Hebrew- and Arabic-speaking children from kindergarten to ninth grade to copy horizontal and vertical lines. Both language groups copied the vertical line from top to bottom, but the Hebrew speakers copied the horizontal line from left-to-right, and the Arabic speakers—except the kindergartners—copied it from right to left. Preference for right or left, then, is open to a variety of influences. Thus, the graphic convention of displaying increases from left to right seems likely to have a cultural origin, in contrast to the convention of displaying increases from down to up, which appears to be rooted in the physics and biology of the world and, in turn, in human perception and cognition.

Examining children from different language cultures produce graphic representations of different quantitative relations allows exploration of these issues. Young children's productions of graphic representations are less likely to reflect learned conventions than those of adults. American children were contrasted to Hebrew- and Arabic-speaking Israeli children. If the graphic convention of representing increases from left to right is just that, a convention, then children from different language communities may differ in their use of direction in the horizontal dimension. In contrast, if the graphic convention of representing increases from down to up is based on a pervasive cognitive bias, children from different cultures should not differ in vertical directionality. All three languages have metaphoric expressions associating greater quantity and quality with upward.

TASK

To address these questions and more, we developed a production task that did not entail writing. Children placed stickers standing for levels of concepts on paper to represent relations between the levels. This was done for several reasons. First, we did not want motor facility with drawing implements to confound our results. Second, we wanted to minimize the application of habits from drawing and writing. Finally, previous research has examined how children compose written symbols (Cohen, 1985; Hughes, 1986; Ferreiro, 1978, 1985; Ferreiro & Teberosky, 1982; Levin & Tolchinsky Landsmann, 1989; Tolchinsky Landsmann & Levin, 1985, 1987). Under some circumstances preschool children successfully represent each real object or event with a single symbol, preserving a one-to-one correspondence between objects and symbols (see especially Hughes, 1986); however, prior to second grade, their marks do not reliably distinguish one object from another (Cohen, 1985). Because we were primarily interested in how children use space to represent relations among symbols, we relieved children of the burden of inventing symbols by providing verbally labeled stickers to stand for the stimuli to be represented. For each of the concepts to be depicted, children were given a large square blank sheet of paper. The experimenter first explained something about the concept to be represented, for example, the major meals of the day. Then the experimenter put a sticker in the middle of the page saying that this represents lunch time. The child was asked to put down stickers representing breakfast time and dinner time. The child knew ahead of time what was to be represented and was free to put the stickers anywhere on the page. The child was first warmed up to the task by producing representations of spatial concepts, for example, the relative positions of three peg dolls in front of the child. In addition to temporal concepts, the child was also asked to produce representations of quantity and preference. One of the quantitative relations to be represented was the amounts of sand in a spoon, cup, and dump truck. For preference relations, preferences were first elicited from the child, for example, the child's favorite TV show, least-liked show, and one show in the middle. Then the child was asked to put down stickers representing the relations among those three shows. Several questions of each type, temporal, quantity, and preference, were asked in order to test for consistency of effects.

INFORMATION REPRESENTED

This technique allows us to examine a second set of questions no less interesting than the questions about directionality of mapped relationship. We can also observe what information in the spatial or temporal or quantitive or preference relations is represented in the childrens' mappings. Children who place all three dots on the page but not aligned represent only *categorical* or *nominal* information. That is, they distinguish between the levels of the concept, but they do not represent the relation between the levels. Children who put all three dots on top of each other, or nearly so, fail to represent nominal relations. Children who place all three dots in order and more or less in line represent *ordinal* information, that is, the ordering of the levels of the concept. Note that the particular direction of the order is irrelevant here. Finally, children who place all the dots in order and on a line and place the dot for the 10:00 snack closer to the breakfast dot than to the dinner dot are representing some *interval* information about time in their graphic productions. They recognize that the inequal time intervals should be represented by inequal spatial intervals. Use of a truly interval scale entails selecting a unit of measurement and using it accurately. Only a weak sense of interval was tested here, namely, representing larger intervals by larger amounts of space, that is, ordering the intervals. As stated earlier, the expectation is that older children's mappings or representations will represent more of the information in the relations than younger children's mappings.

CONTENT INDEPENDENCE

The third major question of interest is whether the specific content of the conceptual relation affects the child's mapping or representation. The concepts to be represented by graphic productions range from concrete to abstract, that is, from spatial to temporal, to quantitative, to preference. Spatial concepts are the most concrete in the sense that they can actually or potentially be seen. The distances between the peg dolls, for example, are visible to the child. The temporal and quantitative relations are less concrete in the sense that they cannot be seen, yet they are more concrete than the preference relations in the sense that they have standard ways of