10 Representational Competence in Shared Symbol Systems: Electronic Media from Radio to Video Games

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A central aspect of human cognitive processes is representational competence. Sigel and Cocking (1977) define representational competence as the capability of the individual to comprehend the *equivalence* of various modes of representation. At the same time, they see the development of an understanding of various media of representation, such as pictures, verbalizations, and gestures, as part of representational competence.

Cognitive processes—the basic processes by which we taken in, transform, remember, create, and communicate information—are universal. But a culture has the power to selectively encourage some cognitive processes, letting others stay in a relatively undeveloped state. As shared symbol systems, media are potent cultural tools for the selective sculpting of profiles of cognitive processes. A medium is not simply an information channel; as a particular mode of representation, it is also a potential influence on information processing. The notion of symbol systems as cultural tools for cognitive development can be traced back to, among others, Vygotsky (1962, 1978) and Bruner (1965, 1966). As applied to media, this notion was importantly expanded by Bruner and Olson (1974).

While individuals respond to and even create media, mass media are also cultural tools. They are both a shared cultural product and a shared cultural representation. To their audience, including children, media not only present culturally relevant content, they also present models and opportunities for particular representational processes.

Each medium has its particular design features such that it presents certain kinds of information easily and well and other kinds with difficulty and poorly. Each medium therefore presents certain opportunities to construct particular kinds of representations. As a consequence, each medium stimulates different kinds of representational processes. Therefore, a second aspect of representational competence must be the ability of an individual to comprehend differences between different modes of representation; such comprehension involves a metacognitive level of awareness. At the level of cognitive, rather than metacognitive, processes lies the ability to comprehend and use, to adapt to, different modes or media of representation.

The discrepancy between the perspectives of Sigel and those of Vygotsky and Bruner lies in Sigel's (1978, 1986) notion of conservation of meaning, the idea that "meaning is retained in spite of media transformations" (Sigel, 1986, p. 52). However, conservation of meaning across transformations of medium is only partial. In any transformation (including the classical Piagetian conservation tests), some things stay the same, while others change. This chapter addresses the meaning changes in the translation of a single content from one medium to another. Specifically, the term *cognitive socialization* is used to refer to the influence of cultural tools on the development and exercise of skills for processing and communicating information. Media are considered in terms of their role as tools of cognitive socialization.

Sigel (1970) identified psychological distancing strategies as a particular category of techniques for the cognitive socialization of representational competence. They are social behaviors that "create discrepancies and require representational thinking for their resolution" (Sigel, 1986, p. 52). In Sigel's research on distancing strategies, the emphasis is on the social experiences created by parents and teachers (e.g., Sigel, 1986). But children of today spend more time with video screens than with teachers and parents (National Institute of Mental Health, 1982). What are the implications of this fact for representational competence? The rest of my chapter attempts to answer this question.

A TRANSFORMATION OF MEDIUM YIELDS ONLY PARTIAL CONSERVATION OF MEANING

Two studies that compare the effects of an audio (radio) versus an audiovisual (television) medium on children's representational processes are summarized next (Greenfield, Farrar, & Beagles-Roos, 1986; Greenfield & Beagles-Roos, 1988). Using techniques based on Meringoff (1980), the studies explored the effects of adding moving visual imagery to an audio narrative. In essence, the questions being investigated involved the effects of external, cultural representations, produced in different media, on the internal representational processes of individual children.

For each study, the stimuli consisted of two narrated stories, based on children's picture books (Haley, 1970; dePaola, 1975). Each story had both a video version (produced at Weston Woods Studios) and an audio version with the exact same soundtrack. With appropriate counterbalancing of media and stories, each

child in each study was exposed to one story in the audio version, the other story in the audiovisual version. One study focused on imaginal representation, the other on memory representation.

For the imagination study, the story was stopped a slight bit before its ending and first through fourth graders were individually asked to continue the story orally. The children's representational construction of elements that had not appeared in the stimulus story constituted our basic operational definition of imagination. The hypothesis was that television, the medium providing the richer information in an external representation, would be less stimulating to the children's internal, imaginal representations. It was expected that radio, leaving more to the imagination, would be more stimulating in this respect.

Table 10.1 shows those imaginal aspects of story continuations in which the medium of representation made a statistically significant difference. In accord with the hypothesis, the audio representations led to significantly greater representation of novel events, characters, and words (an overall measure of imagination), while the television representations led to significantly greater repetition of material from the preceding stimulus story.

In the study of memory representation, the children heard and saw the stories all the way through. Following each story, again presented as either an audiovisual or an audio representation, each child was asked to retell the story to another adult who, the child was told, had never heard or seen the story. After this free recall test, the child was asked a series of cued recall and inference questions. The inference questions did not have right or wrong answers; instead, the questions were posed in order to determine the representational sources for the children's answers.

Table 10.2 presents the statistically significant main effects of medium on memory and inference representations. Note that television leads to significantly better overall recall of information (central propositions, cued recall). It also leads to a greater focus on action representation (action recall and use of action information as a source of inferences). The advantages of the multimodal representation of television can also be seen in the greater use of audiovisual detail, both in direct recall and as a source of inferences, in comparison with the same

TABLE 10.1
Significant Medium Differences: Imagination

	Radio	*TV*
Imaginative events	11.30**	9.49
Imagined specific characters	0.87*	0.61
Imagined vague characters	0.49**	0.26
Imaginative words	107.87***	89.20
Repetitive words	8.17	20.16***

*$p \leq .05$. **$p \leq .025$. ***$p \leq .01$.

TABLE 10.2
Significant Medium Differences: Memory and Inference

Memory	*Radio*	*TV*
Free recall		
Central propositions	7.40	8.95****
Actions	10.57	12.09**
Vague characters	2.12	2.80****
Direct dialogue	2.14*	1.61
Cued recall	8.56	11.73****
Picture sequencing	16.91	19.55****
Audiovisual detail	1.28	1.80****
Inference sources		
Audio	0.72**	0.56
Audiovisual	2.00	2.30***
Action	2.48	3.15****
Outside story	2.31****	1.73

*$p = .05$. **$p \leq .025$. ***$p \leq .01$. ****$p \leq .001$.

details presented in the audio medium alone. Radio, in contrast, led to greater focus on material presented only in the auditory channel (recall of dialogue and use of audio material as an inference source). Radio also led to less frequent vague reference (the vague characters variable) in which the subject used a pronoun or vague noun (e.g., "the man") without an antecedent. It appears that in some cases the visual image of the television representation serves as the unspoken antecedent, visually represented by the subject, but not communicated to the listener. The stimulation of visual representational processes by television is further indexed by the better performance in using pictures to retell the story (picture sequencing) after television than after radio (a not very surprising finding). Finally, radio once again proved more stimulating to the imagination (more frequent use of material from outside the stimulus story as an inference source).

Those features of a medium's representation that are communicated well also tend to be features that appear frequently in that medium. Thus, television programming emphasizes action information, and it communicates this well, whereas, over time, television programming has tended to deemphasize dialogue. (The television series "Miami Vice" was a good example of this trend.) An implication of such foci is that television will tend to provide its viewers with a great deal of practice in the comprehension of action information, but the corresponding representational processes involved in dialogue will get less practice.

In addition to the significant medium differences shown in Tables 10.1 and 10.2, there is also clearly a good deal of overlap in processes of imaginal and memory representation stimulated by the two media. There is not a single variable in which there is an all-or-none difference between the two media. Indeed,

the margin of difference is, in every case, smaller than the overlap between average response to the two media. For this reason, it appears that there only is partial conservation of meaning across media. In the context of much overlap, each medium still leads to different emphases in representational processes and, consequently, different emphases in the communication of content.

IMPLICATIONS OF VIDEO IMAGERY FOR REPRESENTATIONAL COMPETENCE

The technology of television and, especially, that of video games augments skill in reading visual images as representations of three-dimensional space. The presence of print (and, later, photographic) technology is historically associated with the development of conventions of perspective. Such conventions both allow and require the three-dimensional interpretation of two-dimensional representations. Video technologies go beyond print and photography in their presentation of two-dimensional representations of three-dimensional space. The viewer must not only demonstrate an ability to interpret static two-dimensional images in the third dimension, but also skill in mentally transforming, manipulating, and relating dynamic and changing images. Thus, the video screen adds two new interrelated dimensions—time and motion—to the iconic imagery of pictorial representation. These two new dimensions have implications for the representation of three-dimensional space.

Television and the Mental Construction of Space

Television provides informal training in the representation of space. Figure 10.1 shows an item from the Space Construction Test developed by Gavriel Salomon (1979). In this test, the task is to put the four picture fragments together so that they form a single space, in this case a room. Salomon (1979) found that children who did well on this test were better able to understand edited films than children who did less well.

Why this correlation between performance on the Space Construction Test and skill in interpreting edited films? The answer lies in a visual technique that is intrinsic to the film and television media. When a three-dimensional space, such as a room, is filmed, the camera does not and cannot reveal the whole space in a single shot. Instead, the camera pans or cuts from one part of the room to another. It shows but one fragment at a time. To have a sense of the whole space, the viewer must mentally integrate the fragments, constructing the room for him- or herself. Apparently, learning to interpret and integrate the fragmentary shots in a film creates a cognitive skill, which then transfers to this paper-and-pencil test. This skill is also called into play by video games, the next medium to be discussed.

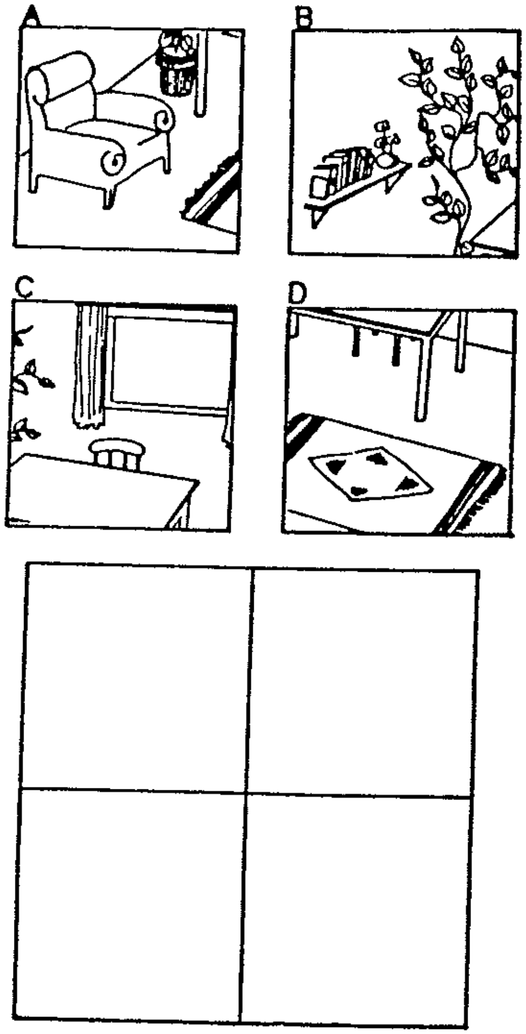

FIG. 10.1. Item from Space Construction Test. *Note.* From *Interaction of media, cognition, and learning* by G. Salomon, 1979, San Francisco: Jossey-Bass. Reprinted by permission of the author.

Video Games as a Representational Medium

The interactive television set called a computer has entered our society on a mass scale. Among all the forms of computer technology, the video game touches most directly a majority of people, and, even more important, touches them during the formative years of childhood, when socialization is taking place.

A study in 1985–1986 by Rushbrook (1986) showed that 94% of 10-year-old children in Southern California (Orange County) had played video games. Eighty-five percent of these children considered themselves as good, very good, or expert players. Since that time the penetration of video games with young children has undoubtedly both increased in scope and decreased in age of first exposure: As of December 1991, there were more than 45 million Nintendos in homes in the United States.

Note that the reference is to video games, not to explicitly educational games, but primarily to the action games found in video arcades and played on home game sets. Indeed, the focus of this discussion is the cognitive implications of games that have commonly not been considered cognitive at all, but merely exercises in eye–hand coordination.

What are some of the implications of video games for representational processes and cognitive distance?

1. Unlike television, the player is not simply in the position of being a consumer of the representation: He or she is also a producer. The player not only interacts with the representation; through the joystick or game controller, the player is a partner with the computer in the construction of the representation. Through the joystick or controller, the player creates the movement patterns of the central character on the screen in an action game. In a simulation game, the player participates in the construction of a whole world. In a role-playing adventure game, the player participates in the creation of characters.

2. Therefore, the joystick (or controller) is itself a representational tool, for it creates its own mark, a moving signifier, on the screen. But it is a particular kind of representational tool, with a high degree of distance between tool and signifier. To get a notion of the representational distance, compare a joystick with a pencil. Unlike the joystick, the pencil creates a representation through spatial contiguity of tool and signifier. The joystick, in contrast, is at a distance from the screen representation it is controlling.

3. Action video games, like television, are a real-time medium. From the point of view of psychological distance, this characteristic probably has the most important implications. Because of the real-time movement of the video media, the player (or the viewer of television) cannot stop to reflect. If a pause to reflect occurs while watching television, the viewer misses the next event. If this is done while playing an action video game, the player's character will be lost or destroyed. This real-time quality finds its purest embodiment in arcade games,

where time is money (Harris, 1992). Consequently, arcade video games, like television, provide no opportunity to develop or practice the reflective or transcendent (Sigel, 1986) aspect of distancing strategies. There is time neither for the reflective abstraction emphasized by Piaget (1978), nor for the further symbolic transformation of ongoing experience emphasized by Sigel (1986).

4. Video games build upon and utilize the visual-spatial skills developed by television. For example, a number of video games require the very same cognitive process of spatial integration that is involved in the Space Construction Test (Fig. 10.1). It appears that the overlap in technology between the two media, television and video games, is also reflected in an overlap of requisite representational skills. For example, Fig. 10.2 shows the first three screens from a game called Castle Wolfenstein, which utilizes this skill. The goal of Castle Wolfenstein is to escape from the castle, which represents a Nazi prison. The castle consists of a series of mazes, only one of which is visible at a time. Yet the mazes are interconnected vertically by stairways (e.g., top right-hand corner of top maze) and horizontally by doorways (e.g., top middle of middle maze). In order to have an overview of the castle as a whole, the player must put together the individual mazes in his or her mind and mentally construct the space.

My own experience in playing the game indicates that this is not a skill to be taken for granted. After my first session with the game, I assumed each maze was independent of the others and that the order of mazes was essentially random. Essentially, I had not only failed to integrate the fragments, but failed to realize that the fragments *could* be integrated. My son Matthew was amazed at my ignorance. ("Most people realize *that*, even if they are not paying attention!") His amazement gave me a clue that spatial integration may be a well-understood convention, as well as a habit, for expert game players like him, more than for other people.

Figure 10.3a presents a map of Castle Wolfenstein that Matthew's friend, Paul Riskin, just sketched out for me when they discovered my interest in the spatial characteristics of the game. It shows quite clearly how developed these spatial integration skills can be in expert players. Although the original idea of a map had appeared in a magazine, Paul produced an initial sketch of the castle completely from memory. Matthew looked at it, thought there were a few errors, and then revised the sketch through a bit of game play. His revised sketch appears as Fig. 10.3b. Comparing the two maps, we see that Paul's map from memory, his internalized representation, although not perfect, was generally accurate. An informal survey in a communications studies class at UCLA confirmed that Castle Wolfenstein players do spontaneously develop mental maps of the castle as they play, even without ever seeing a map drawn out for them. The important point is that expert play requires spatial integration in the form of a mental map, and that expert players develop such representations. Note that the focus here is on iconic rather than symbolic (Bruner, 1965, 1966) modes of representation. That is, the map is iconic in that it bears a physical resemblance to its referent,

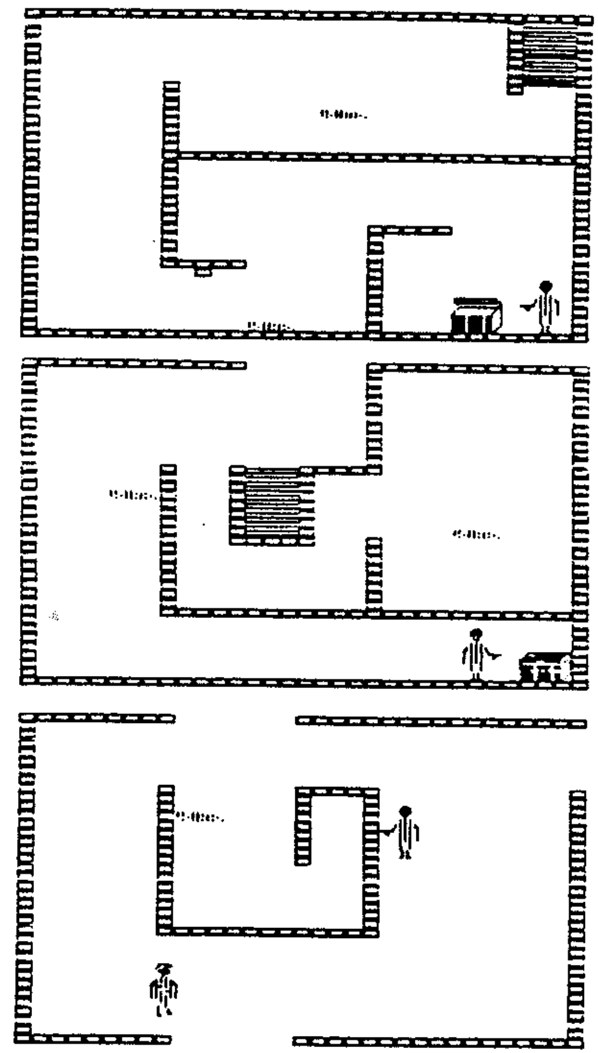

FIG. 10.2. Three interlinked mazes from Castle Wolfenstein.

the castle. In this it differs from symbols such as words that bear, by definition, an arbitrary relationship to their referents.

One interesting point is that the need to integrate fragments of space into a single structure in the video game Castle Wolfenstein closely parallels the task of the Space Construction Test, performance on which was found to be related to an understanding of film. Thus, socialization by the visual media of television and

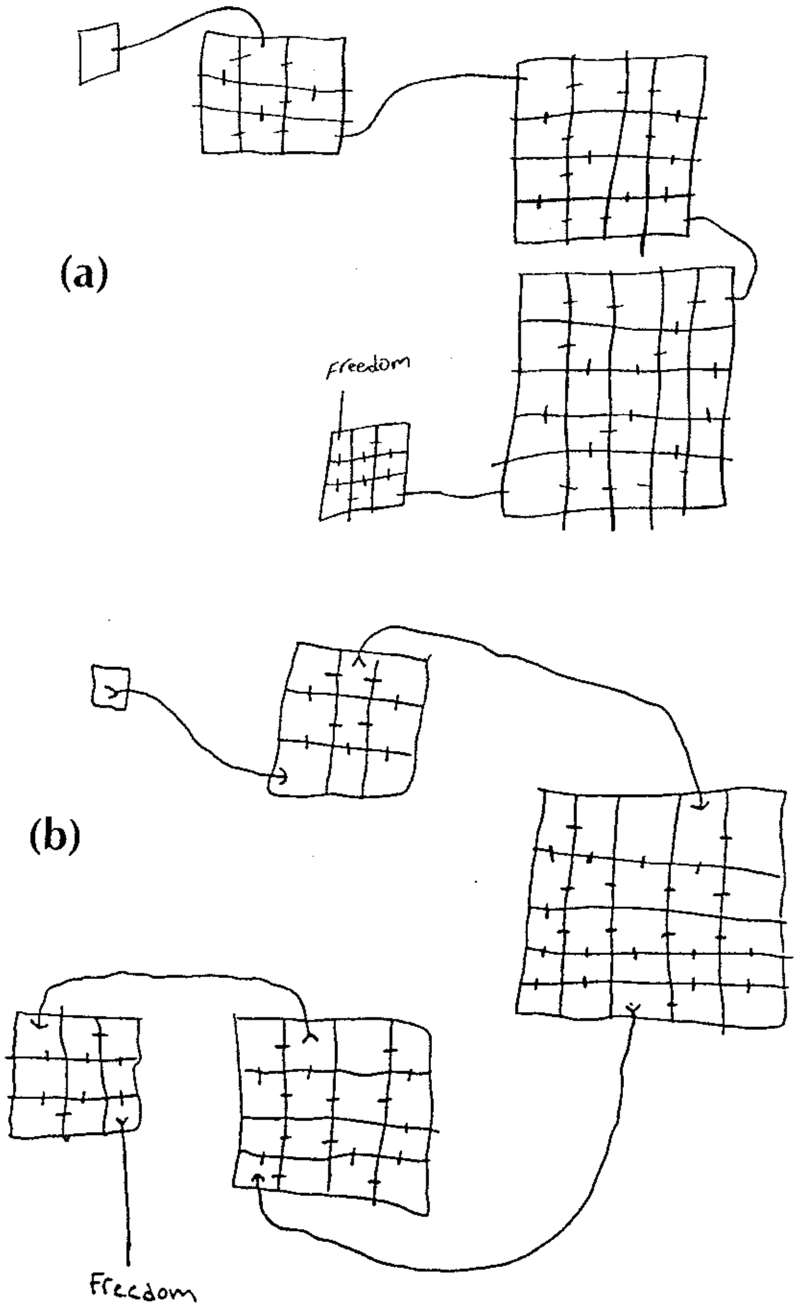

FIG. 10.3. (a) A spontaneous sketch of Castle Wolfenstein. (b) Revised sketch of Castle Wolfenstein.

film may provide informal training that is relevant to understanding (and operating in) the screen displays of video games.

With the advent of ever more complex video games, such as Nintendo's popular Legend of Zelda (1986), reference maps, an iconic metarepresentational guide to video representations of space, have become increasingly popular (Harris, 1992). *Nintendo Power*, for example, which regularly publishes such maps, currently boasts more than two million subscribers (Harris, 1992).

Spatial Integration and Computer Literacy

Spatial integration of computer screen displays, as required by the game Castle Wolfenstein or The Legend of Zelda, is a general requirement for using all sorts of computer programs. In a computer program, the user is not permitted to get to any part of the program, as indexed by a particular screen display, from any other part. There are certain, sometimes branching, paths between any two points in a program. A spatial model of these "paths" can help the user "move around" in the program. It is interesting to note how spatial metaphors such as "move around" have grown up to describe this process of understanding what is connected to what within a program. The situation is quite different in the older print medium. Consider the structure of a book, for example. The reader can move freely from any page to any other page. Unlike a computer program, the ordering is linear, and movement from one part to another is unconstrained.

The increasing utilization of the nonlinear organization of computer programs in software design is making the ability to construct iconic spatial representations ever more crucial for dealing with this medium. For example, the first computer databases were based on a print model: They are linear in their organization. However, in recent years, new types of databases, called hyperprint and hypermedia, have been developed; the information in these is arranged in complex, nonlinear spatial configurations. The ability to integrate fragments (individual screen displays) into a unified spatial representation is crucial to the efficient use of these futuristic systems, already in use. Most recently, there has been discussion of how to keep these systems from exceeding human capacities to represent nonlinear information (Loh, 1990).

There is Also Evidence that Games Further Develop the Spatial Skills That They Require.

The Empire Strikes Back, an arcade action game notable for requiring the player to navigate through three-dimensional space represented on a two-dimensional screen, was used in order to research visual-spatial skills (Brannon & Lohr, 1985; Greenfield, Brannon, & Lohr, in press). The researchers stood around the game in an arcade and tested players who had just finished playing. Their test of visual-spatial skills, mental paper folding (Shepard & Feng, 1972), was also one that demanded visualizing three-dimensional movement from a two-dimensional display. The test is shown in Fig. 10.4. Brannon and Lohr (1985; Greenfield, Brannon, & Lohr, in press) found that the better game players

Below are drawings each representing a cube that has been "unfolded." Your task is to mentally refold each cube and determine which one of the sides will be touching the side marked by an arrow.

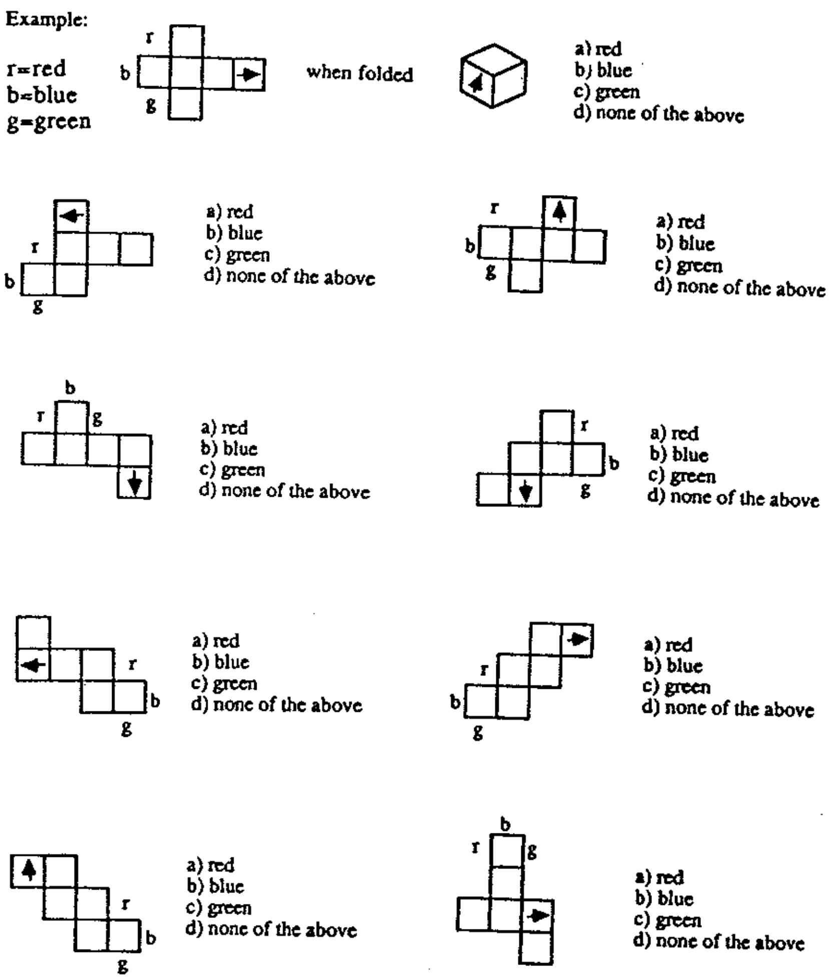

FIG. 10.4. Mental paper folding test used by Brannon & Lohr (1985).

(scoring over 100,000 points) did significantly better on mental paper folding. This study confirms that a video game utilizes and/or develops related visual-spatial skills that are more general than the game itself.

Perhaps most interesting in terms of the television–video game connection are results reported by Pezdek and colleagues (Pezdek, Simon, Stoecker, & Kieley, 1987). They found that skill in comprehending television (but not skill in com-

prehending radio or written material) is strongly correlated with performance on mental paper folding. In other words, in line with the hypothesis developed earlier, here is direct empirical evidence that players of three-dimensional video games are using and, perhaps, developing skills required by television information processing.

In an experimental follow-up to the correlational study (Greenfield, Brannon, & Lohr, in press), the relation between playing The Empire Strikes Back in the context of an experiment and improved mental paper folding was explored with a sample of university students. Although there was no effect from playing for an hour or two in our experiment, path analysis indicated that cumulative skill in The Empire Strikes Back, as indexed by initial performance, is a causal factor in the spatial representational skills of mental paper folding (see Fig. 10.5).

As Fig. 10.5 illustrates, gender is a causal factor in video game skill; video game skill, in turn, influences the spatial representational skills involved in mental paper folding. However, contrary to the notion that boys may be innately better at spatial skills, gender does not influence iconic spatial skills directly (see the nonsignificant dotted link in Fig. 10.5). Gender influences spatial representational skill through the medium of video game expertise. In a subsequent study, this knowledge was applied to reducing gender differences in visual-spatial skills.

In an experiment conducted with 10- and 11-year-old children, the age at which gender differences in visual-spatial skills first stabilize (Johnson & Meade, 1987), we investigated whether video game practice can reduce gender differences in iconic spatial skills (Subrahmanyam & Greenfield, in press). In the experiment, all children were first given a computerized battery of dynamic

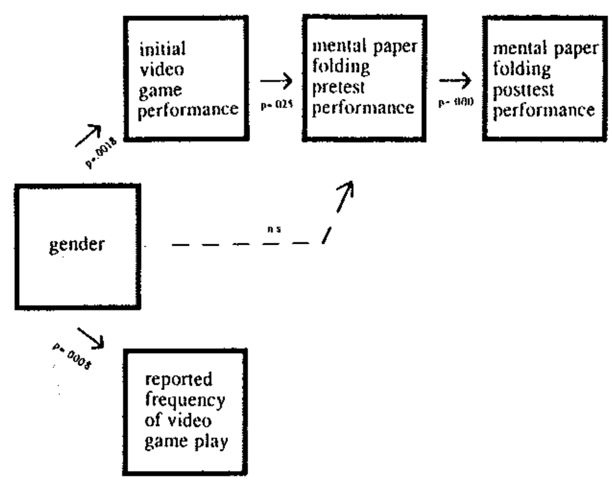

FIG. 10.5. Path model of causal relations between gender, video game behavior, and mental paper folding (Greenfield, Brannon, & Lohr, in press).

spatial skill tests developed by Pellegrino, Hunt, Abate, and Farr (1987). The tests involved judgments of distance and position, and memory for paths. Members of a randomly selected experimental group consisting of half the boys and half the girls then were given $2\frac{1}{4}$ hr of practice on a maze-based video game, Marble Madness (Harvey, 1986). Analysis of the game indicated that it required skills closely related to those tested. A control group played an unrelated word game, Conjecture, on the computer for the same amount of time. Finally in the posttest, all children were retested with two of the three tests given initially.

As expected, boys brought better iconic spatial skills into the experiment, as shown by their significantly lower error scores on the pretest. Also as expected, this gender gap in favor of boys seemed to get smaller on the posttest. The statistically significant pattern of experimental results graphed in Figure 10.6 provides one part of the explanation: Video game practice (but not the computerized word game used as a control condition) generally improved the dynamic spatial skills of anyone, male or female, who started out with relatively weak spatial skills (i.e., high spatial error in Figure 10.6). Those who started out with relatively strong skills (i.e., low spatial error in Figure 10.6) were, by contrast, unaffected by the experimental video game practice. The second part of the explanation lies in the fact that about two-thirds of the children who started out with relatively weak spatial skills were girls. As a consequence, the improvement in dynamic spatial skills that resulted from video game practice affected girls more than boys.

But the positive effect of video game practice on dynamic spatial skills was not a one-way relationship. Better spatial performance on the pretest also led to better video game performance at the end of the experimental practice period. These results indicate that skills in understanding a dynamic representation of

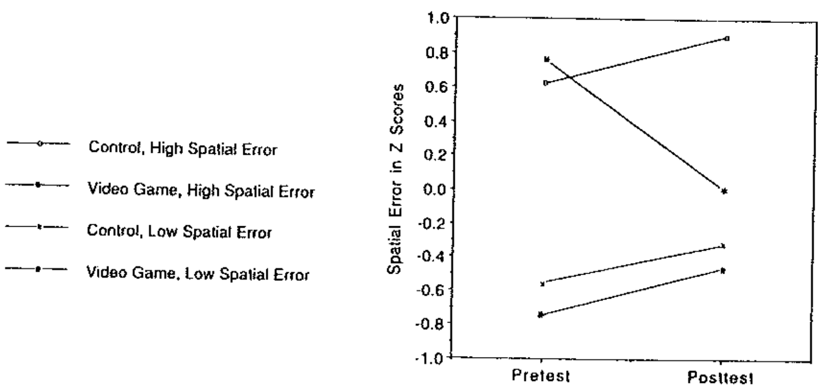

FIG. 10.6. The effect of video game practice on dynamic spatial test performance for children differing in pretest spatial skill (Greenfield & Subrahmanyam, in press).

spatial relations are a factor in the acquisition of video game expertise, as well as vice versa.

Discovering the Rules of a Dynamic Visual Representation

One of the most interesting points about video games as complex, dynamic representation systems is that no one tells you the rules in advance. The rules must be figured out by observation, trial-and-error, and a process of hypothesis testing. Several researchers have noted the problem-solving/discovery aspect of video games (Greenfield, 1983, 1984; Strover, 1984; Turkle, 1984).

In essence, the player creates a part of a dynamic representation using a joystick; he or she must figure out how his or her representation interacts with screen objects controlled by the computer. The rules go beyond the decoding of meaning for individual icons on the screen. More important than figuring out what the symbols mean is discovering how they act.

This process of making observations, formulating hypotheses, and figuring out the rules governing the behavior of a dynamic representation through a trial-and-error process is basically the cognitive process of inductive discovery. It is the process by which individuals learn much about the world, and, at a more formal level, it is the thought process behind scientific thinking and discovery. If video games function to train this process, they would have great educational and social importance.

To test this idea, the process of inductive discovery in the course of video game mastery was documented to determine whether video games could function as a method of informal training for scientific–technical thinking. The study had a cross-cultural aspect as well, involving a comparison between students in Los Angeles and Rome, where computer technology is less widespread (Camaioni, Ercolani, Perucchini, & Greenfield, 1990; Greenfield et al., in press; Sensales & Greenfield, 1991; Sensales & Greenfield, in press).

Learning and the Discovery Process

The experiment involved using the video game of Evolution, a "noneducational" action game for Apple computers (Sember & Mattrick, 1982), as an experimental treatment for university students studying psychology. Apart from being relatively nonviolent, this game had all of the design features of a normal action game found in video arcades, cafés, hand-held games, or home game sets. Most important for our purposes, it had a variety of levels, each one of which had a different set of rules and patterns to figure out.

In Evolution, the player "evolves" from ameba to human (this is *not* a realistic simulation!). At each stage, there are various inductive problems to solve: What is the goal? Who are the enemies? How does the joystick function to control movement? What are effective strategies?

In order to document results of the hypothesized discovery process, one of our experimental groups was given a series of questionnaires assessing their knowledge of answers to questions like those above. Twice in each game session (there were three sessions, totaling 2½ hr in all), players were given such a questionnaire. Figure 10.7 shows the (statistically significant) development of knowledge of the game as game-playing experience increases. It appears that mastery of a video game does, indeed, involve the gradual discovery of rules, patterns, and strategies that allow mastery of a dynamic screen-based representation.

Furthermore, it appears that it was necessary for novices to learn the game inductively, rather than deductively. Before playing Evolution for the first time, a second group of subjects received detailed instructions on how to play the game. These explanations included verbal representations of rules, patterns, and strategies. It also included both static and dynamic iconic representations—slides of all of the Evolution screens (one from each level) and a video tape of the game screen as an expert player moved through all of the levels. However, in both Rome and Los Angeles, the group with these instructions failed to learn to play the game better than a third novice group who figured it out for themselves by trial and error. Nor did metacognitive awareness, presumably stimulated by the periodic questioning experienced by the first group, described above, make any

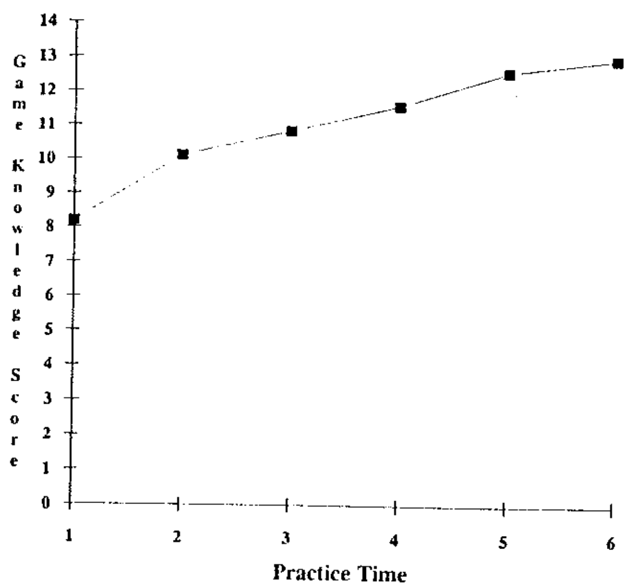

FIG. 10.7. The development of video game knowledge as a function of practice (Greenfield et al., in press). The first point represents knowledge after about 15 minutes of play.

difference. It seems that video games necessitate not only inductive learning of the dynamic representational system, but interactive inductive learning. The instructional and questioning conditions showed that skill is not aided either by deductive application of verbal rules, by observation of a model, or by responding to verbal questions concerning rules and strategies. In terms of distancing theory, verbal and iconic strategies appeared to be of little use for conveying how to become skillful at the interactive dynamic representation called a video game. The interesting contrast, within this theoretical framework, is that strategies can be "too distant" for the performer or too far removed ("distant") from relevance to a particular medium.

On the other hand, Harris has observed that "In video game play, young children as novices are introduced to game play by more experienced players, and once the basics are mastered, the novice further develops his skills on his own through interaction with the game. . . . More experienced players share secrets with less experienced players, often modeling game strategies or providing verbal guidance through difficult moves" (Harris, 1992, p. 6). Given these observations concerning the role of expert instruction in the learning process, why did not visual demonstrations or periodic cuing through questions make a positive difference in mastering the video game Evolution? It may be the interactive and scaffolded nature of the novice-master relationship described by Harris (1992) that is crucial. In other words, the experienced player can observe the learner's level and specific needs for information as the learner plays the game, while the learner can communicate his/her specific informational needs to the master. The master-novice interaction described by Harris (1992) occurs while the learner is on-line with the game, receiving inductively relevant input. The learner creates a representational model of the game by interacting both with the game and with other players simultaneously. If this analysis is correct, our "training" conditions may have been unsuccessful for two reasons (1) training was not shaped by feedback from the learner, and (2) instruction did not occur while the learner was receiving induction-relevant experience by actually playing the game. Perhaps successful distancing strategies for interactive video games must include these two characteristics.

Transferring Discovery Skills from a Video Game to a Scientific/Technical Computer Simulation

Because video games have been widely considered to have little if any redeeming social value in themselves (e.g., "Rebellion Against Video Games," 1983), the next step was to determine if the processes of inductive discovery that they engage might transfer to problem solving in a scientific or technical context, an area of undisputed social importance (Camaioni, Ercolani, Perucchini, & Greenfield, 1990; Greenfield et al., in press). To investigate this, two parallel transfer tasks were developed, one given as a pretest, one given as a posttest; these involved animated simulations of the operation of electronic circuits presented schematically on a video screen (Robinett, 1982). Would the discovery of the rules governing one dynamic screen representation (the video game) help in discovering the meaning of another (animated electronic circuits) (Greenfield, 1990)?

Subjects were told nothing about the demonstrations, not even that what they were seeing were circuits; they were simply told to watch carefully so that they could answer questions later about what was going on. After every few demonstrations on the screen, subjects were given written questions to answer. The questions were such that the subjects not only had to understand what they had been shown on the screen, but also had to generalize their conclusions to new instances of circuits and to a new medium of representation, paper and pencil.

To test for transfer, our subjects were assigned to one of a number of experimental treatment groups. There were the three Evolution video game conditions already described, conceived as involving varying degrees of inductive discovery. A fourth condition involved playing a computer memory game. Like the video game Evolution, it used the computer medium; unlike Evolution, it was not thought to require inductive discovery for its mastery. Contrasting with the computer memory game, a fifth treatment condition was a mechanical memory game; it had the same rules and structure as the computer memory game, but utilized a different medium. Instead of the video screen used in the computer memory game, the mechanical memory game used a board. Finally, there was a "no treatment" control condition.

The experimental results (reported in more detail in Greenfield et al., in press) indicated that both computer games, the inductive action video game and the noninductive computer memory game, provided more transfer to comprehension of the scientific/technical stimulation on the posttest than did the noncomputer conditions. However, the pattern of experimental results suggested that, contrary to expectation, transfer was not mediated by general skill in inductive discovery, but rather by a medium-specific representational skill: ability to decode the iconic representation of computer graphics.

In order to further explore this possibility, a measure of the degree to which subjects used iconic diagrams versus symbolic (verbal) representations in answering questions about the simulated electronic circuits on pre- and posttest was developed. Statistical analysis showed that more use of iconic representation and less use of verbal representation in the pretest was significantly associated with greater initial skill in playing the action video game. More iconic and less verbal representation was also significantly associated with better comprehension of the simulated electronic circuits in the same pretest. Finally, subjects became significantly more iconic (and less verbal) in constructing their test answers after playing the computer memory game (Camaioni et al., 1990; Greenfield et al., in press). Therefore, it appears that one component in figuring out the rules of both an action video game and a technically oriented computer simulation is skill in iconic representation. Finally, the experimental results indicate that a computer game can develop just such representational skill.

Iconicity and Computer Literacy

Iconic computer interfaces were pioneered by Alan Kay, based on Bruner's (1965, 1966) concept of iconic representation. The increasing popularity of these interfaces, initially commercialized in Macintosh computers, has made iconic representational skills an ever more important component of computer literacy. Our study (Camaioni et al., 1991; Greenfield et al., in press) indicates that action video and other kinds of computer games utilize or enhance iconic representational processes.

Educational and Cultural Implications

In a 1977 article in *Science*, E. S. Ferguson pointed out that the language of technology is basically a nonverbal one and that people involved in technology need to be able to think in terms of visual images. He criticized engineering schools for their bias toward educating students to analyze systems using numbers rather than visual images, pointing out that this bias has produced a lack of people who have skills to deal with real machines and materials.

Ferguson's point has applicability way beyond engineering now that so many different kinds of learning and work involve computer screens. Our formal educational system ignores the visual requirements of the new technologies in both teaching and testing. It is concerned about verbal and other forms of symbolic representation, but not about the visual representation of space or other types of iconic representation. Until this situation changes, we shall be relying on television and video games to provide informal education in this important domain.

In many ways, however, the computer culture embodies and requires print as well as image literacy. With more than two million current subscriptions to *Nintendo Power* alone, "Young children not only learn to read complex maps and reference guides, but to understand the value of maintaining books for their reference value in answering questions to specific problems posed. In this respect, children's video game play and a reliance on technical support via print mirrors the behavior of adults within engineering and other technical fields" (Harris, 1992, p. 7).

Indeed, the anthropological study of games has demonstrated that a culture's games socialize children in accord with the needs and adaptational requirements of a particular society (Roberts & Sutton-Smith, 1962; Werner, 1979). Perhaps because video games are a product of the computer culture, as well as a socializing force for it, they have become a mass medium for cognitive socialization. In contrast, formal schooling, because of its historical base in the symbolic codes of print literacy, has been slower to adapt to the expanded requirements for universal technological literacy.

CONCLUSIONS

Video games are the first example of a computer technology that is having a socializing effect on the next generation on a mass scale, and even on a worldwide basis. Many of these effects seem to be preparing children (and adults) to deal with the world of computers in general. For example, in figuring out the rules and patterns of a game, a player is also figuring out the nature of the computer program behind the game, or what the programmer had in mind (Sudnow, 1983; Turkle, 1984). As the program is never visible, this is a mental representation. A willingness to figure out how the program works by interacting with the game rather than by reading instructions is a valuable skill in other computer tasks and environments. The skills in spatial or iconic representation developed by video and other computer games come into play in computer functions as diverse as word-processing (Gomez, Bowers, & Egan, 1982), programming (Roberts, 1984), and, as previously noted, understanding scientific simulations (Greenfield et al.) or decoding and finding your way around in a program.

What is the person like who has been socialized by the technologies of television and video games? So far, it appears that he or she may have more developed skills in iconic representation than the person socialized entirely by the older media of print and radio. The video game and computer, in adding an interactive dimension to television, may also be creating people with special skills in discovering rules and patterns by an active and interactive process of trial and error.

Video Game Violence

With respect to the thematic content of television and video games, there is at least one great problem with socialization by these media. The problem arises from the fact that so much content is violent. Indeed, the impact of playing a violent video game alone is exactly the same as watching a violent cartoon: It makes the young child's behavior more aggressive (Silvern & Williamson, 1987). Violent content is one reason why girls play action video games less frequently than boys (Malone, 1981); girls therefore receive less practice in the technologically relevant cognitive skills provided by the games. If the prevalence of violent themes in television and video games remains high, these media may reinforce or even forge an unfortunate link in society between violent social behavior and technologically oriented cognitive skills.

A New Person?

Are these technologies in the process of creating a new person? The cognitive skills are not new, although the particular combination may well be. In previous

generations a high level of development of these skills was probably restricted to people in certain relatively elite technical occupations—for example, pilots and engineers in the case of visual-spatial skills. Television and, especially, video games have made highly developed iconic-spatial representation potentially accessible to everyone. In this respect, they have much greater potential impact than the so-called "educational" software available mainly to those with access to personal computers.

The preceding chapter has emphasized real-time media and formats such as television and action video games. Although the action games studied by Greenfield and colleagues (Camaioni et al., 1990; Greenfield, 1990; Greenfield, Brannon, & Lohr, in press; Greenfield et al., in press; Greenfield, Dewinstanley, & Kaye, in press; Subrahmanyam & Greenfield, in press) clearly involve strategy and problem solving, they also emphasize quick and accurate manual responses to complex dynamic visual stimuli. This feature is typical of games originating in video arcades, where time is money (Harris, 1992). It is possible that the real-time nature of television and arcade-style video games interferes with the *reflective* function of distancing strategies.

In contrast to television and arcade games, however, video cassette players and home video games, do allow the consumer to stop, think, and replay the tape, or in some cases, the game action (Greenfield, 1984; Harris, 1992). Correlatively, a number of games originating for home game systems, such as the popular role-playing adventure games, require much more complex problem-solving and strategy, with less emphasis on speed. Although actual play still occurs in real time, players stop these games, discuss strategy, consult their *Nintendo Power* or other manuals, and redo unsuccessful moves (Harris, 1992, personal communication, 1992). We know little about which kinds of games are played more or will be in the future; nor do we know how frequently VCRs are actually stopped for replay or verbal discussion. Nevertheless, the modification of real-time media by stop-action and replay may, to some extent, keep these media from undermining the *reflective* function of distancing strategies, perhaps ultimately even supporting the development of this more traditional aspect of representational competence.

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