The cultural evolution of IQ

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1 author:

Patricia Greenfield
University of California, Los Angeles

4

The Cultural Evolution of IQ

Patricia M. Greenfield

"Successful adaptation to its own niche marks an animal form as intelligent" (Scheibel, 1996). This definition leads to the following question: What constitutes specieswide adaptation to the human niche? Three features that reach their apex of complexity in the human species stand out: (a) technology, (b) linguistic communication, and (c) social organization. The ability to acquire competence in each one through development, learning, and socialization is my definition of *panhuman genotypic intelligence*: All normal members of the human species have that ability. However, particular languages, communication conventions, technologies, forms of social organization, and social norms vary from culture to culture. Therefore, *phenotypic intelligence varies from culture to culture.* Figure 1 presents this model of intelligence. The "bottom line" of the model is that although the range of within-culture genotypic variation of intelligence may be the same from culture to culture

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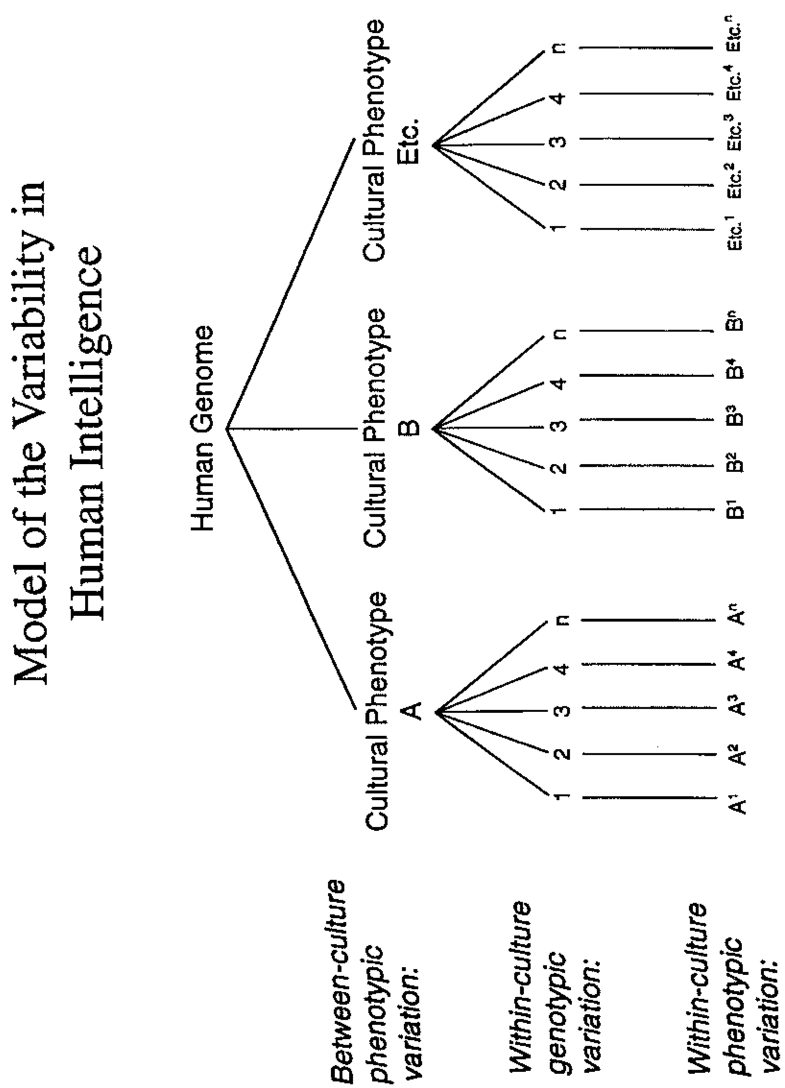


Figure 1

Model of the variability in human intelligence: Within- and across-culture variation in the paths of intelligence.

(1 through *n*, repeated three times in the diagram), a given genotype will be expressed differently (as a different phenotype) in a different cultural milieu (e.g., A^1 vs. B^1 in the diagram).

LANGUAGE, INTELLIGENCE, AND ADAPTATION

Because they possess the panhuman genotype, normal infants are born with the ability to learn any language. However, in most cases, they actually learn one (e.g., Cultural Phenotype A or B, see Figure 1). The universal, innate language-learning capacity is applied in a specific linguistic environment, and the resultant language learned is therefore adapted to this linguistic environment. If one tries to test the "innate linguistic ability" of a child exposed to Language A using stimuli from Language B, the child will look stupid, as though lacking in "innate ability." Of course, this is obvious, and it is something that no one would dream of doing, yet it is done with "intelligence" tests. The cartoon in Figure 2 parodies this practice.

This cartoon makes the important point that each phenotypic form of intelligence is adapted to a particular ecocultural niche. With respect to the top line of the model presented in Figure 1, Cultural Phenotype A would be adapted to Ecocultural Niche A, Cultural Phenotype B would be adapted to Ecocultural Niche B, and so forth. Two important points then follow:

1. Cultures define intelligence by what is adaptive in their particular ecocultural niche.
2. Definitions of intelligence are as much cultural ideals as scientific statements.

The logical necessity of cross-cultural differences in definitions of intelligence follows from these two points, and indeed such differences do exist. For example, in Africa in the 1970s, it was found that there was an emphasis on social (rather than technological) intelligence (Mundy-Castle, 1974), on behavior that leads to respect for and compliance with society's ways (Wober, 1975), and on slowness, that is, deliberation (Wober, 1974). These definitions contrast directly with pre-

Figure 2

The teepee test: An example of cultural bias in testing. The Native American boy on the left has scored 100 on his teepee test, whereas the European American boy on the right has flunked. From *Psychological Tests and Social Work Practice* (p. 39), by M. L. Arkava and M. Snow, 1978, Springfield, IL: Charles C Thomas, Copyright 1978 by Charles C Thomas. Reprinted with permission.

suppositions about intelligence in the Western world: that it involves understanding of the physical world more than the social world, that it involves "being able to think for yourself" rather than compliance, and that it involves speed rather than slowness.

Traditional African definitions of intelligence are adapted to the traditional ecocultural niches of small, face-to-face groups and kin-oriented societies. The Western definition of intelligence is adapted to a different set of ecocultural niches. These niches feature urbanization, high technology, and schooling as the major modes for socializing the young for adulthood. Because schooling is the main method of socialization for adulthood in this type of society, it is not surprising that IQ tests have focused on forms of intelligence that are cultivated in school,

what Neisser (1976) calls "academic intelligence." Indeed, Binet, the originator of intelligence tests, explicitly developed his test to identify children who needed special education in school.

Serpell (1993) and Dasen (1984) have shown that when schooling (the origin of which is a colonial European influence) is introduced to an African community, a school-influenced definition of academic intelligence also develops. African school attendees combine the traditional and academic definitions of intelligence. Nonetheless, these are contrasting definitions with contrasting cultural roots.

In essence American intelligence tests measure what Americans think intelligence is, not what Africans think it is. (Remember, however, that definitions are not static but change as a function of historical time as well as place.) In the words of Cole and Cole, "intelligence cannot be tested independently of the culture that gives rise to the test" (1993, p. 502). The point here concerns the cultural relativity of intelligence tests. Contrary to traditional psychometric theory, intelligence tests are not universally applicable. Instead, they are cultural genres, relevant to a particular definition of intelligence. This is the conceptual context I use to explain the worldwide rise in IQ that has been termed the *Flynn effect.*

THE FLYNN EFFECT

James Flynn has focused on the socially and theoretically important phenomenon of historical IQ rise in many countries over the period of the 20th century and even before (Flynn, 1984, 1987, 1994). At the same time, he has called attention to the seeming paradox of a decline in scores on the verbal Scholastic Aptitude Test (SAT) in the United States during the same period in which IQ has been rising. Finally, Flynn has observed that IQ has risen fastest on nonverbal tests such as the Performance battery of the Wechsler Adult Intelligence Scale (WAIS) or the Raven Progressive Matrices.

In summary, the patterning of the Flynn effect is as follows: a worldwide rise in IQ scores, particularly nonverbal or performance IQ, with a concurrent drop (in the United States) in verbal SAT scores.

I argue that only an explanation that focuses on cultural history can account for the particular patterning of changes Flynn described. The strategy I use to construct this argument goes as follows:

1. Identify historical changes in the ecocultural niche that could account for these changes in test performance. (These must be widespread trends.)
2. Cite both traditional and "natural" experiments to demonstrate a causal link.
3. Develop theory and evidence regarding the mechanisms behind these causal links.

HISTORICAL CHANGES IN THE ECOCULTURAL NICHE

My thesis is that ecocultural changes in three areas—technology, urbanization, and formal education—account for a major portion of the changes in test performance. These areas are closely allied with and complementary to other areas that may also contribute to historical changes in IQ test performance: changing patterns of mother–child interaction, the ubiquitous presence of certain artifacts in the cultural environment, and improved nutrition (see chapters 5, 6, 7, and 8, this volume). From a historical and ecocultural perspective, changes in one of these factors—urbanization—has often been accompanied by changes in the other two—technology and formal education. For example, urban environments often provide higher levels of formal education for their populations and are more technologically sophisticated as well.

Coordinated Development in Technology, Urbanization, and Education

Wheeler (1942/1970) made a study of East Tennessee mountain children in 1930 and 1940, administering the same IQ tests at a 10-year interval. In 1930, approximately 1,000 children in Grades 1 through 8 in 21 mountain schools were tested with the Dearborn IA and IIC

Intelligence Tests. A subset of these children between Grades 3 and 8 were also given the Illinois Intelligence Test. In 1940, children from the same schools, "from the same areas and largely from the same families" (Wheeler, 1942/1970, p. 122), were given the same test. Two thousand additional children from 19 other mountain schools were also tested in 1940. Between 1930 and 1940, Wheeler found that IQs rose an average of 11 points across grade levels from 1 to 8.

What happened in East Tennessee that could account for the 10-point rise in IQ performance? Indeed, a series of coordinated changes in the three hypothesized areas had taken place.

1. *Technology*:
   a. *An excellent new road system.* This "developed transportation facilities for schools and industry" (Wheeler, 1970, p. 122).
   b. *Agricultural income was supplemented by industrial income.* By 1940, the rapid growth of industry in the area enabled about 60% of the families in one county and 40% in another to have one or more members working in industrial plants (Wheeler, 1942/1970).
2. *Access to urban areas.* The road system gave "every community access to progressive areas outside of the mountains" (Wheeler, 1970, p. 122). As part of this trend, new houses tended to be built on or near the new main highways.
3. *Formal education*:
   a. *A rise of 32% in average daily attendance and a rise of 17% in enrollment.* These changes were in large part due to the introduction of a system to transport thousands of children to and from school, which itself depended on the road system, an aspect of technological development.
   b. *Movement from one-room schoolhouses toward larger, better equipped schools.* This change was made possible by the road system and the school transportation system. The improved equipment included a state- and county-provided circulating library.
   c. *Improvement in teacher training.* In 1930, the average teacher

training included less than 2 years of college work. By 1940, all new teachers were required to have 4 years of college training.

d. *Hot lunches served in the larger schools.* Thus, the development of formal education was linked with improved nutrition, another potential factor in IQ rise (see chapters 6, 7, and 8, this volume).

It is notable that the rate of change in this sample was about double that of the typical Flynn effect (Flynn 1984, 1987; chapter 2, this volume). Environmental changes that occurred slowly elsewhere seemed to have occurred rapidly in East Tennessee, with a correspondingly rapid rise in IQ.

The fact that coordinated changes in technology, urbanization, and formal education were correlated with IQ rise over a 10-year period is suggestive of a causal relation but not definitive. Caution in drawing causal conclusions is warranted because we are dealing with a historical correlation rather than an experimental effect. It is possible that still other factors were the motor behind the IQ rise. Another limitation of this study is that even assuming that the three factors of technology, urbanization, and education were of causal importance, it does not reveal what role each factor played. Therefore, I turn now to more specific experiments that isolate a single factor at a time.

Technological Development

This factor was isolated in a field experiment carried out by McFie (1961) in Uganda. He "gave 26 boys entering a training school verbal tests, and a Block Designs (adapted from Koh's Blocks) test. After two years' technical training, scores on Block Designs and related tests had improved, while verbal tests had not similarly shown gains" (Wober, 1975, p. 64). This study is particularly significant because it simulates the *patterning* of the Flynn effect—selective improvement on nonverbal tests—and indexes an ecological factor—technological development—that has been going on in all of the Flynn-effect countries (e.g., France, The Netherlands) throughout the 20th century.

Urbanization

A number of studies (summarized by Cole & Cole, 1993) have indicated that urbanization has a positive effect on IQ. For example, Klineberg (1935) found that after people moved from rural areas to the city, their IQs rose. This demographic factor could be quite relevant to the Flynn effect in the United States, where increases in population density and urbanization have been documented throughout the 20th century (*Encyclopaedia Britannica*, 1938, p. 684, 1972, p. 689, 1990, p. 740, 1994, p. 169). Indeed, a concomitant increase in population density and urbanization is a worldwide phenomenon.

Formal Education

An array of studies (summarized by Wober, 1975) have provided a comparison between schooled and unschooled persons in Africa and showed that schooled persons do better on various intelligence tests, particularly nonverbal ones. One such study using the Raven Progressive Matrices was carried out in the Belgian Congo by Ombredane, Robaye, and Robaye (1957, as reported in Wober, 1975). The Raven is a nonverbal performance test that has provided a substantial proportion of the evidence for the Flynn effect (Flynn, 1984, 1987). The cognitive requirements of this test are examined in a later section of this chapter. In the Congo, Ombredane et al. (1957) found that school experience bore a considerable relationship to scores on the Raven (Wober, 1975). Lynn (chapter 8, this volume) also argues that gains in Raven scores result from schooling.

When variations in school experience are compared with variations in age, schooling is more predictive of test performance than is age. This has been established both in Africa (Schmidt, 1960) and in Israel (Cahan & Cohen, 1989). In other words, actual performance on intelligence tests is more closely related to years of schooling than it is to chronological age. (This research has taken the form of natural experiments in societies where age and and schooling vary more independently than they do in the United States or Europe.)

In Western societies, the role of schooling in producing gains in tested intelligence was probably most important hundreds of years ago when school attendance first became widespread. A similar situation has prevailed in the last 40 years in Africa, where there may well have been a large "Flynn effect" owing to increased schooling. However, the relevant research has not been done.

Even in the United States, adult illiteracy rates have gone down steadily during the 20th century (*Encyclopaedia Britannica*, 1938, p. 684, 1990, p. 740), and high school attendance took a quantum leap between 1900 and 1937 (*Encyclopaedia Britannica*, 1972). This trend might be particularly relevant to the Raven, which may depend heavily on secondary education (Ombredane, 1956, reported in Wober, 1975).

The Connection Between Formal Education and Maternal Behavior

One of the mechanisms by which school works is to change how mothers interact with their children, even after just a few years of schooling. The mother comes to reflect the teacher as a model for maternal behavior (Uribe, LeVine, & LeVine, 1994). For example, schooling provides experience with "known-answer questions" (in which the questioner already has the requested information). Minimally schooled mothers, like teachers, ask their children such questions; unschooled mothers do not (Duranti & Ochs, 1986). Responding to known-answer questions is the most basic convention on an intelligence test. In general, there is a connection between education and the kinds of maternal behavior posited by Ramey (1996) to make a positive contribution to children's IQ (e.g., Laosa, 1978).

The Factors Across Space and Time

Note that although some general principles may explain the Flynn effect across cultures, particular factors, their instantiation, and their strength vary from country to country and epoch to epoch. Focusing particularly on the United States and on symbolic technologies, the remainder of this chapter provides a closer look at the mechanisms that mediate the operation of these factors.

THE SEARCH FOR MECHANISMS TO EXPLAIN THE FLYNN EFFECT

The key to understanding these mechanisms is to be able to explain the patterning of the Flynn effect. The patterning in the United States,

as described earlier, is as follows: There has been a modest rise in verbal IQ, in concert with a considerable decline in verbal SAT scores. Over the same period, a much larger rise in nonverbal, or performance, IQ has taken place. In the United States, a rise of at least 21 IQ points took place between 1918 and 1989 (Flynn, 1984, 1994), with a spurt (close to half a point a year) between 1972 and 1989 (chapter 2, this volume). The next step in the argument being developed is to provide evidence concerning the causal factors and mechanisms for each element in the pattern.

A Relatively Large Rise in Nonverbal IQ Scores

My search for the mechanisms to explain the relatively large rise in nonverbal IQ focuses on communication and information technologies: film, TV, video games, computers. Ever since film became popular in the 1920s, the spatial and iconic imagery featured by such media has been getting increasingly important. This has been a gradual change, involving the diffusion as well as invention of new communication and information technologies. This development of the technological environment is not a matter of a single medium at a particular time but involves many media and a long-term trend. In the next section of this chapter, I use experimental data to demonstrate that the spatial and iconic imagery characterizing this technological environment has effects on the mental processes of the users. External modes of representation enhance and develop the corresponding internal modes of representation required to handle them. These internal modes are required by performance IQ tests.

I start by discussing video games as an example pertinent to recent gains in nonverbal IQ. Video games are interesting from the perspective of the Flynn effect because they are a mass medium with over 90% penetration in the United States. In turn, I demonstrate how video games develop skills in visual–spatial representation and iconic imagery and how these same skills are utilized in important nonverbal portions of major IQ tests. Although my examples come mainly from action video games, many other popular electronic games (e.g., Scriven, 1987) and computer applications involve the same cognitive and perceptual skills.

Visual-Spatial Skills

Tetris is a dynamic spatial puzzle. It involves the putting together of pieces that fall from the top of a computer screen (see Figure 3). Using a joystick or keyboard, the player must turn and horizontally position descending pieces to make a solid wall at the bottom of the screen. Okagaki and Frensch (1994/1996) investigated the effects of Tetris on the mental manipulation of spatial imagery, tasks common on nonverbal IQ tests. In their experiment, 6 hr of playing Tetris enhanced performance on several paper-and-pencil tests that are similar to nonverbal IQ measures. One example was a puzzle assembly task (see Figure 4). In this task, the participant had to figure out which pieces were required to compose the large triangle shape on the left. Note, however, that the same skills enhanced by playing the video game Tetris are tested in performance, or nonverbal, IQ tests. For example, the Object Assembly subtest of the Wechsler intelligence scales for both children and adults (Wechsler, 1981, 1991) involves the manipulation and fitting together of puzzle pieces. Figure 5 shows a simulated item from the Object Assembly subtest of the Wechsler Intelligence Scale for Children (WISC-III).

Block design tests, found on many major IQ tests including the Wechsler scales for adults and children and the Stanford–Binet children's intelligence scale, also involve puzzle assembly skills related to those enhanced by Tetris. An example is the Pattern Analysis test from the Stanford–Binet. The point of these examples is clear: If practice on a video game can affect puzzle task performance in an experiment, why not on IQ tests?

It is interesting that the experimental effects of playing Tetris on paper-and-pencil tests, such as the one shown in Figure 4, occurred in male participants only (Okagaki & Frensch, 1994/1996), particularly because most of the Flynn data involve male army recruits (e.g., Flynn, 1984, 1987). (However, female participants in the Okagaki and Frensch study did show a positive effect of playing the video game on computer-tested [rather than paper-and-pencil] spatial skills more similar to Tetris itself.)

The effect of Tetris play on the mental manipulation of spatial imagery indicates, on a theoretical level, that external forms of repre-

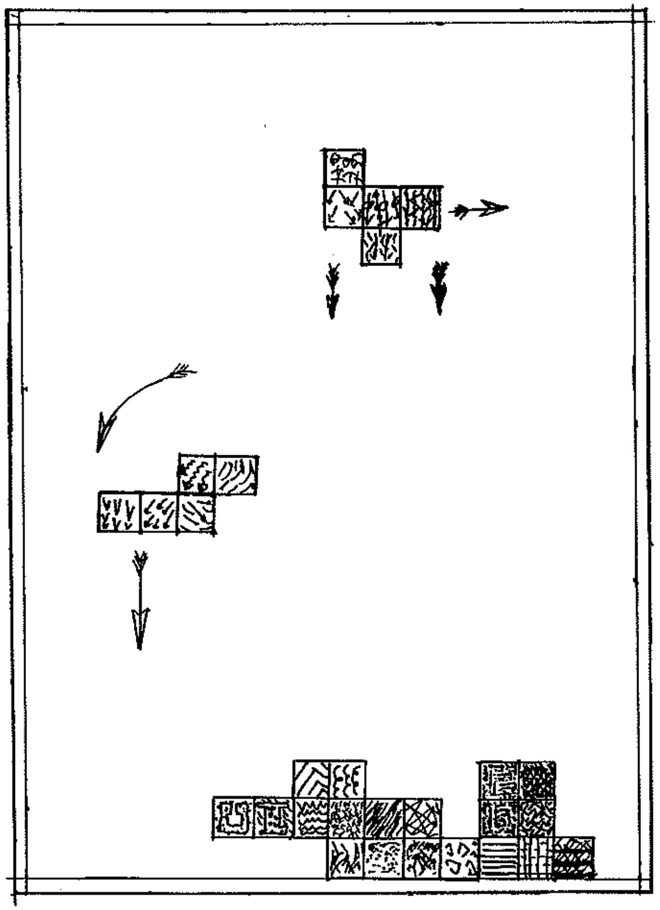


Figure 3

Schematic drawing of a screen from the popular video game Tetris, with arrows to indicate the direction of the movement of the pieces. In Tetris, puzzle pieces fall from the top of the screen (indicated by downward facing arrows). The player uses a joystick or keyboard to control horizontal position (indicated by a horizontal arrow) and to rotate pieces (indicated by a curved arrow). The goal is to fill all the spaces in each row of squares at the bottom of the screen. Given the location of the pieces at the bottom of the illustration, this can no longer be done in Row 1, but it is still possible to fill in Rows 2 and 3. Drawing by Abraham Seidman, 1996.

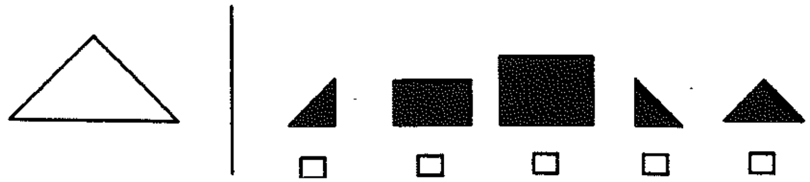


Figure 4

Performance on this puzzle assembly task was enhanced after participants played 6 hr of the computer game Tetris. From "Effects of Video Game Playing on Measures of Spatial Performance: Gender Effects in Late Adolescence," by L. Okagaki and P. A. Frensch, 1994, *Journal of Applied Developmental Psychology, 15,* p. 40. Copyright 1994 by Ablex. Reprinted with permission. (See also Greenfield & Cocking, 1996.)

sentation stimulate internal forms of representation. That is, the spatial manipulation of puzzle pieces on a computer screen both requires and develops internal modes of spatial representation that can be subsequently generalized to paper-and-pencil tests. These modes of spatial representation are among those assessed in performance IQ tests.

Other popular video games, including older ones, utilize still other skills in spatial representation that are also assessed on nonverbal IQ

Figure 5

Simulated item similar to item in the Wechsler Intelligence Scale for Children: Third Edition. The pieces are asembled to form a duck. Copyright © 1990 by The Psychological Corporation. Reproduced by permission. All rights reserved. "Wechsler Intelligence Scale for Children" and "WISC-III" are registered trademarks of The Psychological Corporation.

tests. Whereas the video game Tetris and tests of puzzle assembly involve the manipulation of two-dimensional spatial representations, other games and performance tests involve the mental manipulation of three-dimensional representations presented on a two-dimensional screen or piece of paper. This is a more complex level in the mental representation of space.

For example, some genres of action video games require navigation through a two-dimensional representation of three-dimensional space. Mental paper-folding tests (see Figure 6 for an example) also require active mental manipulation of a two-dimensional representation of three-dimensional space. In the test shown in Figure 6, the participant must mentally fold the designs into a cube, noting which side of the two-dimensional design would touch the side of the hypothetical cube marked with an arrow.

Would a video game requiring the navigation through a two-dimensional representation of three-dimensional space require the same skills as mental paper folding? In a first study of one such game, *The Empire Strikes Back,* my students and I found a significant positive correlation between expertise in this game and performance on the mental paper-folding task shown in Figure 6 (Greenfield, Brannon, & Lohr, 1994/1996). In a second, experimental study, we explored whether experience with the game has a causative influence on the spatial skills required by mental paper folding (Greenfield, Brannon, & Lohr, 1994/1996). Our results indicated that an experimental treatment involving relatively brief exposure to *The Empire Strikes Back* game had no effect on mental paper folding. However, we did find, through structural equation modeling, that the initial level of accumulated expertise on *The Empire Strikes Back* was causally related to mental paper-folding skill (Figure 7). The model in Figure 7 showed a good fit to our data. It indicates that initial skill level with *The Empire Strikes Back* game (itself strongly influenced by gender) traces a significant causal path to mental paper-folding performance.

The importance of these findings in contributing to an explanation of the Flynn effect is that mental paper folding can be part of the measurement of nonverbal IQ. For instance, a version of mental paper

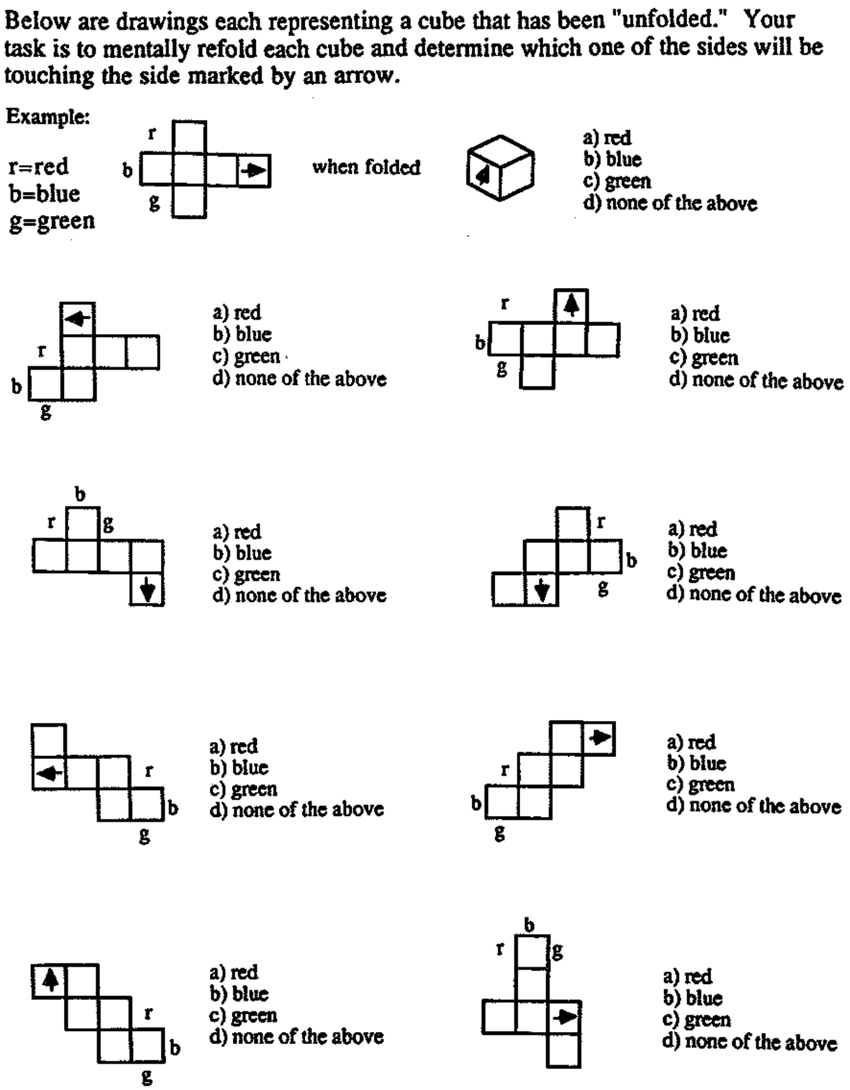


Figure 6

A mental paper-folding test, like a video game, requires active manipulations of a two-dimensional representation of three-dimensional space. From "Two-Dimensional Representation of Movement Through Three-Dimensional Space: The Role of Video Game Expertise," by P. M. Greenfield, C. Brannon, and D. Lohr, 1994, *Journal of Applied Developmental Psychology, 15*, p. 91. Copyright 1994 by Ablex. Reprinted with permission. (See also Greenfield & Cocking, 1996.)

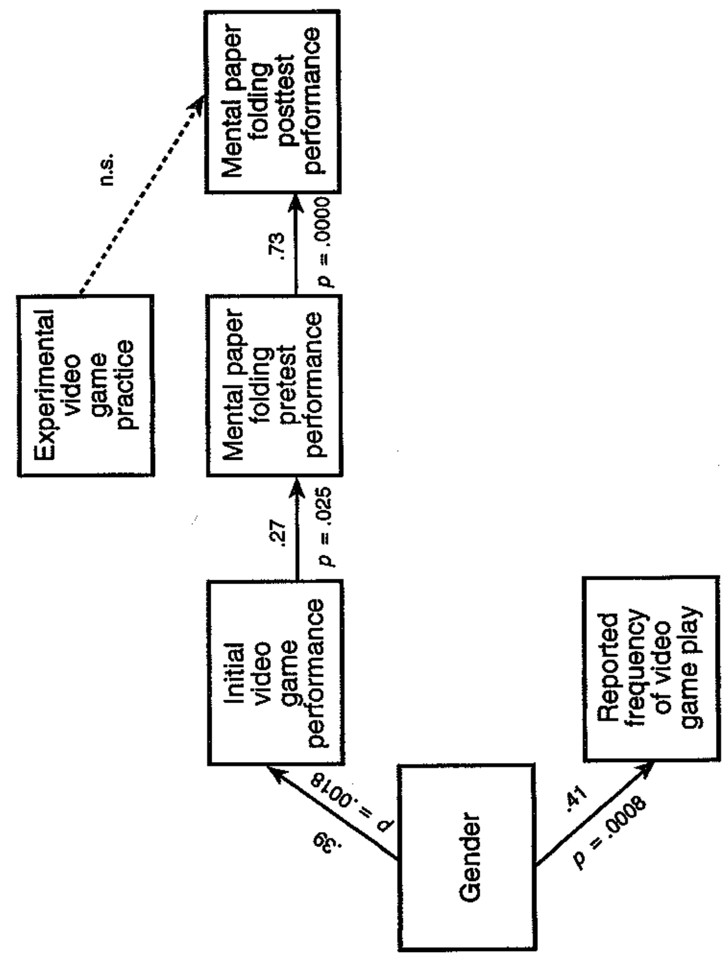


Figure 7

Relationship between video game playing and performance on a mental paper-folding task. From "Two-Dimensional Representation of Movement Through Three-Dimensional Space: The Role of Video Game Expertise," by P. M. Greenfield, C. Brannon, and D. Lohr, 1994, *Journal of Applied Developmental Psychology, 15*, p. 97. Copyright 1994 by Ablex. Reprinted with permission. (See also Greenfield & Cocking, 1996.)

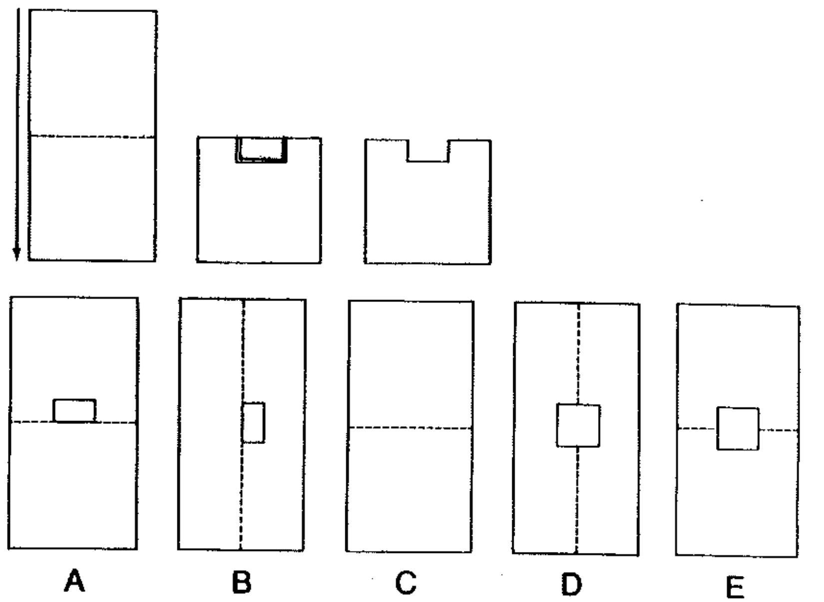


Figure 8

Practice item from the Stanford–Binet Mental Paperfolding Test. From *Stanford–Binet Intelligence Scale, Fourth Edition, Item Book 4* (p. 108), by Robert L. Thorndike, Elizabeth P. Hagen, and Jerome M. Sattler, 1986, Chicago: Riverside Publishing Company. Copyright 1986 by The Riverside Publishing Company. Reprinted with permission. All rights reserved.

folding is one of the subtests on the Stanford–Binet Intelligence Scale (see Figure 8 for a sample item). In this test, the experimenter first folds and cuts the sample (top row of the figure); the participant must look at the folded sample and select which of several choices (bottom row of figure) the unfolded sample will look like.

The message is the following: If video game expertise develops mental paper-folding skill as measured in an experimental situation, it should logically have the same effect on mental paper folding when this type of task appears on an IQ test.

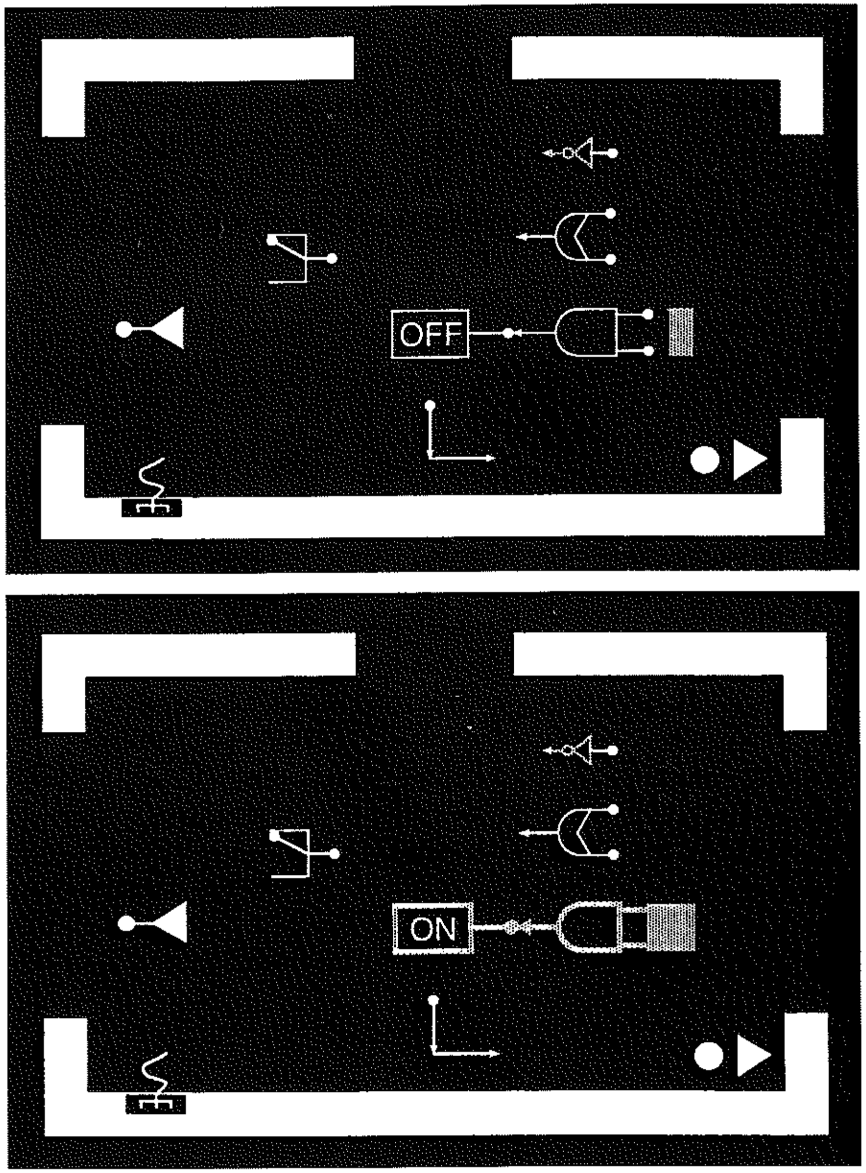
In sum, there is a suite of visual–spatial skills developed by video games that are also tested in nonverbal IQ assessment. It follows that the historical ascendance of popular video games would contribute to

the historical rise in nonverbal IQ. Indeed, this ascendance began within the span of years in which Flynn found a spurt in the rate of IQ increase in the United States (from 1972 to 1989).

Iconic Imagery

Film, television, video games, and computers all privilege iconic, or analog, representation over symbolic, or digital, representation. That is, they privilege image over word. This distinction between iconic and symbolic representation has a strong background in studies of cognitive development (Bruner, Olver, & Greenfield, 1966). For purposes of the present argument, the importance of iconic imagery in these communication media is that nonverbal IQ tests are also iconic in nature. Has experience with the iconicity of these media contributed to the historical rise in nonverbal IQ?

A cross-cultural study carried out in Los Angeles and Rome has provided some experimental results that are relevant to answering this question (Greenfield et al., 1994/1996). In fact, my colleagues and I demonstrated that a computer game can shift representational style from verbal to iconic. University students were required to write down their answers to a paper-and-pencil test of comprehension of an animated video display of the logic of computer circuitry. Figure 9 presents an example of one particular sequence in the animated displays; the sequences were taken from a piece of software called Rocky's Boot (Robinett, 1982). The two frames from this animated sequence, shown to participants on a video screen, demonstrate the operation of an *and*-circuit. An *and*-gate must receive energy input at both of two points to be activated. Activation causes energy to flow through the whole circuit; energy flow and activation are represented by the broader lines and lighter color and the switching of the sign from off to on in the figure. The rectangle shown in the figure represents an energy source. None of this was explained to the participants; they were simply asked to watch carefully and try to figure out what was going on so that they could answer questions about it afterward. After the animated simulation was shown to them, participants were given a paper-and-pencil test to assess their comprehension of the meaning of what they had just seen. Figure 10 shows some sample test items. One of these items



(middle of Figure 10) assesses understanding of the simulated *and*-circuit shown in Figure 9. The results showed that participants used three different modes of representation in communicating their answers to the experimenter. These three modes were verbal, iconic, and mixed; examples are shown in Figure 11.

The paper-and-pencil comprehension test was given before and after a number of conditions. Of special relevance for the present argument are two conditions: the memory game of Concentration played on a computer screen and the same memory game played on a board. The point of the game is to find identical pairs, in this case, pairs of numbers. In both versions, numbers hidden behind "doors" are arranged in a grid.

In the *computer version*, virtual doors are "opened" by a joystick controlling a cursor in the shape of a hand (see Figure 12). In the board version, doors (shown in Figure 13) are opened manually; for this reason, this was termed the *mechanical version.*

Most relevant to the present argument is the fact that communication about the animated computer simulation became more iconic and less symbolic after participants played the computer game, but not after they played the same game on the board. The computer medium was the decisive factor. This finding is important for explaining the historical rise in performance IQ: Iconic images and diagrams are basic to all of the nonverbal performance tests. If modern computer tech-

Figure 9

(*Facing page*) Sequence from an animated video display of the logic of computer circuitry (Rocky's Boot; Robinett, 1982). In the top frame of the animated video display, the energy source is not touching the two input contacts of the *and*-gate; therefore, the circuit is not activated and the sign is switched off. In the bottom frame, the energy source has been moved to touch the two input contacts of the *and*-gate, thereby activating the circuit and turning the sign on. From "Cognitive Socialization by Computer Games in Two Countries: Inductive Discovery or Mastery of an Iconic Code," by P. M. Greenfield, L. Camaioni, P. Ercolani, L. Weiss, B. A. Lauber, and P. Perucchini, 1994, *Journal of Applied Developmental Psychology, 15,* p. 69. Copyright 1994 by Ablex. Reprinted with permission. (See also Greenfield & Cocking, 1996.)

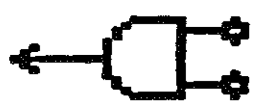
NAME:

DATE: **FORM B**

What does this represent? 

What is its function?

How would you get the orange color to flow through the following game elements?



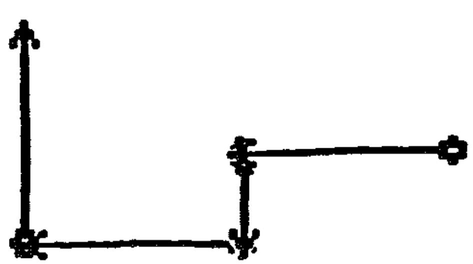


Figure 10

(*Facing page*) Sample items from the test of comprehension of the animated video display of the logic of computer circuitry. From "Cognitive Socialization by Computer Games in Two Countries: Inductive Discovery or Mastery of an Iconic Code," by P. M. Greenfield, L. Camaioni, P. Ercolani, L. Weiss, B. A. Lauber, and P. Perucchini, 1994, *Journal of Applied Developmental Psychology, 15,* p. 71. Copyright 1994 by Ablex. Reprinted with permission. (See also Greenfield & Cocking, 1996.)

nology is making people more iconic in their style of representation, it follows logically that people will do better on nonverbal IQ tests.

The cross-cultural findings were also relevant to the argument. Before being exposed to any experimental treatments, university students in Rome were predominantly symbolic in their representations,

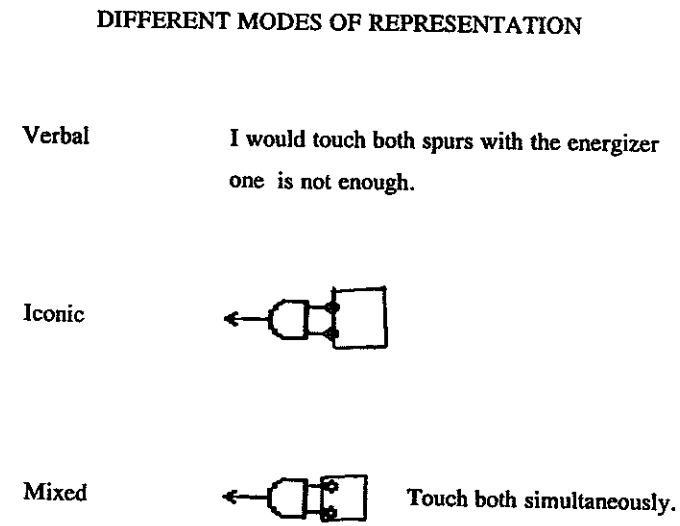
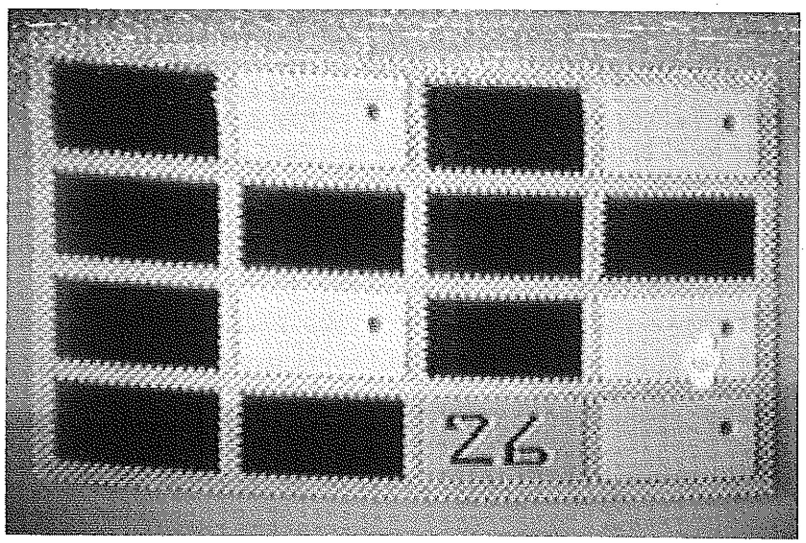


Figure 11

Examples of different modes of representation: Verbal, iconic, and mixed. These examples are responses to the questions about an *and*-gate. From "Cognitive Socialization by Computer Games in Two Countries: Inductive Discovery or Mastery of an Iconic Code," by P. M. Greenfield, L. Camaioni, P. Ercolani, L. Weiss, B. A. Lauber, and P. Perucchini, 1994, *Journal of Applied Developmental Psychology, 15,* p. 73. Copyright 1994 by Ablex. Reprinted with permission. (See also Greenfield & Cocking, 1996.)

A



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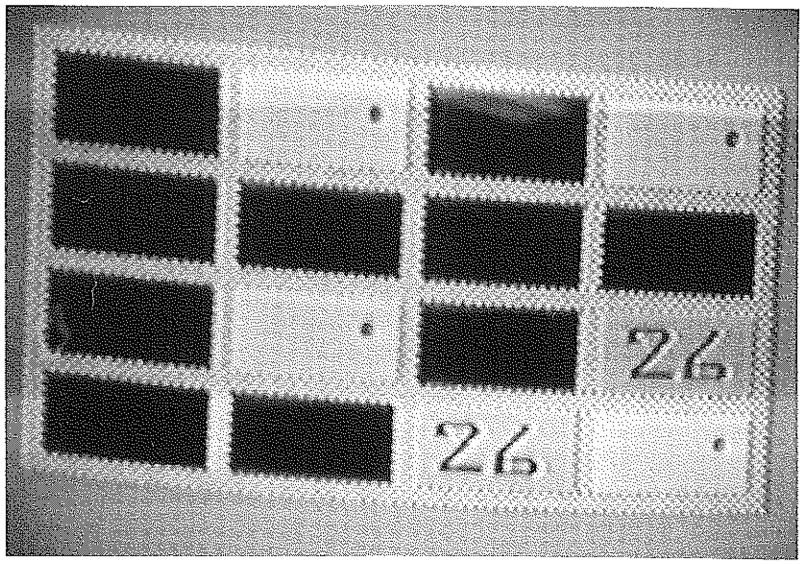

Figure 12

Computer version of memory game Concentration. (A) Player has found one *26* and placed the cursor to open a second "virtual door." (B) The door has opened, revealing a successful search for the matching *26*.

Figure 13

Mechanical version of Concentration memory game. Each door has a knob that lifts up. A pair of *66*s has been found.

whereas students in Los Angeles were predominantly iconic; this difference was statistically significant. Its cause, we hypothesized, lay in the greater diffusion in the United States, compared with Italy (in the late 1980s), of all the electronic media that feature iconic imagery. Whereas the experimental effect described earlier implicates a causal mechanism for enhanced use of iconic imagery, this cross-cultural population difference implicates the role of the everyday environment in producing the real-world effect. The two findings complement each other; together, they suggest that the use of iconic imagery, not only in an experimental situation but also in the everyday environment, can have an impact on representational habits. It is therefore likely and logical that part of this real-world effect occurs on nonverbal intelligence tests.

The Raven Progressive Matrices and Cultural Bias

One might ask why the Raven is so culturally sensitive. The Raven is the test most often used to demonstrate large historical gains in performance IQ (Flynn 1984, 1987). It was designed to be "culture free." More recent terminology has included "culture fair" and "culture reduced." However, all these terms are misnomers. Instead, the Raven constitutes a conventionalized cultural genre.

The matrix is a culture-specific form of visual representation. To solve matrix problems, one must understand the complex representational framework in which they are presented. Figure 14 presents an example of a simple item from the Raven. To solve this or any other matrix item, one needs to know, for example, that a matrix is organized in rows and columns (Figure 14). Matrices presuppose much more than "acquaintance with certain simple shapes" (Flynn, 1994, p. 620).

The next sample (Figure 15) is a more complex item, developed by Carpenter, Just, and Shell (1990) to be analogous to items on the Raven. It illustrates additional conventionalized knowledge required by the test. It requires understanding of an ordinal relationship among the columns and among the rows as well as specific knowledge concerning what mental operations are relevant to perform on the test matrix. This item involves the figure addition rule (Carpenter et al., 1990): The operation of adding the black part of the figures from each row from left to right yields the figures in the far right column; the operation of adding the black part of the figures in a column from top to bottom yields the figures in the bottom row. In fact, research has shown that there are five rules that can generate all of the answers to matrix items (Carpenter et al., 1990). The understanding of these rules is culture specific. There is nothing in the matrix figures themselves that tells what operations to perform on them.

Indeed, I would like to make the case that the comprehension of matrices is socialized and taught in a particular cultural environment, the school. My evidence comes from research in Nabenchauk, a Zinacante Maya community in Chiapas, Mexico. There, the first matrices, cross-stitch patterns laid out on graph paper, were introduced into the

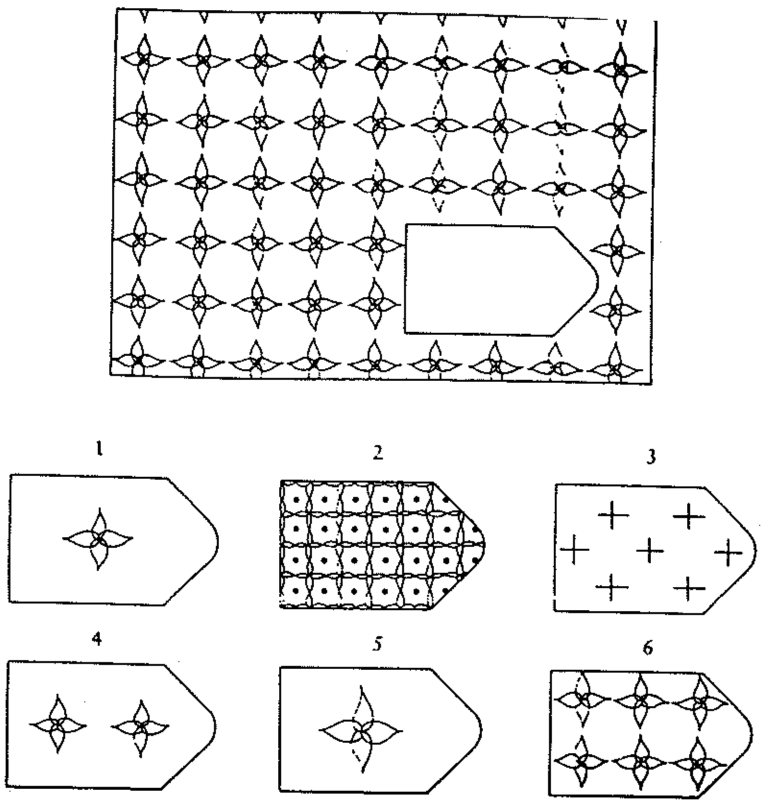

Figure 14

An example of a simple item from the Raven Standard Progressive Matrices. From the six inserts at the bottom of the figure, the participant must select the one that logically fits in the matrix above. Figure A5 of the Raven Standard Progressive Matrices, by J. C. Raven. Copyright 1938, 1976 by J. C. Raven Ltd. Reprinted with permission.

then agrarian community by school teachers. A more recent example is shown in Figure 16.

Currently, our research shows a statistically significant association between use of these patterns and some (vs. no) schooling (Greenfield & Maynard, 1997). That is, women who have had a few years of schooling are significantly more likely to use these patterns for embroidery or weaving than women who have never been to school. However, note

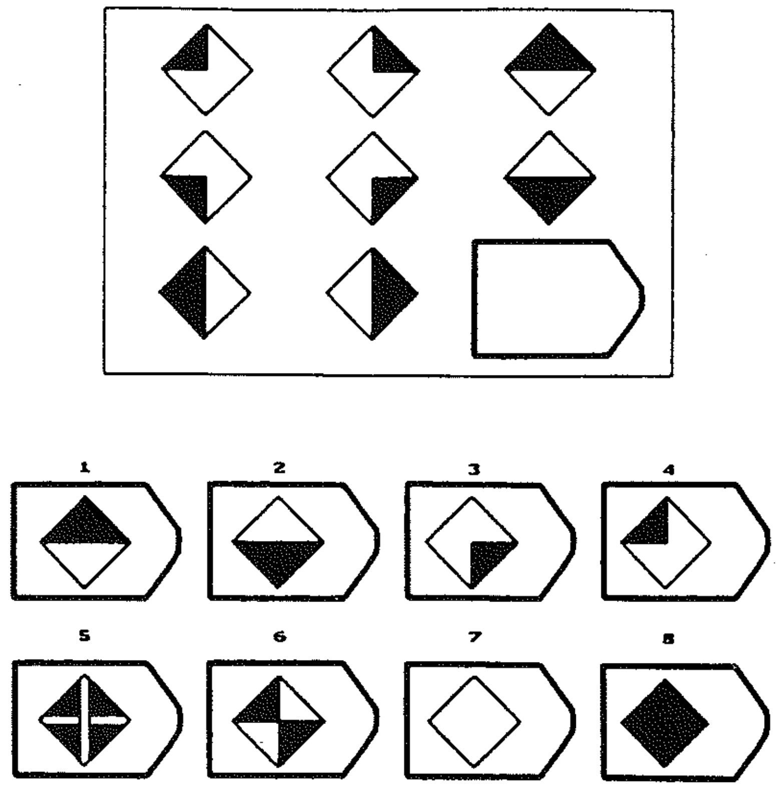

Figure 15

An example of an additive matrix item. The correct answer is *8*. From "What One Intelligence Test Measures: A Theoretical Account of the Processing in the Raven Progressive Matrices Test," by P. A. Carpenter, M. A. Just, and P. Shell, 1990, *Psychological Review, 97*, p. 409. Copyright 1990 by the American Psychological Association. Reprinted with permission.

that this, the only matrix in the Zinacantec cultural environment, does not involve any ordinal relationship between columns and rows. The matrix is used simply to indicate relative positions that can be used in transferring the pattern from paper to textile, either embroidered or woven. This is the simplest form of matrix; however, experience with it could form a cognitive foundation for ordered matrices, which could be introduced at a later point.

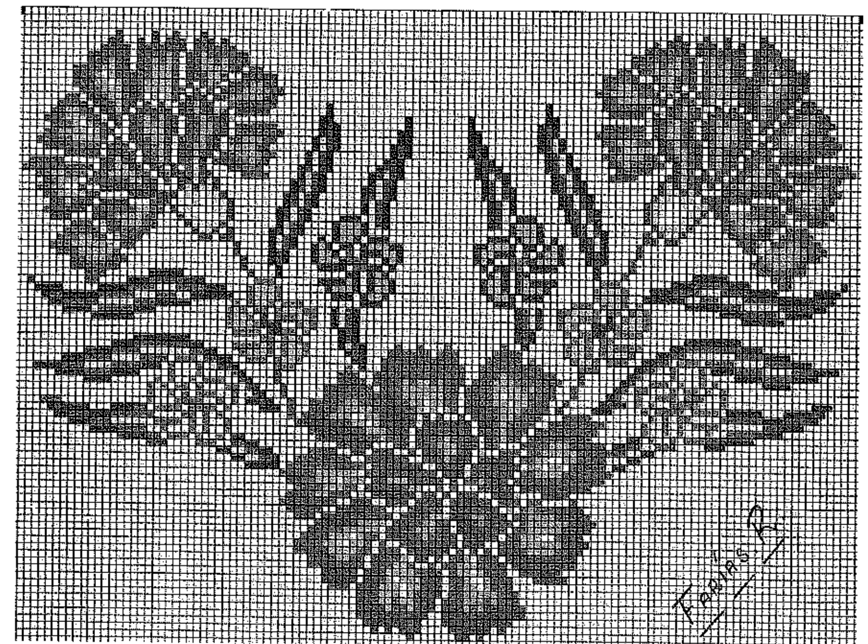

Figure 16

Cross-stitch pattern laid out on graph paper. The first type of matrix in use by the Zinacantec Maya in Chiapas, Mexico.

The association of schooling and use of cross-stitch patterns among the Zinacantec Maya people suggests that historically, in U.S. society, the advancement of basic literacy (which has continued even into the current century) would have improved performance on the Raven. In addition, higher levels of schooling seem required for the complex matrices on the Raven that combine multiple rules. Ombredane (1956, cited in Wober, 1975) reported a study in Africa that found divergence on the Raven between schooled and unschooled persons beginning at age 12–13 years. This finding could be extremely relevant to the Flynn effect for particular periods in different countries when postprimary education was greatly expanded. For example, there was a 10-fold increase in rates of secondary education in the United States in the first third of the 20th century (*Encyclopaedia Britannica*, 1972).

In addition, the use of matrices has become increasingly culturally diffused in recent years in the United States and other technologically advanced countries because of computers; a good example is the use of popular spreadsheet programs such as Microsoft Excel. These programs are simply blank matrices, organized by columns and rows, to be filled in by the user. Clearly, such a program requires users to represent their data mentally in matrix form, while providing practice in the use of this representational format.

From Film to Video Games: Shifting Visual Perspective

Another visual skill required by some performance tests is the ability to shift visual perspective. There are two major points concerning this skill. First, such tests are based on culture-specific conventions for representing spatial information and require culture-specific knowledge. Figure 17 provides an example of a spatial ability item that requires a shift in imagined perspective. This item from the Guilford–Zimmerman Aptitude Survey requires one to identify the upside-down alarm clock on the left, mentally rotate it a quarter turn to the right, as indicated by the ball with an arrow on it; and finally match the resulting visual perspective with one of the five choices on the right.

This item is extremely culture specific. Note that it requires knowl-

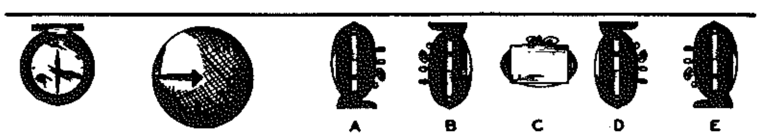

Figure 17

An item from the Guilford–Zimmerman Aptitude Survey: IV. Spatial visualization, Form B, 1953. From "Further Evidence of Sex-Linked Major-Gene Influence on Human Spatial Visualizing Ability," by R. D. Bock and D. Kolakowski, 1973, *American Journal of Human Genetics, 25*, p. 2. Copyright 1973 by the University of Chicago Press. Reprinted with permission.

edge of what the back of an alarm clock looks like. It also requires knowledge of the arrow as a visual symbol as well as even more specific knowledge that the arrow as portrayed does not symbolize a horizontal direction on a flat plane but rather represents rotation in the third dimension.

The second major point is that this culturally based skill in mentally shifting visual perspective has been used and developed, in turn, by the cultural technologies and genres of film and video games. Compare the test item shown in Figure 17 with the item shown in Figure 18. The latter is drawn from an analogous test of shifting visual perspective, one that has been shown to be related to the understanding of film editing techniques (Salomon, 1979). Such techniques can be used to show different perspectives on a scene; an example is the classic reaction shot, in which views of two faces interacting with each other are intercut in alternation.

Video games require and develop even more than film in the arena of visual perspective-taking skills. First, video games provide much more incentive to understand shifting perspectives (or any other visual convention) than does film; to fail to understand is to fail at the game. The player, moreover, must not only understand shifts of visual perspective but also actively coordinate them in playing the game. Figure 19 provides an example of a video game from the 1980s that requires the player to coordinate mentally two visual perspectives. This game, called Tranquility Base, involves coordinating a long shot and a close-up of terrain, as players land their spacecraft. Such coordination of perspectives has become ever more complex as the games have evolved and become more realistic; the advent of CD-ROM games such as Earthsiege, with its multiple three-dimensional perspectives, has increased the complexity even more.

But in the domain of computer technology, the representation of shifting perspective is not limited to video games. Complex perspective shifts and coordination are also intrinsic to using computer-assisted design (CAD) software for the home and popular programs like Adobe Photoshop. Of course, certain professions like architecture and photography here always required the ability to represent and comprehend

The Modest Rise in Verbal IQ Scores and the Considerable Decline in Verbal SAT Scores

My analysis of mechanisms turns now to the modest historical rise in verbal IQ, combined with a simultaneous decline in verbal SAT scores. I begin by considering the role of vocabulary in creating this apparent paradox. Vocabulary is one of the most important motors for both verbal IQ and verbal SAT scores. My first hypothesis is that television has driven basic vocabulary up a bit in the population as a whole (verbal IQ) but that the decline of reading for pleasure (Beentjes & Van der Voort, 1988; Duchein, 1993) has driven the literary vocabulary required by the verbal SAT down. My second hypothesis is that the context-dependent grammatical structures favored by television and telephone differ from the context-independent structures that are so crucial for the verbal SATs. My third hypothesis is that the very nature of literature is being transformed by the electronic media. Each of these hypotheses will be developed more fully.

Vocabulary Development

There is evidence that vocabulary is learned from TV (Ball & Bogatz, 1970; Bogatz & Ball, 1971; Rice, Huston, Truglio, & Wright, 1990), which is a mass medium. However, this product of TV is a basic vocabulary, because the vocabulary of television is quite a limited one. On the basis of talking to teachers, Healy reported that "unless students read a lot on their own, their vocabulary growth slows down somewhere near the fourth grade level—approximately the level of media language" (1990, p. 100).

Similarly, the vocabulary used on IQ tests such as the Wechsler is quite basic. This, however, is not true of the vocabulary used on the verbal SAT, which is a more literary vocabulary. Compare the vocabulary list that must be defined for the vocabulary subtest of the WAIS-R (Wechsler, 1981) with a sample vocabulary list from the antonym section of the verbal SAT (Brownstein, Weiner, & Green, 1989). The range of difficulty of the two lists is quite different. The WAIS-R vocabulary subtest ranges from *bed* and *ship* (practice items) to more difficult items like *vehement* or *fallacious* (simulation items). In contrast,

the range of the practice SAT antonym test is much harder; it runs from *fertile* to *stolid* and *expatiate*. One can imagine *vehement* being used on a TV talk show. However, it is difficult to imagine items such as *expatiate* ever being used in such a context.

This analysis is confirmed by research. Holding education constant, Glenn (1994) found a decline in vocabulary between 1974 and 1990 (cf. the work of Huang & Hauser, chapter 12, this volume). This decline was associated with a decline in the reading of newspapers and other print sources. One of the sources of the reading decline was the rise of television viewing.

Grammar

The verbal SAT requires analysis of passages from literature and science. TV ill prepares the viewers for the complex syntax that such passages use. TV shows for children use significantly more simple sentences and significantly fewer complex sentences than do children's picture books (Fasick, 1973). Content analysis of TV shows for children has also shown that the most common sentence structure in this genre is the incomplete sentence. Children's picture books, in contrast, use significantly more complete sentences (Fasick, 1973). Clearly, comparable comparisons of adult books and TV shows would reveal the same pattern.

The relative frequency of the incomplete sentence on TV has important significance for the verbal SAT, which tests the use of *decontextualized language*. Reading-comprehension passages on the SAT are decontextualized in the sense that all the information needed to answer a question must be found in the passage. If students use any outside knowledge to answer the questions, they are in trouble. TV language, in sharp contrast, is not decontextualized. As in face-to-face conversations, the propositions or ideas in those incomplete sentences are completed by the visual image.

One way in which the *contextualized* communication of television as a visual medium is manifest is in the high frequency of vague reference, that is, the use of pronouns or general terms of reference without antecedents that specify the referent. In television, the visual context is often relied on to provide this specification. In purely verbal media such as print or radio, the linguistic message must be self-contained. For example, Greenfield (1984) found that the announcer in a televized broadcast of a baseball game often took the identity of the batter for granted in announcing what the batter did. Faced with the same situation, a radio announcer always identified the batter. Compared with his colleague on TV, his verbal messages were more context independent.

There is also evidence that this phenomenon has a cognitive effect on the viewer. My colleagues and I did an experimental study comparing recall of radio and TV in elementary schoolchildren (Greenfield & Beagles-Roos, 1988). Recall of a TV story elicited more vague reference (e.g., using "he" or "she" or "it" without prior specification of the referent) than did recall of the same radio story by a given child. The same mechanism was at work: The participant was letting memory of an image tell part of the story (even though participants had been told that the listener had not viewed the story). The hypothesis is that this mode of processing and communicating information is a detriment to performance on the comprehension part of the verbal SAT. These passages must be comprehended without reference to any extralinguistic images.

Another area in which electronic media have promoted more contextualized language use than their predecessors is in the replacement of letter writing by telephone calls and now electronic mail. In telephone conversations particularly, the sentences of one person are conventionally completed by the conversational partner. An example is in the following interchange: "How are you?" "Fine." The second person does not make the complete sentence "I am fine." That would be considered impolitely redundant; instead, the second person uses the informational context provided by the first person to specify to whom "fine" refers. The same information would be conveyed in a letter by a complete sentence (e.g., "I am fine"). Similarly in electronic mail, replies often include the instigating message and depend informationally on its context. For example, I find myself often replying to an electronically mailed suggestion for action by simply attaching the single word *okay* to the message sent to me. Hence, the ascendance of these new forms

of communication, along with the concomitant decline of letter writing, provides more practice in contextualized forms of verbal communication and less practice in decontextualized forms.

The Transformation of Literature by Electronic Media

Popular literature is more and more derived from television and film (e.g., the popular book about the TV show *The Real, Real World* and the numerous bestsellers resulting from the televised trial of O. J. Simpson). Popular literature has also become increasingly visual and interactive (e.g., the electronically assisted push-button book starring the outrageous animated TV characters Beavis and Butthead; Doyle, 1995). Literature becomes increasingly like TV. Because of this transformation of print by the electronic media, it follows that even the written vocabulary and grammar to which people are exposed is becoming increasingly basic.

In summary, TV slightly raises the average level of vocabulary on a mass scale; however, with the decline of reading purely literary works for pleasure and the increase of popular literature derived from television, the literary vocabulary required on the verbal SAT does not get developed. In addition, TV, telephone, and electronic mail develop contextualized language use, whereas reading literary works and writing letters develop the decontextualized language (Greenfield, 1972) required by the verbal SAT. From a historical perspective, TV has been in ascendance since the 1940s in the United States; the telephone's ascendance as a mass medium began at the end of the 19th century (Schwartz, 1994). The relative importance of print, both reading and writing, has been in a corresponding decline, particularly the reading of purely literary works for pleasure and the writing of letters.

CONCLUSION

There has been a change in the balance of print and visual media with the development of new modes of technology and visual communication; the balance has shifted toward images and diagrams (chapter 5, this volume). This change has produced the pattern of the Flynn effect, involving greater historical gains on visual and spatial than on verbal intelligence tests. For the United States, the focus on these technologies in the present chapter is consistent with Flynn's recent finding of an IQ spurt in this country between 1972 and 1989 (chapter 2, this volume); in other words, the Flynn effect accelerated in this period. Such a spurt is exactly what my model would predict. Because of its interactivity, I would expect modern computer technology, which became a mass medium in this period, to accelerate the Flynn effect on visual tests. Unlike film, computers provide constant feedback that should accelerate the development of the visual skills they require. Finally, I believe that the visual skills required by current games—such as Earthsiege, where, for example, the game is played from the visual perspective of both robots and the planes that oppose them (*Interaction*, 1996, p. 17)—have far outpaced the difficulty level of current nonverbal IQ tests. (A similar point is made by Williams in chapter 5, this volume.) It would not surprise me if ceiling effects had begun to show up on performance IQ tests.

The analysis presented in this chapter leads to the conclusion that nonverbal IQ tests are, in fact, more, not less, culture sensitive than verbal tests. Indeed, this fact has been known since the 1950s, mainly because of research in Africa (see Wober, 1975, for an excellent summary of research on ability testing in Africa). Why is this the case? One important part of the answer is that verbal tests get translated, whereas nonverbal ones do not, yet nonverbal, or performance, tests do rely on their own language of visual conventions. As I have shown, even the term *culture reduced* is a misnomer for visual tests such as the Raven Progressive Matrices.

If IQ Is Going Up, Are People Becoming More Intelligent?

This is an important question raised by Flynn (1984, 1987, 1994). My answer is *yes*, but in very specific ways. These ways include everyday examples such as provided by the legion of computer-literate hackers. They also include creative leaps. The recent discovery of a new muscle in the jaw by a dentist, Dr. Gary Hack, is just such an example. The report on National Public Radio news is instructive for this purpose.

> Robert Siegel: Now, the question that your discovery provoked immediately was how can somebody find anything new in a field so long gone over as anatomy and human anatomy of the head?
>
> Dr. Gary Hack: The anatomy textbooks teach a very precise way of dissecting this area, and that is from the side of the head. You go in from the side to this area behind the eye. If you do that, you cannot appreciate this structure. You must go from the front of the head, which is a novel and unique approach. But if you keep an open mind that there are new structures to be found and that to truly understand three-dimensional relationships, you must dissect from unique and novel approaches, you see things that others have not appreciated. (*All things considered*, 1996)

The preceding dialogue indicates that this creative discovery of a new muscle in the jaw was a result of the development of perspective-taking abilities, the same ones used in film and TV (cf. Figure 18) and in video games and software applications such as CAD software and Adobe Photoshop. Informal educational experiences with video games and other perspective-switching software would, I hypothesize, provide a certain type of cognitive socialization. In the course of this socialization, these external software tools would be appropriated and become internal cognitive tools (Salomon, Perkins, & Globerson, 1991; Saxe, 1991). As internal tools, they can be used for discoveries, such as that made by Dr. Hack.

The Cultural Evolution of IQ

To conclude, the Flynn effect is an example of the historical evolution of culturally phenotypic intelligence, as depicted in Figure 1. It is not the evolution of "general intelligence." However, the fact is that general intelligence must always be instantiated in a specific cultural form. Culture takes general intelligence and makes it specific.

REFERENCES

All things considered. (1996, February 14). *NPR Fax Service, No. 025,* pp. 2–3.

Arkana, M. L., & Snow, M. (1978). *Psychological tests and social work practice.* Springfield, IL: Charles C Thomas.

Ball, S., & Bogatz, G. (1970). *The first year of Sesame St.* Princeton, NJ: Educational Testing Service.

Beentjes, J., & Van der Voort, T. (1988). Television's impact on children's reading skills: A review of research. *Reading Research Quarterly, 23,* 389–413.

Bock, R. D., & Kolakowski, D. (1973). Further evidence of sex-linked major-gene influence on human spatial visualizing ability. *American Journal of Human Genetics, 25,* 1–14.

Bogatz, G., & Ball, S. (1971). *The second year of Sesame St.* Princeton, NJ: Educational Testing Service.

Brownstein, S. C., Weiner, M., & Green, S. W. (1989). *How to prepare for the Scholastic Aptitude Test* (SAT., 15th ed.) New York: Barron.

Bruner, J. S., Olver, R. R., & Greenfield, P. M. (1966). *Studies in cognitive growth.* New York: Wiley.

Cahan, S., & Cohen, N. (1989). Age versus schooling effects on intelligence development. *Child Development, 60,* 1239–1249.

Carpenter, P. A., Just, M. A., & Shell, P. (1990). What one intelligence test measures: A theoretical account of the processing in the Raven Progressive Matrices test. *Psychological Review, 97,* 404–431.

Cole, M., & Cole, S. R. (1993). *The development of children.* New York: Scientific American Books.

Dasen, P. (1984). The cross-cultural study of intelligence: Piaget and the Baolé. In P. S. Fry (Ed.), *Changing conceptions of intelligence and intellectual functioning: Current theory and research* (pp. 107–134). Amsterdam: North Holland.

Doyle, L. (1995). *This sucks, change it!* New York: Pocket Books.

Duchein, M. A. (1993). Remembrance of books past . . . long past: Glimpses into aliteracy. *Reading Research and Instruction, 33,* 13–28.

Duranti, A., & Ochs, E. (1986). Literacy instruction in a Samoan village. In B. B. Schieffelin & P. Gilmore (Eds.), *Acquisition of literacy: Ethnographic perspectives* (pp. 213–232). Norwood, NJ: Ablex.

Encyclopaedia Britannica. (1938). United States. In *1938 Britannica book of the year* (pp. 677–688). Chicago: Author.

Encyclopaedia Britannica. (1972). United States (Vol. 22, pp. 578–742). Chicago: Author.

Encyclopaedia Britannica. (1990). United States. In *1990 Britannica book of the year* (pp. 740–743). Chicago: Author.

Encyclopaedia Britannica. (1994). United States (Vol. 29, pp. 149–457). Chicago: Author.

Fasick, A. M. (1973, February). Television language and book language. *Elementary School English,* pp. 125–131.

Flynn, J. R. (1984). The mean IQ of Americans: Massive gains 1932–1978. *Psychological Bulletin, 95,* 29–51.

Flynn, J. R. (1987). Massive IQ gains in 14 nations: What IQ tests really measure. *Psychological Bulletin, 101,* 171–191.

Flynn, J. R. (1994). IQ gains over time. In R. J. Sternberg (Ed.), *Encyclopedia of human intelligence* (pp. 617–623). New York: Macmillan.

Glenn, N. D. (1994). Television watching, newspaper reading, and cohort differences in verbal ability. *Sociology of Education, 67,* 216–230.

Greenfield, P. M. (1972). Oral or written language: The consequences for cognitive development in Africa, the United States and England. *Language and Speech, 15,* 168–178.

Greenfield, P. M. (1984). *Mind and media: The effects of television, video games, and computers.* Cambridge, MA: Harvard University Press.

Greenfield, P. M., & Beagles-Roos, J. (1988). Radio vs. television: Their cognitive impact on children of different socioeconomic and ethnic groups. *Journal of Communication, 38*(2), 71–92.

Greenfield, P. M., Brannon, C., & Lohr, D. (1994). Two-dimensional representation of movement through three-dimensional space. *Journal of Applied Developmental Psychology, 15,* 87–103. Reprinted in P. M. Greenfield & R. R. Cocking (Eds.), 1996. *Interacting with video* (pp. 169–185). Greenwich, CT: Ablex.

Greenfield, P. M., Camaioni, L., Ercolani, P., Weiss, L., Lauber, B. A., & Perucchini, P. (1994). Cognitive socialization by computer games in two countries: Inductive discovery or mastery of iconic code? *Journal of Applied Developmental Psychology, 15,* 59–85. Reprinted in P. M. Greenfield & R. R. Cocking (Eds.). (1996). *Interacting with video* (pp. 141–167). Greenwich, CT: Ablex.

Greenfield, P., & Maynard, A. (1997). *Women, girls, apprenticeship, and school-*

ing: A longitudinal study of historical change among the Zinacantecan Maya. Washington, DC: American Anthropological Association.

Healy, J. M. (1990). *Endangered minds: Why children don't think and what we can do about it.* New York: Simon & Schuster.

Interaction. (1996, Spring). Bellevue, WA: Sierra On-Line.

Klineberg, O. (1935). *Race differences.* New York: Harper & Row.

Laosa, L. (1978). Maternal teaching strategies in Chicano families of varied educational and socioeconomic levels. *Child Development, 49,* 1129–1135.

McFie, J. (1961). The effect of education on African performance on a group of intellectual tests. *British Journal of Educational Psychology, 31,* 232–240.

Mundy-Castle, A. C. (1974). Social and technological intelligence in Western and non-Western cultures. *Universititas, 4,* 46–52.

Neisser, U. (1976). General, academic, and artificial intelligence. In L. Resnick (Ed.), *The nature of intelligence* (pp. 135–144). Hillsdale, NJ: Erlbaum.

Okagaki, L., & Frensch, P. A. (1994). Effects of video game playing on measures of spatial performance: Gender effects in late adolescence. *Journal of Applied Developmental Psychology, 15,* 33–58. Reprinted in Greenfield, P. M., & Cocking, R. R. (Eds.). (1996). *Interacting with video* (pp. 115–140). Greenwich, CT: Ablex.

Ombredane, A. (1956). Etude psychologique des Noirs Asalampasu. I. Le comportement intellectuel dans l'épreuve du Matrix-Couleur. *Mémoires de l'Academie Royale des Sciences Coloniales, 1re Classe, 6,* fasc. 3.

Ombredane, A., Robaye, F., & Robaye, E. (1957). Etude psychotechnique des Baluba. Application experimentale du test d'intelligence. Matrix 38 à 485 noirs Baluba. *Mémoires de l'Academie Royale des Sciences Coloniales, 1re Classe, 6,* fasc. 5.

Ramey, C. (1996, April). Mother–child interaction and intelligence. In *Intelligence on the rise? Secular changes in I.Q. and related measures.* Paper presented at a conference sponsored by the Emory Cognition Project and the American Psychological Association, Atlanta, Georgia.

Rice, M. L., Huston, A. C., Truglio, R., & Wright, J. C. (1990). Words from Sesame St.: Learning vocabulary while viewing. *Developmental Psychology, 26,* 421–428.

Robinett, W. (1982). *Rocky's boot.* Portola Valley, CA: Learning Company.

Salomon, G. (1979). *Interactions of media, cognition and learning.* San Francisco: Jossey-Bass.

Salomon, G., Perkins, D. N., & Globerson, T. (1991). Partners in cognition:

Extending human intelligence with intelligent technologies. *Educational Research, 20*(3), 2–9.

Saxe, G. (1991). *Culture and cognitive development.* Hillsdale, NJ: Erlbaum.

Scheibel, A. (1996, March). *Introduction to Symposium on the Evolution of Intelligence.* Center for the Study of Evolution and the Origin of Life, University of California, Los Angeles.

Schmidt, W. H. O. (1960). School and intelligence. *International Review of Education, 6,* 416–430.

Schwartz, M. (Ed.). (1994). Telecommunication systems. In *Encyclopaedia Britannica* (Vol. 28, pp. 473–504). Chicago: Encyclopaedia Britannica.

Scriven, M. (1987). Taking games seriously. *Education Research and Perspectives, 14*(1), 82–135.

Serpell, R. (1993). *The significance of schooling: Life journeys in an African society.* Cambridge, England: Cambridge University Press.

Thorndike, R. L., Hagen, E. P., & Sattler, J. M. (1986). *Stanford–Binet Intelligence Scale, Item Book 4.* Chicago: Riverside.

Uribe, F. M. T., LeVine, R. A., & LeVine, S. E. (1994). Maternal behavior in a Mexican community: The changing environments of children. In P. M. Greenfield & R. R. Cocking (Eds.), *Cross-cultural roots of minority child development* (pp. 41–54). Hillsdale, NJ: Erlbaum.

Wechsler, D. (1981). *WAIS-R manual.* Cleveland, OH: The Psychological Corporation.

Wechsler, D. (1991). *WISC-III manual.* Cleveland, OH: The Psychological Corporation.

Wheeler, L. R. (1970). A trans-decade comparison of the IQ's of Tennessee mountain children. In I. Al-Issa & W. Dennis (Eds.), *Cross-cultural studies of behavior* (pp. 120–133). New York: Holt, Rinehart & Winston.

Wober, M. (1974). Towards an understanding of the Kinganda concept of intelligence. In J. W. Berry & P. R. Dasen (Eds.), *Culture and cognition* (pp. 261–280). London: Methuen.

Wober, M. (1975). *Psychology in Africa.* London: International African Institute.