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Action Video Games and Informal Education: Effects on Strategies for Dividing Visual Attention

PATRICIA M. GREENFIELD
PATRICIA DEWINSTANLEY
HEIDI KILPATRICK
DANIEL KAYE
University of California, Los Angeles

Two experiments investigated the effects of video game expertise on divided visual attention in college students. Divided attention was measured by using response time to targets of varying probabilities at two locations on a computer screen. In one condition the target appeared 10% of the time in one location (low probability position), 80% of the time in the other location (high probability position), and 10% of the time in both locations. In the other condition the target appeared 45% of the time in each position (equiprobable or neutral positions) and 10% of the time in both positions. The subjects for Experiment 1 represented two extremes of video game skill (labeled experts, novices), whereas the subjects for Experiment 2 were an unselected group with a continuous distribution of video game performance (labeled more skillful, less skillful). Experiment 1 established that video game experts were similar to novices in manifesting an attentional benefit (manifested in faster response time) at the high probability position (relative to a neutral or equiprobable position). However, unlike novices, experts did not show an attentional cost (manifested as slower response time) at the low probability position (again relative to a neutral position). Experts also had significantly faster response times than novices at both the 10% and 80% positions, but not at the 45% position. Experiment 2 established that video game experience was a causal factor in improving strategies of divided attention. Five hours of play on a video game called Robotron produced a significant decrease in response time at the 10% location, the locus of the expert–novice difference in Experiment 1.

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Patricia deWinstanley is currently at Oberlin College. Heidi Kilpatrick is now with Mattel Corporation, Los Angeles. Daniel Kaye is currently with Applause, Inc., Los Angeles.

Correspondence and requests for reprints should be sent to Patricia M. Greenfield, Department of Psychology, University of California, Los Angeles, 405 Hilgard Avenue, Los Angeles, CA 90024–1563.

Mass media constitute an important aspect of the informal educational environment provided by our culture. As such, they can be expected to affect processes of "everyday cognition" (Rogoff & Lave, 1984). Although basic cognitive processes are universal, cultural tools (Vygotsky, 1962) have the power to encourage selectively some cognitive processes, while letting others stay in a relatively undeveloped state. We use the term *cognitive socialization* (Greenfield, 1989) to refer to the influence of cultural tools on the development and exercise of skills for processing and communicating information. Media in general (Bruner & Olson, 1974; Greenfield, 1984; Salomon, 1979) and the computer in particular (Papert, 1980) are potent cultural tools for the selective sculpting of profiles of cognitive processes.

Among all the forms of computer technology, there is one that touches people on a mass scale and, even more important, touches them during the formative years of childhood when cognitive development is taking place. This form of technology is the action video game. For example, a study in 1985–1986 by Rushbrook (1986) showed that 94% of 10-year-old children in Orange County, Southern California, played video games. Eighty-five percent of these children considered themselves good, very good, or expert players.

Action video games were designed to entertain, not to educate. Informal education is often characterized, however, by its unintentional effects. In any case, our interest does not lie in either the intended or unintended educational *content* of video games. It lies instead in the unintentional cognitive effects of the *forms* of the medium, forms that are derived from computer technology and that can be used to transmit a wide range of content, designed either to entertain or to inform (Greenfield, 1983, 1984). Content can be defined as the topical themes transmitted by a medium. For example, violent battle is one frequent content theme of action video games; geometric puzzles constitute a less frequent content area. Forms are defined as the design features of a medium that transcend particular content (Rice, Huston, & Wright, 1982). Interactivity and dynamic iconic imagery are examples of two formal features that are important in action video games.

We extended and subjected to scientific study Marshall McLuhan's (1964) dictum, "The medium is the message" as we focused on the cognitive "messages" of the video game medium. Because they are not a part of formal education, any cognitive effects of video game forms might be expected to appear primarily in the domain of "everyday," rather than that of school-related cognition.

Up to now, research has investigated the cognitive effects of video game experience on inductive discovery skills (Camaioni, Ercolani, Perrucchini, & Greenfield, 1990; Greenfield, Camaioni, et al., 1994), on the decoding of dynamic computer graphics (Camaioni et al., 1990; Greenfield, et al., 1994), on visual-spatial skills (Chatters, 1984; Dorval & Pepin, 1986; Forsyth & Lancy, 1987; Gagnon, 1985; Greenfield, Brannon, & Lohr, 1994; McClurg & Chaillé, 1987; Subrahmanyam & Greenfield, 1994), on eye–hand coordination (Drew &

Waters, 1986; Favaro, 1983; Gagnon, 1985; Griffith, Voloschin, Gibb, & Bailey, 1983), and on reaction time (Clark, Lanphear, & Riddick, 1987; Orosy-Fildes & Allan, 1989). The results have generally been positive in all areas, although the positive impact on eye–hand coordination has been demonstrated for elderly people (Drew & Waters, 1986), but not young adults (Favaro, 1983; Gagnon, 1985). A number of cognitive skills related to video game expertise are useful in dealing with computers and high technology more generally (Compaine, 1983; Greenfield, 1989, 1993; Strover, 1984).

The U.S. military noted the similarity between the skills required to pilot an aircraft and those required to play video games (Nawrocki & Winner, 1983). For example, the army and, especially, the navy participated in and funded research on video games as performance tests (Carter, Kennedy, & Bittner, 1980; Jones, Dunlap, & Bilodeau, 1986; Jones, Kennedy, & Bittner, 1981; Kennedy, Bittner, & Jones, 1981). Researchers established a high correlation between performance on a flight simulator configured for aircraft carrier landing and performance on the Atari home video game Air Combat Maneuvering (Lintern & Kennedy, 1984).

One reason for the correlation might be the skill of divided attention that we isolated for study in this article. Indeed, many flight tasks involve divided attention. For example, a pilot told us that trying to keep track of a lot of different things—for example, a row of six engine dials—is a lot like a video game. One would imagine that air traffic controlling, also similar to video games (Jones, 1984), would involve skilled use of divided attention. Thomas Longridge, a member of the Human Resources Laboratory at Williams Airforce Base, used an aircraft carrier landing game for research on pilot judgment (Trachtman, 1981).

The military have recognized other areas of relevance for video games, such as recruitment and training (Provenzo, 1991). The U.S. Army modified the Atari game Battlezone for use in military training (Nawrocki & Winner, 1983; Trachtman, 1981). The U.S. Navy designed its own video game, a war game called NAVTAG, intended for tactical training of junior officers (Jones, 1984), and the British Navy has used a computer-based antisubmarine training game in a similar vein (Kiddoo, 1982); the U.S. Army has done something of a similar nature (Compaine, 1983). During the Gulf War, Commodore Tom Corcoran called the complex process of monitoring electronic screens to distinguish friends from foes in the air "an enormous video game with life-or-death consequences" (Healy & Fritz, 1990, p. A12).

In an effort closely related to our research, video games have been used to expand the effective field of visual attention for brain-damaged patients suffering from left neglect (Murphy, 1983). Such patients, as a result of paralysis on their left side, do not pay attention to the left side of the visual field. Video games that require scanning various locations were found to help repair this deficit of visual attention.

The research presented here focuses on the relation between video game expertise and divided visual attention. The hypothesis of the research came from the observation that in most video games, a player must be able to deal with events occurring simultaneously at several locations on the video screen (Gagnon, 1985; Greenfield, 1984). It was therefore hypothesized that: (a) video game experts would be better than nonexperts at tasks requiring divided visual attention, and (b) video game experience would play a causal role in improving performance on such tasks.

THE MEASUREMENT OF ATTENTION

Posner, Snyder, and Davidson (1980) conducted a series of studies designed to examine the effects of attention on the detection of signals in a visual field. In general, they found that response times to indicate the presence or absence of a target were reduced when subjects received information about the probable location of the target in the visual field. That is, if the stimulus occurred in an expected location (i.e., where the subject had been told there was an 80% probability of a stimulus occurring), responses were faster than if a stimulus occurred in a neutral location (i.e., where there was a 50% probability of a stimulus occurring). Likewise, if a stimulus occurred in an unexpected location (i.e., where there was a 20% probability of the stimulus occurring), responses were slower than if the stimulus occurred in a neutral location.

The increased response time for the unexpected location and the decreased response time for the expected location have been referred to as *cost* and *benefit*, respectively. The finding that, relative to a neutral location, the allocation of attention to a probable location leads to benefit, and the nonallocation of attention to an improbable location leads to cost, has been found by other researchers as well (e.g., Bashinski & Bacharach, 1980; Eriksen & Yeh, 1985; Posner, Nissen, & Ogden, 1978).

Like the study conducted by Posner et al. (1980), our experiments had a neutral condition in which the targets were equally likely to appear briefly in either one of the two locations, and a probable/improbable condition in which the target was much more likely to flash in one of the two locations. It was hypothesized that video game novices would show a pattern of cost and benefit similar to that reported in the attentional literature. That is, it was predicted that video game novices would be faster at responding to the probable target, when compared to the neutral targets, and slower at responding to the improbable target.

However, it was hypothesized that video game experts would show a pattern of cost and benefit quite different from that reported in the attentional literature. Again, it was hypothesized that video game experts would also be faster at responding to the probable target, when compared to the neutral targets; yet they would *not* be slower at responding to the improbable target. That is, it was predicted that the experts would show a benefit at the probable location without

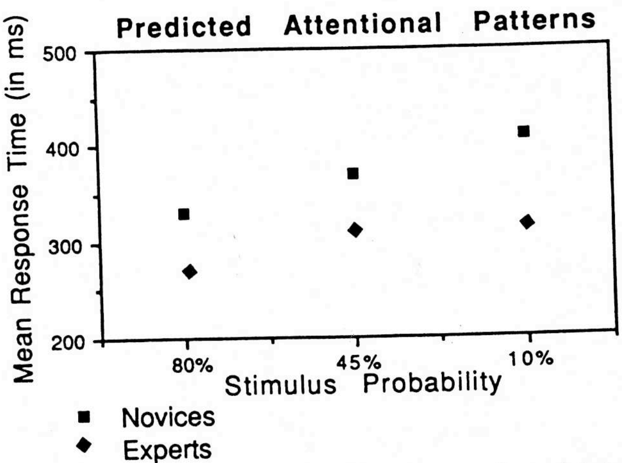

Figure 1. Hypothesized relationship between video game expertise and strategies for dividing attention. As in the experiments that follow, 80% represents a high-probability location, 10% a low-probability location, and 45% a neutral location.

suffering a cost at the improbable location. This makes sense when one considers that in order to play a video game well, players must be able to focus most of their attention on the starship, the robot, or the Pac-Man (the probable target), as well as to maintain some of their attention on other objects (the improbable target). The hypothesized relationship between video game skill and strategies is shown in Figure 1. Lastly, because video game experts simply have more practice in manually responding to flashes on a screen, it was hypothesized that they would be faster than video game novices at responding to all the targets.

EXPERIMENT 1

Method

Subjects. There were 34 male undergraduates at UCLA who participated in the video game portion of this experiment in partial fulfillment of an introductory psychology course requirement. All subjects were right-handed and had normal or corrected vision. Of these subjects, 16 (8 were video game experts, 8 were video game novices) were asked to return to complete the attention portion of the experiment. The selection of the 16 subjects was based on the criteria described later.

Selection Criteria. Video game ability was assessed with the Apple IIe version of the game Robot Battle. This game was chosen because of its face validity. That is, in the game Robot Battle robots attack the player from all directions. It seemed that in order to play the game successfully, one would need to allocate one's attention across the playing screen. Furthermore, extensive pilot testing of this game showed that subjects' scores on Robot Battle were highly correlated with the number of video games that the subjects had played and the number of hours spent playing these games, both $rs\ (17) = .67$, $ps < .001$.

Subjects were asked to play two games of Robot Battle on an Apple II computer. Subjects scoring above 200,000 on either game or below 20,000 on both games were asked to return for the attention portion of the experiment. Pilot testing indicated that these cutoff points were sufficient in that a substantial number of subjects met these criteria, but not so many as to make the categories of expert and novice meaningless.

Attention Task. For the attention portion of the experiment, subjects were seated in front of the terminal screen; a chin and head rest were adjusted so that their eyes were exactly 12 in. from the screen. They were then shown where to place their fingers on the keyboard. The lights were turned off, and the subjects were allowed to adapt to the dark while they read the instructions. The instructions, presented via the computer, provided information about the percentage of trials that the target would appear at each location as well as instructions for initiating and responding to each trial. Subjects were encouraged to ask the experimenter about anything that was unclear. The experiment was conducted in a darkened room, with the experimenter present at all times.

A luminance detection task requiring a choice reaction time response was used to elicit a measure of attention. Stimuli were presented on a Northstar Horizon microcomputer in white against a black background. There were two possible target stimulus locations, each indicated by a pair of short horizontal lines (.36°) located 1° above and below the target location. The two target locations fell on a horizontal axis in line with the center of the screen and were separated by 14° of visual angle.

The target was an asterisk that increased in luminescence, thereby giving the appearance of a brief flash (33 ms). It was located between the set of bars on the right or the left, or on both sides simultaneously. There were two conditions that differed in the probabilities associated with the target's appearance at a given location. In one condition, the target appeared at one location on 80% of the trials, at the other location on 10% of the trials, and at both locations simultaneously on 10% of the trials. In the other condition, the target appeared equally often at the two locations (on the right 45% of the trials, on the left 45% of the trials). On 10% of the trials the target appeared at both locations simultaneously.

The subjects initiated each trial by pressing the space bar. Following a variable interval of 500 to 1,500 ms, one or both of the asterisks flashed between the set or sets of bars. Subjects responded to the asterisk or asterisks as quickly as possible with a choice reaction: They pressed the left key with the right forefinger if the left target stimulus was detected, the right key with the right middle finger if the right target was detected, and both keys with both fingers simultaneously if both targets were detected.

Response times were recorded by the computer. The screen cleared following each response. When the bar markers returned, subjects began another trial. Trials were repeated when the response times were too fast (i.e., an anticipation response). Subjects were encouraged to rest between blocks of trials and could stop at any point during the experiment by not pressing the space bar.

Eight blocks of 50 trials each (plus 20 practice trials that occurred only at the beginning of each condition) were given to each subject. Before the first block of trials, each subject was told that the asterisk would flash on the left side 45% of the time, on the right side 45% of the time, and on both sides 10% of the time (Condition 1). Before the fifth block of trials, half of the subjects were told that the asterisk would flash on the right side 80% of the time, on the left side 10% of the time, and on both sides 10% of the time. The other half of the subjects were told that the asterisk would flash on the right side 10% of the time, on the left side 80% of the time, and on both sides 10% of the time (Condition 2). In this way the side of the screen for the most probable location was counterbalanced across subjects for Condition 2.

Data Analysis. Duncan (1980) showed that when subjects are required to respond to two separate stimuli simultaneously, they suffer a decrement in performance relative to conditions in which subjects are required to respond to only one stimulus. Furthermore, he suggested that this decrement was not due to the inability to attend to two locations; rather, it was due to a response incompatibility. Therefore, the trials in which two targets appeared were not analyzed.

In keeping with Hertzog and Rovine's (1985) suggestions for data analysis, planned comparisons were run. The two 45% probability locations of Condition 1 were combined in order to compare them with the 80% and 10% locations of Condition 2.

Results

The means for the equal probability condition and the unequal probability condition for both the experts and novices are presented in Figure 2. As was expected, the video game novices' mean reaction time (RT) was longer for the 10% location compared to the 45% location (cost), and their mean RT was significantly shorter for the 80% location compared to the 45% location (benefit), $t(7) = -1.18$, $p < .07$, and $t(7) = 1.97$, $p < .05$, respectively. The power to detect an effect of the magnitude that was obtained was .30, which may explain why only trend level significance was reached in the 10% to 45% comparison. However, the direction of the effect was very consistent, as evidenced by 6 of the 8 subjects showing the same pattern, $p < .05$, by binomial probability.

It was also hypothesized that video game experts would show a benefit in the

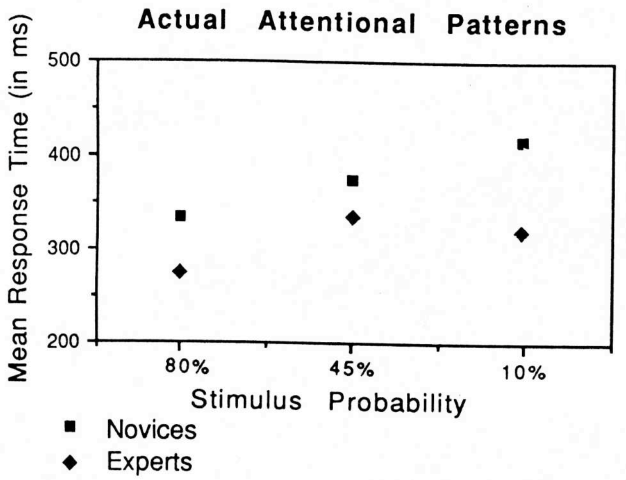

Figure 2. Actual relationship between video game expertise and strategies for dividing attention: Experiment 1.

probable location but would not show a cost in the improbable location. Again, as was expected, video game experts' mean RT was significantly shorter in the 80% location when compared to the 45% location, $t(7) = 2.68$, $p < .05$. Video game experts' mean RT for the 10% location was *not* significantly different from their mean RT for the 45% location.

Finally, video game experts' RTs were significantly faster than video game novices' RTs for the 80% location and the 10% location, $t(14) = -2.07$, $p < .025$, and $t(14) = -2.18$, $p < .025$, respectively. There was no difference between experts and novices in the even probability condition. The error rate did not exceed 4% in any of the analyzed conditions.

Discussion

The expectation that video game ability would be predictive of cost–benefit patterns was supported. Both novices and experts showed benefit to a probable location, a finding that is consistent with the attentional literature to date. This indicates that, regardless of any specific abilities, people in general can use information about target probability to focus their attention. The finding that novices showed a cost to an improbable location is also consistent with the attentional literature. However, the experts did not show the cost to the improbable location that has been found by other researchers (Bashinski & Bacharach, 1980; Eriksen & Yeh, 1985; Posner et al., 1978; Posner et al., 1980).

The focusing of attention has been likened to the focusing of a zoom lens on a camera (Eriksen & Yeh, 1985). As one focuses the zoom lens, the resolution at the periphery becomes less and less acute. Therefore, when attention is focused on an expected location, the resolution at an unexpected location is low. The zoom lens model is supported by the pattern of cost–benefit shown by the novices as well as the cost–benefit patterns found by other researchers (Bashinski & Bacharach, 1980; Eriksen & Yeh, 1985; Posner et al., 1978). However, when the experts focus their attention, one possibility is that they do not lose resolution in the periphery.

A study conducted by Shulman, Wilson, and Sheehy (1985) found that reaction times increased as the distance between the target and the focus of attention increased. Furthermore, Shulman et al. suggested that the distance effect was indicative of a gradient of attention, called an attentional field, that extends from the focus of attention outward. They qualified their findings with the suggestion that "attentional field sizes [could] be expected to vary with task demands and the spatial distribution of spatial attention" (p. 64). Moreover, in light of the present experiment, it also can be suggested that attentional field sizes can be expected to vary with the expertise of the subjects.

The question remains, did video game players have a greater attentional field that facilitated performance with video games, or did the playing of video games develop the greater attentional field demonstrated by the experts?

EXPERIMENT 2

The second experiment was designed to answer these two questions: To what extent was the strategic deployment of divided spatial attention a function of video game expertise? To what extent did attentional skills facilitate the development of video game expertise? With this in mind, we designed an experiment in which the attention task used in Experiment 1 served as the pre- and posttest for a new experiment. Between the pre- and posttest, an experimental group spent 5 hr playing a video game requiring the allocation of attention to many points on the screen. The major goal of the study was to see whether the experimental group subjects improved their attentional skills as a result of video game practice. This prediction was tested by comparing the experimental group with a control group that did not receive any experimental treatment between the pre- and posttest.

Following the pattern of Experiment 1, we divided subjects into groups of more and less experienced players (although the criteria were a little different, as will be seen). On the basis of Gagnon (1985), we predicted an effect of experimental practice on attentional skills in the less experienced group only. For the more experienced players, it was thought that the video game experience provided by the experiment would not significantly improve their attentional skills beyond the large amounts of practice they had already received in the real world. However, because our main goal was to detect an experimental effect rather than to discriminate between experts and novices, we did not restrict our groups to the two extremes of video game skill used in Experiment 1, but used all subjects. Consequently, we labeled the two groups in this experiment less experienced and more experienced rather than novice and expert, the labels used in Experiment 1.

Method

Subjects. Subjects were 40 male undergraduate students at UCLA. All subjects were right-handed and had normal or corrected vision. On the basis of a subsample of 20 for whom ages were available, the mean age of the sample was 19 years. Students participated as fulfillment of a partial requirement for an introductory psychology class and received nominal monetary compensation when the time required for the experiment exceeded class requirements.

Apparatus

The video game portion of the experiment was conducted on a Robotron arcade video game machine fixed at conventional arcade settings (i.e., level of difficulty). The apparatus used to measure attention was the same as in Experiment 1.

Design and Procedure

Group Assignment. Subjects were randomly assigned to either an experimental or a control group, with an equal number of subjects per group. The experimental group received 5 hr of practice at a video game; the control group did not play the video game beyond the initial five games used for assessment of skill. During the first experimental session, subjects' performance on an attention task, which served as a pretest, and on a video game (Robotron) was tested. The testing order of the attention task and video game was counterbalanced such that half of the subjects in each group received the attention task first and half were tested on the video game first.

Subjects within the experimental and control groups were also assigned to a more skilled or less skilled player category based on their best performance in five games of Robotron. Those above the median were classified as more skilled; those below the median were classified as less skilled.

Attention Task. The attention task was exactly as described in Experiment 1. The pretest and posttest consisted of eight blocks of 50 trials, four blocks per condition. Each condition was preceded by 20 practice trials. All subjects began with the 45%/45%/10% condition (Condition 1). For Condition 2, the side of the most probable target was counterbalanced such that the most probable location was at the left for half the subjects and at the right for the remaining subjects. The side of the most probable target was reversed for each subject during a second session, the posttest.

General Procedure. Using the procedures just described, we spent the initial experimental session assigning subjects to an experimental or control group, evaluating video game skill (more or less skilled), and assessing visual attention with the computerized task (pretest attention measure). All subjects returned 1 to $1\frac{1}{2}$ weeks later for a second attention task session (posttest attention measure). During the period between the first and last sessions, the experimental group received 5 hr of practice playing Robotron. Practice sessions were usually held on consecutive days, with subjects playing 1 to $1\frac{1}{2}$ hr per session. The video game practice sessions began 1 to 3 days following the initial session.

Results

A primary focus in analyzing the data was to test for the possible effects of video game training on performance on a visual attention task. Whereas a cost–benefit analysis was used to conceptualize the results of Experiment 1, the addition of the temporal element in Experiment 2 led us to focus our analysis on the change in attentional performance at each probability level of the target stimulus (10%, 45%, 80%). Change in attentional performance could occur as a result of repeated testing (when it occurred in both the control and experimental group) or it could occur as a result of the video game treatment (when it occurred in the experimental group alone).

As in Experiment 1, a cost–benefit analysis was used to conceptualize and analyze attentional performance at one point in time. In the cost–benefit analysis, response time in the 45%/45% condition, where both locations were equally likely to contain the target, served as a baseline, exactly as in Experiment 1. Table 1 shows that for each group at both pretest and posttest, an attentional

TABLE 1
Mean Response Time (in ms) as a Function of Treatment Group, Game Skill, Session, and Stimulus Probability

	Stimulus Probability				
	80%	45%	10%	Benefit	Cost
Experimental Group					
More Skilled Players					
Pretest	254.14	280.33	312.28	26 ms	32 ms
Posttest	240.82	258.85	289.86	18 ms	31 ms
Less Skilled Players					
Pretest	259.41	300.02	326.23	41 ms	26 ms
Posttest	253.40	272.11	280.71	19 ms	9 ms
Control Group					
More Skilled Players					
Pretest	244.23	291.37	311.16	47 ms	20 ms
Posttest	222.42	255.68	293.43	33 ms	38 ms
Less Skilled Players					
Pretest	270.95	296.83	299.06	26 ms	2 ms
Posttest	251.21	265.22	290.62	14 ms	25ms

benefit, relative to the equiprobable baseline, occurred for responding to the target at the 80% probability location, whereas an attentional cost was incurred at the 10% probability location. The repeated-measures analysis of variance (ANOVA) and post-hoc tests reported later indicate that this pattern is statistically significant.

A 2 (Treatment: Experimental, Control) × 2 (Skill: More, Less) × 2 (Session: Pretest, Posttest) × 3 (Stimulus Probability: 80%, 45%, 10%) mixed model repeated-measures ANOVA was performed on the entire data set to examine the overall effects. Treatment and skill served as between-subjects variables; sessions and stimulus probability served as within-subjects measures. Because the purpose of the 45%/45% condition was to obtain a baseline measure of response latency when the target stimulus was equally likely to occur at either of the possible locations, the data from these two targets were averaged for this and all subsequent analyses, as in Experiment 1.

There was an overall decrease in response latency from the pretest to the posttest (287.17 ms and 264.53 ms, respectively), as reflected in the significant main effect of session, $F(1, 36) = 35.02$, $p < .001$. A main effect of stimulus probability was also observed, $F(2, 72) = 132.11$, $p < .0001$, showing at the very least that subjects were able to use the probability information. Mean RT for the 10%, 45%, and 80% targets was 300.42 ms, 277.55 ms, and 249.57 ms, respectively. This pattern indicated the expected cost at the 10% target and the expected benefit at the 80% target. According to Newman-Keuls tests, both cost and benefit were significant at the .05 level.

A significant interaction was found for Session × Stimulus Probability, $F(2, 72) = 3.44$, $p < .05$, reflecting the fact that performance improved least at the 80% location, the location at which performance was best on the pretest. Newman-Keuls tests indicated that the 10% and 45%, but not the 80%, probability targets showed a significant improvement from pretest to posttest.

More important, there was also a significant interaction between video game skill and stimulus probability, $F(2, 72) = 5.83$, $p < .005$, showing that, overall, superior performance of the more skilled players was observed only for the 80% and 45% probability targets (see Figure 3). According to Tukey tests, the difference between the more and less skilled players attained statistical significance at the .05 level only for the 80% probability targets. However, a significant three-way interaction between treatment group, game skill, and stimulus probability, $F(2, 72) = 3.39$, $p < .05$, indicated significantly lower response times for the more skilled players in the control group at the 45% probability location and significantly lower response times for more skilled players in the experimental group at the 80% probability location. Note that this three-way interaction is much weaker than the two-way interaction shown in Figure 3.

Experiment 2 replicates the general finding of Experiment 1 insofar as experienced players had faster response times in both studies. However, whereas the specific locus of the effect was the 10% probability location in Experiment 1, the loci were the 80% and 45% (equiprobable) targets in Experiment 2.

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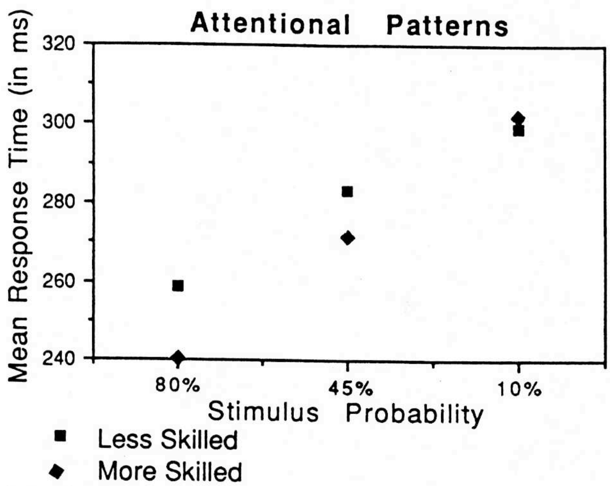

Figure 3. Relationship between video game expertise and strategies for dividing attention: Experiment 2.

A significant Treatment × Session × Stimulus Probability three-way interaction, $F(2, 72) = 5.58$, $p < .005$, showed that video game practice selectively improved performance on the 10% target as predicted (Newman-Keuls test, $p < .05$). Because of this significant reduction, video game practice decreased the response time cost for a low-probability target location (see Figure 4, Table 1). The control group significantly improved performance for the neutral (equiprobable 45%) targets (Newman-Keuls test, $p < .05$), thus increasing response time cost at the low-probability location (see Figure 4, Table 1).

In other words, the experimental video game treatment moved players from a cost–benefit pattern of attention that, at pretest, was relatively more like that of novices in Experiment 1 to a pattern that, at posttest, was relatively more like that of experts in Experiment 1 (cf. Figure 2, Figure 4). At the same time, the control group moved from a cost–benefit pattern that, at pretest, was similar to that of the experts in Experiment 1 towards one that, at posttest, was more like that of the Experiment 1 novices.

Discussion

Experiment 2 replicated findings from Experiment 1 and from previous research (Bashinski & Bacharach, 1980; Eriksen & Yeh, 1985; Posner et al., 1978; Posner et al., 1980) that there is attentional facilitation when a target stimulus appears in an expected position and attentional inhibition when it appears in an unexpected position. We were not able to demonstrate, as we had in Experiment 1, that more skilled players are able to monitor the least probable (10%) location better than less experienced players; in Experiment 2, both more and less experienced players showed attentional cost in responding to a target in the 10% location (Figure

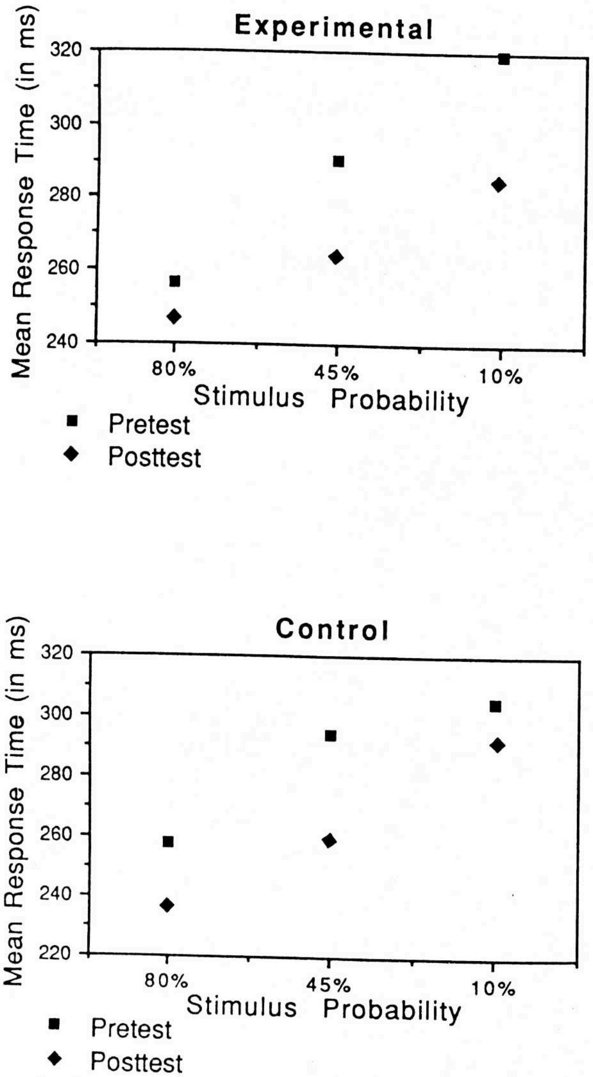

Figure 4. Effect of video game practice on cost–benefit patterns in the allocation of visual attention.

3). However, the experimental treatment did succeed in lowering the relative cost on the 10% target.

Experiment 2 also showed that repeated attentional testing improves overall visual monitoring performance. In line with the previous discussion, the across-the-board attentional improvement (i.e., at all probability levels) could have resulted either from expansion of the visual field, improvement in RT, or both.

Because expansion of the visual field generally leads to a lower visual resolution (Eriksen & Yeh, 1985), improvement in reaction time seems the most likely explanation.

GENERAL DISCUSSION

The results obtained with the expert video game players in the first study indicate that video game expertise is most highly associated with the reduction of cost in attending to a low-probability location in a task that demands divided attention. Recall that the 10% location occurred in the condition in which the target appeared 80% of the time in the alternative location. Compared with novices, video game experts were faster responders at both the low and high probability locations in the 80%/10% probability condition. They were not, however, significantly faster in the 45%/45% condition, when targets were equally likely to appear at either location.

Experiment 2, however, yielded a somewhat different pattern of findings. Again, the more skilled players had faster reaction times than did the less skilled players, but this time the superiority was observed only on the 80% and 45% probability targets. One hypothesis was that the different pattêrn of results in the two studies was due to the fact that Experiment 1 used extremes of video game skill, whereas Experiment 2 did not. However, follow-up analyses based only on extreme subjects in Experiment 2 did not succeed in replicating the cost–benefit pattern of Experiment 1. Therefore, it does not appear that the more selective sample of Experiment 1 was responsible for the different cost–benefit pattern of more skilled video game players in Experiment 2.

Given the results of the first study, the next question was whether video game play promoted or simply utilized strategies for deploying attention to more than one location. Experiment 2 showed that although experimental video game practice did not improve attentional performance overall, practice on a video game requiring visual monitoring of more than one location could develop strategies for reducing the relative attentional cost of monitoring the location of a low-probability target. Video game players themselves reported using strategies of visual attention, sometimes as a function of increased experience (Gagnon, 1985; Small, 1983; "Video Games," 1985).

Our results are partially in line with the results of a study of the effects of action video game play on the choice RT of older people (over age 60). As a result of playing a minimum of 14 hr of Pac-Man and Donkey Kong over a period of 7 weeks, subjects improved, relative to a control group, in a task that paralleled our equiprobability attention task; this result parallels the relative superiority of the more skilled video game players with the 45% target in Experiment 2. However, the largest effect of video game practice in Clark et al.'s (1987) study appeared in the more strategic RT task, in which the right hand had to respond to a stimulus on the left while the left hand had to respond to a stimulus on the right. This latter result agrees with our finding of a strategic change in the pattern of attention deployment as a result of experimental video game practice.

However, Clark et al. (1987) found a clear-cut experimental effect, whereas we did not. The discrepancy can perhaps be explained by the fact that subjects in Clark et al.'s study had a minimum of 14 hr of video game practice, whereas our subjects had only 5 hr of practice. Five hours of practice was perhaps not enough to affect such an overlearned, automatic skill as RT. Another possibility is that young people, such as the subjects in our studies, are at the peak of their RT because of youth and everyday life experiences, whereas older people, such as those in Clark et al.'s study, lack both the youth and the practice to keep their RT functioning at an optimal level.

From the point of view of research in attention, the results add another example to those gathered by Neisser (1976) that practice can lead to strategic improvement in what Neisser termed dual attention. Indeed, the research literature on divided attention implicitly recognizes the effects of practice on attentional strategies; experiments generally stabilize performance through thousands of trials and report the results of only the last session.

Even more relevant, Biocca (1989) showed that visual attentional strategies acquired from print literacy *transfer* to television viewing. In analogous fashion, our study showed that practice could also lead to a transfer of dual or divided attention strategies to a new task. This transfer seems to be an example of what Salomon and Perkins (1987) termed "low-road" transfer—that is, automatic transfer of an overlearned skill to a closely related situation. It contrasts with "high-road" transfer, conceptually based transfer that has potentially greater breadth of application.

From the point of view of attentional theory, the effect of video games appears to provide an example of attention as perception: "We choose what we will see by anticipating the structured information it will provide" (Neisser, 1976, p. 87). Gagnon (1985) reported that when game play became rapid, many frequent players "claimed to focus their gaze at the center of the play field in order to see the entire screen at once" (p. 272). Indeed, Shapiro (1990) succeeded in improving performance on an action video game by training subjects to focus their peripheral rather than central attention on peripherally appearing objects while eliminating unnecessary eye movements.

If this were a general strategy for increasing the effective (although not actual) visual field, one would expect improved performance by more skilled video game players under all conditions in our test, a result that did occur if we consider both Experiment 1 and Experiment 2. One might also expect that this strategy, combined with a reduction in visual resolution at the periphery of the field, as in Eriksen and Yeh's (1985) model, would lead to reduced cost at the low-probability location, along with reduced benefit at the high-probability location. This was exactly the pattern of results shown by our experimental group.

Taken together, the two studies showed that skilled or expert video game players had better skills for monitoring two locations on a visual screen and that experimental video game practice could alter the strategies of attentional deployment so that the response time for a low-probability target was reduced. Although the results of the two experiments were not entirely consistent, together they provided evidence that video games are a tool of informal education for the development of strategies of divided attention in both the short and long term. In the long term, both studies provided evidence that more skilled video game players had better developed attentional skills than less skilled players, although the results were stronger in Experiment 1. In the short term of our experimental treatment, 5 hr of video game practice significantly affected the strategic aspect of divided visual attention, as shown in improved skill in monitoring the low-probability target.

This new mass medium of the action video game thus seems to provide informal education for occupations that demand such skills in divided visual attention—for example, instrument flying, military activities, and air traffic control. For the same reason, the games may provide a positive influence on performance in sports such as basketball or ordinary activities like driving a car where skilled performance requires the monitoring of multiple visual locations. Our two studies showed that strategies for dividing visual attention are part of the cognitive "message" of action video games.

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