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Impact of Virtual Reality on Young Adults' Physiological Arousal and Aggressive Thoughts: Interaction Versus Observation

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The purpose of this study was to compare the impact of playing versus observing a violent virtual reality game on young adults' arousal levels, feelings of hostility, and aggressive thoughts. Physiological arousal and aggressive thoughts, but not hostile feelings, were higher for participants than for observers of the virtual reality game. Results suggest that technologies varying from observational to participatory modes of interaction can have differing physiological and cognitive consequences.

The information age has brought about opportunities for symbolically mediated experiences that affect human behavior. Viewing televised violence, for example, has been implicated as one causal agent in the acquisition and performance of aggressive actions (Friedrich-Cofer & Huston, 1986). Nevertheless, one can learn aggressive content from television without translating that knowledge into one's personal behavior (Bandura, 1965).

The heir apparent to the action–violence formula, which is already the staple of television programs and video games (Greenfield, 1984), is the *virtual reality* game. Virtual reality is defined as a three-dimensional computer-simulated scenario in which a person can look, move around in, and experience an imaginary world (Pimentel & Teixeira, 1993). The perception of this artificial world is

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accomplished by wearing special virtual reality goggles and other gear to immerse the perceptual systems within the virtual reality simulation. The more a computer simulation submerges a person's sensory systems, the more immersed he or she feels in that world (Biocca, 1992).

Unlike television, video games and virtual reality require direct action for a game to continue. In the case of aggressive content in the virtual reality game used in this study, a person must *kill* or *be killed* in this life-like, computer-simulated reality. Consequently, aggressive action is incorporated directly into a person's behavioral repertoire when virtual reality games are played. Bruner, Olver, and Greenfield (1966) advanced the idea that people can represent information at three levels: (1) enactive (e.g., with the body), (2) iconic (e.g., with the visual system), or (3) symbolic (e.g., with words). Video game play cultivates iconic, visual–spatial representational skills (Greenfield, Camaioni, et al., 1994; Subrahmanyam & Greenfield, 1994). Interactions with an aggressive virtual reality game may well cultivate enactive, bodily representations (e.g., firing a gun) that may then be easily recoded into subsequent aggressive behavior in future situations.

It is the shift from observational to interactive, immersive technologies that is the focus of the inquiry here. Specifically, we examine the impact of acting upon versus observing aggressive content in a virtual reality environment.

Theoretical Models in Relation to Aggression

Various theoretical models have been used to examine the impact of violence on a person's aggressive behavior. According to the *arousal theory*, physiological responses to aggression should initially increase as one engages in a threatening experience. For example, a person's blood pressure, a measure of the autonomic nervous system, increases when he or she is exposed to an aggressive situation. Physiological arousal can then be channeled into the activities that one is exposed to—aggressive ones in this instance.

As stated in the *social cognitive theory* (previously known as the social learning theory), a person can become more aggressive after observing and then imitating a model who is acting aggressively. Observational learning is regulated by attention, retention, production, and motivation (Bandura, 1986). Once attended to, aggressive content can be retained in memory to be reproduced when a person is motivated to do so. According to social cognitive theory, a second way that aggressive behavior can occur is by disinhibition. With age and development, internal impulse controls are created to inhibit aggressive actions. As stated by Bandura, these controls can be disinhibited, or weakened, when one observes another act aggressively, thereby resulting in more personal aggression.

Finally, according to the *psychoanalytic theory* (Hall, 1954), a subsequent decrease in aggression should occur through catharsis as one releases aggressive drives safely in symbolic games rather than actual experiences. Hall suggested that drive reduction should occur when a person participates in fantasy experi-

ences that allow him or her to "drain off" dangerous aggressive impulses, a primary human drive. In a game, one can kill another person symbolically.

Impact of Information Technologies on Aggressiveness

Over the past two decades, a significant body of research has been gathered which indicates that viewing television violence increases aggressive behavior (Friedrich-Cofer & Huston, 1986). Children who observe aggressive television models sometimes imitate those behaviors or have the internal controls disinhibited that prevent aggressive action (Stein & Friedrich, 1972; Steur, Applefield, & Smith, 1971). Blood pressure increases after viewing sexual or aggressive content, providing support for the arousal theory (Zillmann, 1971). However, children rarely act less aggressively after viewing televised violence as would be predicted by a drive-reduction hypothesis via the psychoanalytic theory (Friedrich-Cofer & Huston, 1986).

In a seminal study for the social cognitive theory, Bandura (1965) drew a distinction between acquisition and performance. Children viewed a violent film. After viewing the program, some children, particularly boys, spontaneously incorporated those aggressive actions in their play. Other children, primarily girls, did not spontaneously imitate the observed aggression. However, when offered incentives to do so, most children were quite capable of depicting the aggression they had viewed which indicated that the actions had been learned even if not performed. This finding suggests that girls may think about the aggressive actions that they view, even if they do not necessarily act aggressively.

Games created for new technologies often require aggressive performance by participants. In many video games, players must shoot or harm their symbolic opponents in order to win. Consistent with television studies on observed aggression, children who played aggressive video games subsequently became more aggressive in their social play, supporting both the social cognitive and arousal theories (Silvern & Williamson, 1987). Similarly, children who interacted with a violent video game were found to imitate those aggressive behaviors in their later free play (Schutte, Malouff, Post-Garden, & Rodasta, 1988). Prosocial behavior that benefits others can also be inhibited for those who play violent video games (Chambers & Ascione, 1987). Hostile feelings increased for young adults who played violent video games (Anderson & Ford, 1986), supporting the arousal theory. Although video game play is associated with increased hostility, the effect is smaller than that produced by television or darts (Favaro, 1983).

There is also a set of studies that suggest catharsis or tension release from video game play (Brooks, 1983; Egli & Meyers, 1984; Graybill, Kirsch, & Esselman, 1985). For instance, aggressive ideation was lower for children who played an aggressive rather than a nonaggressive video game, suggesting a discharge of aggression in a socially acceptable way (Graybill et al., 1985). However, Graybill, Strawniak, Hunter, and O'Leary (1987) found no differences

in the aggressive behavior of children who played a violent versus a nonviolent video game.

In summary, as in the television area, imitation (Schutte et al., 1988), disinhibition (Silvern & Williamson, 1987), and arousal (Anderson & Ford, 1986; Silvern & Williamson, 1987) are viable constructs for explaining the impact of aggression on children. To the extent that girls become active participants in these aggressive games, one might expect a closer link between acquisition and performance than has been reported in the television literature. However, drive reduction via catharsis has received more support in the video game literature than in the television literature (Brooks, 1983; Egli & Meyers, 1984; Graybill et al., 1985).

Appearing now in video arcades, a male haven (Greenfield, 1984), virtual reality interfaces can create the illusion that a person is part of the game. Player movements control the virtual reality game. For instance, turning one's head to the right yields one visual perspective; turning it to the left yields a different one. No screen boundaries are seen, as in the case of a television screen, because the goggles provide a continuous, peripheral view. Actions within this setting may be more realistic than those encountered in previous technologies because information is presented in a three-dimensional form that is responsive to player movements. As in video game play, the person is now the character, not an observer as in television viewing (Shapiro & McDonald, 1992).

In the case of aggression, the virtual reality game player has the personal experience of being pursued by or shooting an opponent. As in video games, aggressive performance is required for successful performance; in this way, aggressive action may be incorporated directly into a person's behavioral repertoire. The immersive quality of the technology may increase both arousal levels and aggression more than previous formats because people feel they are directly and personally experiencing violent events. Involuntary emotional responses may be influenced by such immersive, life-like experiences (Shapiro & McDonald, 1992).

Person Characteristics

Characteristics of people also impact the ways that technologies influence them. In the case of aggression, we considered two primary personal attributes: gender and aggressive traits. Men have long been identified as demonstrating more aggressive behavior than women (Huston, 1983; Maccoby, 1980). Some argue that differences in aggression between men and women, as well as within a particular gender group, are based on biologically based traits (Maccoby, 1980) and thus certain people are simply inherently more aggressive than others. Other theorists approach aggressive behavior as a state at a given point in time (Huston, 1983). From the latter perspective, aggression is learned just like any other behavior: through reinforcement and punishment.

Regardless of the origins, aggression is clearly stable within people of both

genders for many years (Maccoby, 1980). Aggressive youth are likely to become aggressive adults. Consequently, we included a priori trait measures of aggression in order to control for initial differences in aggression. After treatments, we also examined two temporary state measures of aggressiveness in feelings and thoughts, respectively.

The Present Study

The purpose of this study was to compare the impact of participation versus observing an aggressive virtual reality game on young adults' arousal levels, feelings of hostility, and aggressive thoughts. The major hypothesis was that physiological arousal and aggressive thoughts would increase more for those who participated directly in the virtual reality experience than for those who observed it. The arousal and social cognitive theories were expected to provide the best fit for explaining how virtual reality impacts adults' aggressive behaviors. No support was expected for a tension-reduction hypothesis, indexed by hostile feelings, as would be predicted by the psychoanalytic theory. Gender and aggressive traits were included in order to examine differential effects of aggressive exposure on different kinds of people.

The following five hypotheses were made: (1) physiological arousal and aggressive thoughts were predicted to be higher in the virtual reality immersion condition than in the virtual reality observation and control conditions; (2) subjects in the virtual reality observation condition were predicted to report more aggressive thoughts than were those in the control condition; (3) hostile feelings were not expected to decrease from baseline to treatment in the virtual reality or observation conditions, as would be predicted via a drive-reduction hypothesis; (4) because one aggresses directly in the virtual reality immersion condition, gender differences in aggressive thoughts were not predicted within this condition; and (5) as aggression is more in keeping with male rather than female roles, men were expected to report more aggressive thoughts than were women in the observation condition.

METHOD

Subjects

Subjects were 36 middle-class college students (*M* age = 20 years, 6 months), equally distributed by gender, who attended a private university in a large metropolitan area. Few had ever seen or played a virtual reality game or even knew what it was.

Procedure

Pretest. Subjects initially came for a 5 to 10 min pretest in the 2-week period prior to the experimental conditions. Each subject completed three subtests of the

Buss and Durkee (1957) personality trait measure assessing hostility. The subtests measured assault (n = 10 items), verbal hostility (n = 13 items), and irritability (n = 11 items). Subjects circled either *true* or *false* for each item. An example of an assault item is, "Once in a while, I cannot control my urge to harm others." A verbal item is, "When people yell at me, I yell back." An example of an irritable item is, "I often feel like a powder keg ready to explode." Test–retest correlations were .78 for assault, .72 for verbal hostility, and .65 for irritability (Buss, 1961). Using factor analysis techniques, Buss and Durkee clustered these three subscales into a *motor* component of hostility.

On the day of the study, a physiological measure of pulse rate was taken in the virtual reality setting. This pretest pulse rate was taken manually by an experimenter by placing her fingers on a subject's left wrist. She then counted the number of heart beats for 15 s and multiplied by four. At a later time, reliability was assessed for 6 subjects. To do so, two experimenters simultaneously took the pulse rate of individual subjects. One experimenter placed her fingers on a subject's left wrist and counted heart beats for 15 s while the other experimenter placed her fingers on the subject's right wrist and counted heart beats during that same 15-s time frame. Each score was then multiplied by four. Interobserver reliability for pulse rate, computed as two times the number of agreements divided by the total number of scores for both experimenters, averaged 98% for the six protocols where each beat was counted as a judgment.

Treatment Conditions. On a Saturday afternoon, subjects assembled outside a building at their home university. Within gender groups, each randomly signed one of three lists, thereby determining their respective treatment condition. Subjects were then transported by one van in groups of 12 (i.e., by treatment condition) to another university campus that was hosting a fair. Transportation time was about 10 min. The virtual reality game was located outside on campus grounds at this fair.

Upon arrival, the pretest pulse rates were taken individually for the first group: the *virtual reality condition*. They then joined a line and waited 30 to 45 min to play a virtual reality game. A research assistant, who waited with them, told them not to watch the monitors. Subjects were given a virtual reality pass instead of money to play the $5 game.

Subjects in the virtual reality condition played Dactyl Nightmare. In this game, two opponents stand on raised platforms called pods. Each wears a set of goggles and a belt and holds a pistol-action device to control the perception of bodily movement through space and of shooting a gun. The goggles provide visual images of the game: by turning one's head to the left or to the right, one alters the visual images appearing through the goggles. The belt controls the direction of movement, and one pushes the top of the hand-held device to move. It is analogous to turning one's body to face a particular direction (controlled by

the belt) and then walking in that direction (controlled by pushing the top of the hand-held device). To fire the gun, one pulls the trigger.

The 4-min virtual reality game, much like a video game in content, consists of two players whose physical bodies are represented as a green or yellow cartoon-stick figures inside a three-dimensional animated world. Unlike a video game where you see both players, in a virtual reality game the player is one of the characters, and thus, sees only the represented opponent. The players are adversaries of one another. Several black-and-white checkerboard platforms appear in a multilevel acropolis. Stairs connect the platforms and columns appear in various parts of the platforms. The edge of the platforms end in black space. However, one can jump onto a small disc and ride to other levels of the platforms by pushing the forward position of the hand-held device. A pterodactyl, an additional adversary of both players, flies overhead. Players can shoot the pterodactyl; the pterodactyl can also pick up the players, lift them into the sky, and then drop them. The object of the game is to move through the platforms and shoot both the opponent and the pterodactyl. Whenever a player is dropped by the pterodactyl or shot by the other player, his or her character explodes and is then reassembled at another point on the platforms. Points are scored every time an opponent is shot. To win, a player must shoot his or her opponent more times than being hit by his or her opponent. Scores are kept mechanically.

While the first group was waiting to play, the van returned with the second group: the *observation condition*. Upon their arrival, the observation group had their pulses taken. Same-gender groups of three then watched another person's 4-min virtual reality game on a 3 ft $\times$ 3 ft video monitor.

The *control group* arrived last. Pulses were taken, and a research assistant led them as a group in the motions that are used when playing the virtual reality game. For example, subjects moved their heads and torsos 180° from side to side while keeping their feet in a constrained space. They did not see or interact with the virtual reality game. They were told to dodge the pterodactyl, one property of the virtual reality game, but aggression was not mentioned. The 4-min simulation controlled for possible arousal effects from movement per se.[1]

Posttest. The 10-min posttest consisted of three measures: (1) pulse rate, (2) the Multiple Affective Adjective Check List, and (3) a thought-listing questionnaire.

After their respective treatment conditions, each subject's pulse was immediately taken, as described in pretest procedures.

Next, subjects selected adjectives from the revised Multiple Affective Adjective Check List that described how they felt at that moment. Following the procedure of Bushman and Geen (1990), the state version of the hostility sub-

[1]The authors thank Daniel N. Robinson for this suggestion.

scale was used with filler items. Hostility was operationally defined as the number of hostile adjectives, such as *aggressive, angry, annoyed, complaining, critical, cross, cruel, disagreeable, disgusted, enraged, furious, hostile, incensed, irritated, mad,* and *mean,* that a subject chose. *Dizzy* and *nauseous* were added to the list because some players report motion sickness after virtual reality experiences (e.g., Biocca, 1992; Psotka, Davison, & Lewis, 1993).

Subjects also completed a questionnaire about their thoughts during the 4 min when they played, observed, or simulated the virtual reality game. Subjects were told to write about their thoughts without concern for grammar or spelling (Cacioppo & Petty, 1981). A research assistant timed them in this 4-min task. The protocols were evaluated following procedures developed by Bushman and Geen (1990) for words having aggressive meanings, such as *kill, hit, shoot, shot,* and *blow up.* In the present study, two raters later scored all 36 protocols for both aggressive thoughts and for the total number of thoughts, the latter measure reflecting general arousal. The reliability coefficient was $r = .78$, $p < .0001$ for aggressive thoughts, and $r = .94$, $p < .0001$ for total thoughts.

At the end of the study, subjects in the observation and control conditions were given the option of playing the virtual reality game. The treatment procedure, from the time subjects were picked up until they returned to their university, lasted about 3 hr.

RESULTS

Pretest Scores

Condition was assigned to subjects on the day that the experiment was conducted. We then examined the pretest information to ensure that subjects were initially equivalent on various measures. Specifically, arousal scores and hostile personality scores were examined as dependent variables with condition and gender as independent variables.

Arousal Scores. The 3 (Condition) × 2 (Gender) between-subjects analysis of variance (ANOVA) computed on pretest arousal scores yielded no effects for condition or gender. Thus, subjects were initially equivalent across groups in arousal on the day of the study.

Hostile Personality Scores. The Buss and Durkee (1957) subscales of assault, verbal aggression, and irritability were summed to create a total hostile personality score. A 3 (Condition) × 2 (Gender) between-subjects ANOVA was run on pretest hostile personality scores. No differences were found for condition or gender. Thus, there were no pretest differences in hostile personality scores across groups. However, a two-factor ANOVA computed on the three respective subtests of Buss and Durkee did yield a main effect of gender for assaultive personality, $F(1, 30) = 4.30$, $p < .05$. Specifically, men reported more assaul-

tive personalities than did women ($M = 4.17$, $SD = 2.48$ vs. $M = 2.67$, $SD = 1.50$, respectively). There were no gender differences reported for personality traits like verbal aggression or irritability. There were also no condition effects on the subtests.

Posttest Scores

The analysis strategy for the posttest was to examine arousal and aggression as dependent variables as a function of condition and gender. One dependent measure examined only arousal (i.e., pulse rate), one measured hostile feelings (i.e., revised Multiple Affective Adjective Check List), and one examined both arousal (measured as total number of thoughts) and aggressive thoughts. Pretest scores were used as covariates. When a significant F ratio was found, Duncan's (1955) multiple-range follow-up contrast was used for post-hoc comparisons.

Pulse Rate Scores. A 3 (Condition) × 2 (Gender) analysis of covariance (ANCOVA) was run on posttest pulse rate scores with pretest pulse rate scores as the covariate. The two-factor ANCOVA computed on posttest pulse scores yielded a main effect of condition, $F(1, 29) < 3.35, p < .05$; pretest pulse scores were also significant as a covariate, $F(1, 29) = 10.23, p < .01$. As seen in Table 1, subjects in the virtual reality immersion condition increased in arousal more than those in either the control (i.e., the virtual reality movement simulation condition) or the observation condition.

Responses of Nausea and Dizziness to Virtual Reality. Participation in a virtual reality game could increase arousal by disrupting a person's sense of equilibrium. Therefore, we asked subjects if they felt dizzy or nauseated after their treatment conditions. Dizziness scores for the three conditions were submitted to a chi-square analysis. As seen in Table 2, subjects in the virtual reality immersion condition reported feeling dizzy or nauseated more often than those in the observation or control conditions, $\chi^2(2, N = 36) = 16.89, p < .001$.

TABLE 1
Mean Pretest and Posttest Pulse Rate Scores for the Control, Observation, and Virtual Reality Conditions

Condition	Pretest Pulse Rate		Posttest Pulse Rate	
Control	74.67[b]	(7.69)	79.67[b]	(9.57)
Observation	75.67[b]	(15.39)	78.00[b]	(15.49)
Virtual Reality	81.00[b]	(12.24)	92.33[a]	(11.11)

[a,b]Means are significantly different from pretest to posttest at $p < .05$. Standard deviations are presented in parentheses. Cell means are based on 12 subjects.

TABLE 2
Frequency of Subjects Reporting Dizziness by Condition

Condition	No Dizziness	Dizziness
Control	12	0
Observation	11	1
Virtual Reality	4	8

$N = 36$.

Within the virtual reality immersion condition, partial correlations were computed between dizziness/nausea scores and pulse rate scores after participating in the game; pretest pulse rate scores were partialled out of the equation. The partial correlation was not significant (two-tailed, $p > .10$).

Multiple Affective Adjective Check List Scores. The number of adjectives reflecting hostile feelings was summed for each subject (range 0–4). Hostility scores were submitted to a 3 (Condition) × 2 (Gender) ANCOVA with pretest scores of hostile personality traits as the covariate. The two-factor ANCOVA computed on hostile feelings yielded a main effect of gender, $F(1, 29) = 7.80$, $p < .01$. Men reported more hostile feelings during the posttest than did women ($M = 1.06$, $SD = 1.16$ vs. $M = .17$, $SD = .38$, respectively). Contrary to prediction, neither condition nor hostile personality covariate scores were significant.

Aggressive Thoughts. The next analysis examined the content of subjects' thoughts as they participated, observed, or simulated virtual reality movements. The number of aggressive thoughts was submitted to a 3 (Condition) × 2 (Gender) ANCOVA with pretest scores of hostile personality traits as the covariate. The two-factor ANCOVA computed on aggressive thoughts yielded a main effect of condition, $F(1, 29) = 6.18$, $p < .01$. As predicted, aggressive thoughts were reported more often by subjects in the virtual reality immersion condition ($M = 1.42$) than by those in the observation ($M = .17$) or control ($M = .33$) conditions. As expected, men and women reported similar frequencies of aggressive thoughts in the virtual reality condition ($M = 1.50$ vs. $M = 1.33$, respectively). Contrary to prediction, men did not report more aggressive thoughts than did women either in the observation condition ($M = .17$ vs. $M = .17$, respectively) or in the control condition ($M = 0$ vs. $M = .67$, respectively). The hostile personality trait covariate score was not significant.

Total Number of Thoughts. To test for overall arousal effects, an analysis strategy developed by Bushman and Geen (1990) was adapted. Specifically, the total number of thoughts was submitted to a 3 (Condition) × 2 (Gender)

ANOVA. As expected, there were no significant differences in the number of thoughts in varying conditions. Thus, the type of thought (i.e., aggressive) was affected by playing the virtual reality game, not the quantity of thoughts as would be predicted by the arousal theory.

DISCUSSION

The purpose of this study was to examine the impact of participating in versus observing aggressive acts, as represented in a virtual reality game, on young adults' physiological arousal, feelings of hostility, and aggressive thoughts. Individual variations were considered by including both gender and a priori levels of hostile personality traits.

As expected, subjects' heart rates increased after participation in the virtual reality game. Physiological arousal was a function of the virtual reality experience rather than of movement per se because the control condition moved in ways that paralleled the virtual reality group. This finding provides support for the arousal theory.

Those who played the virtual reality game also reported more dizziness and nausea than did those in either the observation or control conditions. Physiological arousal, however, was unrelated to motion sickness. This suggests that other factors were causing their arousal to increase.

As expected, aggressive thoughts increased more for those who played than for those who observed the virtual reality game or simulated game movements, providing support for the social cognitive theory over the arousal theory. More specifically, the aggressive content of thoughts separated virtual reality game players from those in other conditions. In contrast, the total number of thoughts, as would be expected from a straight arousal effect, did not distinguish the three conditions. One implication is that immersion has a more profound impact on thoughts than does observation.

In contrast, no differences were found between participants versus observers of a violent video game (Cooper & Mackie, 1986; Silvern & Williamson, 1987). In the Silvern and Williamson study, young children who viewed a Road Runner cartoon or who played a Space Invaders video game increased in their subsequent aggressive interpersonal behavior. Thus, participants and observers were affected similarly by exposure to a violent television program or video game. Our virtual reality study differed from both of these studies in several respects. First, we studied young adults rather than children. Second, arousal, thoughts, feelings, and personality traits were the focus of our inquiry; aggressive behavior was the focus of the television and video game studies. Third, immersion may potentially be a more powerful perceptual experience than video game play, thus increasing the impact of interactive over observational experiences. Fourth, one child at a time played the video game whereas two adults played the virtual reality game.

Minimal observer involvement was apparent in another aspect of our study.

Those who observed the aggressive virtual reality game did not report more aggressive thoughts than did those in the control condition. Based on the social cognitive theory (Bandura, 1986), differences should also have occurred between these groups.

Parallel to most television studies (Friedrich-Cofer & Huston, 1986) but unlike the video game literature where the results are more diverse (Egli & Meyers, 1984; Graybill et al., 1985; Silvern & Williamson, 1987), no support was found for catharsis for virtual reality participants. Specifically, neither aggressive ideation nor hostile feelings decreased from baseline to treatment for young adults who played an aggressive virtual reality game, as would be predicted by the psychoanalytic theory's drive-reduction hypothesis. However, hostile feelings did not increase for virtual reality participants either, as would be predicted by the arousal theory.

Personal characteristics seemed to provide the best explanation for hostility. In particular, men reported more hostile feelings on the posttest and had a more assaultive personality on the pretest than did women. These findings provide further support for gender differences in aggression (Huston, 1983; Maccoby, 1980).

Even so, men and women had similar levels of aggressive thoughts when they interacted with violent content. When aggressive action is represented directly in a person's behavioral repertoire (e.g., Bruner et al., 1966), aggressive thoughts are generated and available for action. Bandura (1965) demonstrated that gender differences occurred in children's spontaneous aggressive behaviors after viewing a violent film, but there were no gender differences in aggressive learning. Moreover, this learning could easily be translated into action, given motivational incentives to reproduce the observed aggression. Consistent with Bandura's findings concerning learning, the number of aggressive thoughts was similar for men and women who played a violent virtual reality game. Repeated participation in this type of virtual reality game could eventually reduce gender differences in aggressive behavior, but only if women are motivated to play violent games. Given the appearance of virtual reality games in video arcade contexts, where men outnumber women and play more games than women do (Greenfield, 1984), it seems that aggressive differences may actually be accentuated in natural environments.

The study of behavior in everyday situations, such as playing a virtual reality game at a fair, provides an example of the ways that people act in naturalistic rather than laboratory settings. This kind of study allows us to observe behavior in context as well as to analyze context and behavior interactions. Video games and virtual reality games, as cultural artifacts, have the potential for exploring the roles that situations play in the initiation, maintenance, termination, and constraint of human behaviors.

In summary, young adults who played an aggressive virtual reality game exhibited increased physiological arousal and increases in aggressive thoughts

more so than those who observed another person play the game or who simulated virtual reality game movements. Increases in heart rate provided support for the arousal theory, and increases in aggressive thoughts provided support for the social cognitive theory. However, the observational condition did not produce more aggression, as would be predicted by the social cognitive theory. Drive-reduction via a decrease in hostile feelings, as would be predicted by the psychoanalytic theory, was not found; nor did hostile feelings increase, as would be predicted by the arousal theory. Hence, the arousal and social cognitive theories received the most support in this study, but no one theory adequately described the impact of virtual reality game play on aggression.

In general, violent virtual reality interactions override personal characteristics like gender and prior levels of hostile personality traits, resulting in similar aggressive effects for all players. These results suggest that virtual reality is an even more potent purveyor of aggression than are historical villains like television.

The symbolic nature of this interaction suggests that participants may not generalize these actions to real-life situations. However, the long history of television research suggests the opposite (Friedrich-Cofer & Huston, 1986). Interactive behaviors with violent video games can also result in interpersonal aggression (Schutte et al., 1988; Silvern & Williamson, 1987), and now we have an even more realistic medium: one in which a person can actually be perceptually immersed in a world of violent activities.

Shifts from observational to interactive technologies provide tools that allow researchers to link emotion, behavior, and ideation. Such developments can be used to challenge and modify theoretical positions by providing direct links between symbolic media, thinking, and behavior. Personal and societal levels of aggression may well increase when participants become actively immersed in these violence-laden forms of entertainment. Research in this area can provide guidance to policymakers about the potential behavioral consequences of these new interactive technologies.

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