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Cognitive Effects of Video Games: Guest Editor's Introduction

Video Games as Cultural Artifacts

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Everyday cognition (Rogoff & Lave, 1984) refers to the cognitive processes that are used in real-world situations, as opposed to the psychological laboratory. Everyday cognition is embedded in a particular social and cultural setting. Although psychologists often think of cognition as being something that goes on inside the head of an isolated individual, cognitive processes most often depend on interaction either with other people (e.g., Cole & Traupmann, 1981; Gauvain, 1993; Greenfield, 1984b; Rogoff, 1990; Wood, Bruner, & Ross, 1976) or with cultural artifacts (Gauvain, 1993; Greenfield, 1984a; Lave, 1988; Saxe, 1991; Scribner & Cole, 1981). The study of the cognitive processes elicited or stimulated by video games is the study of one particular example of everyday cognition that depends upon interaction with one particular class of cultural artifact: the action video game (Greenfield, 1983; Greenfield, 1984a; Greenfield, 1993; Turkle, 1984).

Often a cultural artifact will embody a particular symbol system, the use of which involves its own sort of representational competence. Representational competence (a term coined by Sigel & Cocking, 1977) is concerned with the means, modes, and modalities by which we take in, transform, and transmit information. Bruner (1965, 1966) developed a theory of three modes of representation and their role in development. In essence, this was a theory of the development of representational competence. The three modes of representation were the enactive, the iconic, and the symbolic. The essence of representation is a relationship between signifier and signified. In enactive representation, motor action serves as a signifier; in iconic representation, an analogue image serves as the signifier; and in symbolic representation, an arbitrary sign such as a word serves as the signifier.

For each mode, according to Bruner, there are amplifiers. An amplifier is a cultural artifact that expands the range of motor, sensory, or thinking processes associated with a particular mode of representation. With his studies of the cultivation of mental skills through the symbolic forms of film, Salomon (1979) was the first to apply this notion to the audiovisual media.

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A major theme of the studies that follow is that video games are cultural artifacts that both depend on and develop the iconic mode of representation, particularly one important aspect of iconic representation: the dynamic representation of space. As a group, the studies by Subrahmanyam and Greenfield (1994), Okagaki and Frensch (1994), and Greenfield, Brannon, and Lohr (1994) show that video game experience and expertise require and develop skills in the dynamic representation of space. In the study by Greenfield, Camaioni, et al. (1994), computer games are shown to use and develop skills using the iconic code of computer graphics. Finally, the study by Greenfield, deWinstanley, Kilpatrick, and Kaye (1994) demonstrates the effects of video game experience on the attentional skills required to process the quickly moving multiple iconic images that constitute the visual stimuli of action video games.

Video games not only embody particular symbol systems; they do so in a context of goal-directed activity with instantaneous feedback. Activity theory, elaborated by Leont'ev (1981), emphasizes the importance of goal-directed activity in cognitive development (Gauvain, 1993). The goal-directed activity involved in video games is certainly a reason for their popularity (Malone, 1981) and may well be a reason for their power in exercising and stimulating cognitive skills, as demonstrated by the articles in this special issue.

Goal-directed activity has content as well as form. In principle, content and form are independent dimensions of video games, as of any other medium. In practice, however, the violent nature of much video game activity has been an ongoing cause for concern, as it has been in the older medium of television (e.g., Greenfield, 1984a). The effects of video game violence on social behavior (cf. Silvern & Williamson, 1987) and attitudes is an area that demands much more research, particularly because of the increasingly graphic violence in popular video games such as Mortal Kombat.

However, the articles in this section deal with the cognitive effects of video games as interactive symbol systems and not with the social effects of their thematic content. In principle, the cognitive effects of video games are independent of any particular content. Therefore, in reading the articles that follow, the reader should keep in mind that the same cognitive effects should generally be obtained from games with similar symbolic design features (e.g., representation of three-dimensional space) but dissimilar content. In practice, however, the cognitive effects of action video games may not be totally independent of thematic content. In fact, the findings as a whole are suggestive concerning an interactive relation between violent video game content, gender, game mastery, and cognitive skill building.

Video games as a cultural or cognitive artifact have tremendous social importance because of their nature as a mass medium. For most children, video games are their introduction to the world of computer technology. As an example of the diffusion of video games, in December of 1991 there were more than 45 million Nintendo game sets in the U.S., representing 34% of all homes. In

1991, the home video game industry had $4.4 billion worth of sales (of which Nintendo had $3.5 million). The primary age range of Nintendo game players is 6 to 11 years, with 12- to 17-year-olds in second place (Berkhemer Kline Golin/Harris Communications, 1992). With this degree of market penetration, the video game has gone beyond a relationship with individual children to become a part of child and adolescent culture in the U.S. (Kinder, 1991; Provenzo, 1991).

The set of studies in this section indicates that video games are cultural artifacts that require and develop a particular set of cognitive skills; they are a cultural instrument of cognitive socialization. A major theme is that, just as different kinds of games have, in the past, prepared children and youth for the varying adult skills required by different societies around the world (Roberts & Sutton-Smith, 1962), so too do video games prepare children and youth for a future in which computer skills will become ever more crucial to thriving in a technological world. As writer Donald Katz put it, Nintendo (and other video games) hails "from a world in which the grown-up games of shopping, banking, moneymaking, and even war really are played out on video screens" (Katz, 1990, p. 50).

Video games are part of a trend in cultural history that started 20,000 years ago, as the number and types of symbolic codes external to the individual mind went from none to few to many (Donald, 1993). In a world in which devices for external memory storage have become increasingly important (Donald, 1993), video games socialize the minds of players to deal with the symbolic systems of the computer, society's latest form of external memory storage. As will become clear later, the spatial and iconic skills developed by video games are important for all sorts of computer applications from word processing (Gomez, Egan, & Bowers, 1986) to spreadsheets, programming, desktop publishing, databases, multimedia (Tierney et al., 1992), and scientific/technical simulations (Greenfield, Camaioni, et al., 1994). The games are revolutionary in that they socialize children to interact with artificial intelligence[1] on a mass scale and from a very early point in their development.

But video games are a cultural artifact that have greater appeal to some groups than to others (e.g., the special appeal of action video games for the military, discussed in Greenfield, deWinstanley, et al., 1994). Most pervasive and important for the topic of selective appeal, gender was an issue that could not be avoided as the study of the relationship between action video games and cognitive skills began. In several of the studies (Greenfield, Camaioni, et al., 1994; Subrahmanyam & Greenfield, 1994), it was clear that, relative to boys, girls lacked motivation to participate in a video game study. In Greenfield, Camaioni, et al. (1994), male university students in Rome and Los Angeles showed more

[1]Rick Sinatra, a computer programmer, originated the idea that video games are revolutionary because they involve human interaction with artificial intelligence.

skill on the average at the video game, both initially and after several hours of practice, than did female university students. The rates of improvement were, however, roughly comparable. In the study by Greenfield, Brannon, and Lohr (1994), female subjects were recruited without advance knowledge that the study involved video games. In addition, the experimental task was to learn a violent action game (The Empire Strikes Back). In that study, the male subjects generally mastered the game whereas the female subjects did not, even though they played more games in their attempts to reach criterion.

It seemed quite possible that the problem of female mastery in the Greenfield, Brannon, and Lohr research might have arisen from the violence in the particular game that was used. Research on video game tastes indicates that whereas boys are turned on by a violent game theme, girls are turned off (Malone, 1981). Studies of children and adult television preferences confirm this finding: Boys and men are much more attracted to violent action themes than are girls and women (Condry, 1989; Korich & Waddell, 1986). With this in mind, a study was designed to explore gender issues using a nonviolent action game, Marble Madness (Subrahmanyam & Greenfield, 1994). In that study, fifth-grade boys and girls were not significantly different in video game skill at the outset of game play. After a few hours of practice, however, the average boy performed better in the game than did the average girl.

However, action per se is recognized by children as a male characteristic, according to research on responses to television commercials with different formal features (Welch, Huston-Stein, Wright, & Plehal, 1979). Hence, the genre of action video game could by its very nature have greater appeal for boys than for girls. Contrary to this explanation, in the Subrahmanyam and Greenfield study it was informally observed that children of both genders preferred the action game Marble Madness to the control condition, a nonaction computer word game called Conjecture. For whatever reason, however, it is clear that males do have more video game experience than females, both in childhood (Subrahmanyam & Greenfield, 1994) and adulthood (Greenfield, Brannon, & Lohr, 1994; Greenfield, Camaioni, et al., 1994). Through this experience, they may have "learned how to learn" video games, therefore benefiting more from video game practice. Myers's (1984) extensive ethnographic study in a computer store confirmed the development of such learning strategies.

Another factor in better average male performance on video games could be that the average male may take a more experimental (trial and error) approach to the games than the average female. That is, the average male may be more willing than the average female to learn by acting before he understands all of the rules and patterns of the game. Smith and Stander (1981) found this to be the case with anthropology students who were first-time users of a computer system. This gender difference in being willing to act without full understanding could be related to the possible link between male gender and physical action noted earlier. Given an interactive medium in which experimentation yields instant feedback, an experimental approach logically has to be of great advantage.

Gender differences in the application of logical and strategic planning skills to game playing may also be a factor in gender differences in learning to play video games. Mandinach and Corno (1985) found that boys used these processes more than girls and were more successful at playing a computer adventure game called Hunt the Wumpus. These differences showed up despite equal experience with computers in general and equal liking for the game.

Another factor in gender differences in video game skill could be differences in the requisite spatial skills; such skills were a major focus of the studies that follow. All three of the articles that measured spatial skills (Greenfield, Brannon, & Lohr, 1994; Okagaki & Frensch, 1994; Subrahmanyam & Greenfield, 1994) found gender differences in favor of males at the outset of the studies, whether the participants were children (Subrahmanyam & Greenfield, 1994) or university students (Greenfield, Brannon, & Lohr, 1994; Okagaki & Frensch, 1994) and whether spatial skills were measured using paper-and-pencil stimuli (Greenfield, Brannon, & Lohr, 1994; Okagaki & Frensch, 1994) or computer stimuli (Okagaki & Frensch, 1994; Subrahmanyam & Greenfield, 1994). Nonetheless, it should be noted that under some conditions and with some tasks, gender differences did not appear (e.g., the perceptual speed test given by Okagaki & Frensch). It is also clear from the results that spatial skills are related to video game performance (Greenfield, Brannon, & Lohr, 1994; Okagaki & Frensch, 1994; Subrahmanyam & Greenfield, 1994).

Nonetheless, Okagaki and Frensch (1994) found that gender differences in performance on the nonviolent game of Tetris remained even when spatial skills, as measured by their tests, were partialed out. These remaining differences could reflect males' greater overall experience with video games, as found in many surveys (e.g., Berkhemer Kline Golin/Harris Communications, 1992; Rushbrook, 1986) as well as in the studies in this issue (Greenfield, Brannon, & Lohr, 1994; Greenfield, Camaioni, et al., 1994; Subrahmanyam & Greenfield, 1994).

There is also evidence (Ferrini-Mundy, 1987; Lowery & Knirk, 1982–1983) that spatial skills exert a positive influence on math and science performance in addition to their positive influence on the use of various computer applications. We must remember that average gender differences hide both important variability within each gender group and a large overlap between the genders. Nevertheless, even average differences in video game experience and mastery must be of concern, given the pervasiveness of the games in the early socialization of spatial and other skills of iconic representation important to developing facility with computers, math, science, and technology in general (Ferguson, 1977).

A concerted effort needs to be made to develop games that appeal to girls. Clearly this involves the development of more nonviolent games (Malone, 1981), which is socially desirable for other reasons as well. The effort should also involve developing games with more female characters that take an active role

(Provenzo, 1991; Rushbrook, 1986). Other design features, such as music (Malone, 1981), could enhance the appeal of video games to girls. Greater thematic emphasis on the drama of human relationships might make video games more appealing to girls, by analogy with female tastes in television programs (e.g., Korich & Waddell, 1986). Games designed by females are part of the answer (Kafai, in press). But there are also types of television programs (notably comedy) that appeal equally to males and females (e.g., Korich & Waddell, 1986). There must be possible video game themes that would have equal appeal for boys and girls.

The studies in this section cover a range of arcade-style action games that reflect the constant change in software from the more primitive graphics of Evolution (Greenfield, Camaioni, et al., 1994) to the more sophisticated three-dimensional representations of Marble Madness (Subrahmanyam & Greenfield, 1994). This trend toward more sophisticated graphics has continued and will continue into the foreseeable future. The games also range from arcade games (The Empire Strikes Back used by Greenfield, Brannon, & Lohr, 1994; Robotron used by Greenfield, deWinstanley, et al., 1994) to home computer games (Evolution used by Greenfield, Camaioni, et al., 1994; Robot Battle used by Greenfield, deWinstanley, et al., 1994) to games that are available for varying combinations of arcade machines, home computers, and home game sets (Marble Madness used by Subrahmanyam & Greenfield, 1994; Tetris used by Okagaki & Frensch, 1994). The studies also include other kinds of computer games in comparison conditions (a computer memory game in Greenfield, Camaioni, et al., 1994, and a computer word game in Subrahmanyam & Greenfield, 1994).

It should not be assumed that every computer game or even every action video game develops all of the skills assessed in the studies as a whole. Each game was selected to relate to the specific skill assessments used in that particular study. Indeed, earlier research by Gagnon (1985) showed that skill in each of two video games, Targ and Battlezone, was related to an overlapping but not identical set of spatial skills. However, the nature of the technology is such that skill in reading iconic and spatial representations will, in some form, come into every video game just as it comes into every computer application. As the graphics of games become ever more realistic, the particular nature of the iconic and spatial representations changes but remains central to the medium.

One reason for the predominance of spatial skills in action video games is that spatial strategies can be carried out more quickly than verbal-analytic strategies (Lowery & Knirk, 1982–1983). Neural research (Goffinet, De Volder, Bol, & Michel, 1990) indicates that action video games hyperactivate the visual cortex while depressing activity in the prefrontal cortex, the part of the brain responsible for complex linguistic grammar and sequential motor planning (Greenfield, 1991).

There is a tendency for people to use a verbal-analytic approach to visual-spatial tasks when given sufficient time to do so (Lowery & Knirk, 1982–1983). As Harris (1992) pointed out, home video games, unlike arcade games where time is money, often permit stopping time for reflection. It will be interesting to see whether nonspatial symbolic approaches to this genre, termed the adventure game, are more successful than they are to speed-based arcade-style action games, the focus of the research presented in this section.

However, as Harris pointed out, even nonspeed-based adventure games elicit iconic as well as symbolic strategies, insofar as players consult complex maps which are forms of iconic representation. The use of printed maps should add a more conceptual knowledge of space to the procedural knowledge developed by navigation through a game, if navigation through the two-dimensional representational space of a video game is cognitively similar to navigation through the real three-dimensional world studied by Thorndyke and Hayes-Roth (1982).

Video games make it possible for the first time to actively navigate through representational space. How does this experience relate to skills in navigating real-world space such as those studied by Hazen, Lockman, and Pick (1978)? How does this experience with a dynamic two-dimensional spatial representation relate to skills in dealing with static spatial representation such as map reading (Liben & Downs, 1989; Uttal & Wellman, 1989) or map making (Spencer, Harrison, & Darvizeh, 1980)? How does it relate to skills in utilizing three-dimensional models of real-world space such as those studied by DeLoache (1989)? How does navigating through a two-dimensional external representation affect internal mental representations of space such as those studied by Somerville and Bryant (1985)? A case study by Coty (1985) indicated that navigating through the representational space of linked video screens leads to the rapid development of a mental map, but more extensive research is needed. Finally, is there a connection between navigational activity in the two-dimensional representational space of video games and the communication of spatial information studied by Gauvain and Rogoff (1989)? These are important questions for future research.

Harris (1992) pointed out that home video game players consult elaborate reference manuals (which include symbolic words as well as iconic maps and other iconic images), and use the Nintendo telephone hot line (a more purely symbolic form of communication). Some statistics put these communication media and representational tools in social perspective: Nintendo of America received more than 7.2 million calls and letters from players in 1991 and its magazine *Nintendo Power* has the largest subscription base of any child- and youth-directed magazine in the U.S. with a circulation of 1.2 million.

The relatively new Super Nintendo gives an idea of the way the technology is moving: It allows players to become creators, as they produce their own animation, complete with music and sound effects. Complex simulation games, such as Sim City (the player builds a functional city) and Sim Ant (the player constructs a functional ant colony), have also become very popular. Future study of video games and their cognitive effects will have to take account of this multimedia and multimodal set of representational tools surrounding the increasingly fertile marriage of television and the computer.[2]

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[2]Credit for the phrase "the marriage of television and the computer" belongs to Gardner (1983).

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