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OBSERVING BEHAVIOR IN A COMPUTER GAME

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Contingencies studied in lever-pressing procedures were incorporated into a popular computer game, "Star Trek," played by college students. One putative reinforcer, the opportunity to destroy Klingon invaders, was scheduled independently of responding according to a variable-time schedule that alternated unpredictably with equal periods of Klingon unavailability (mixed variable time, extinction schedule of reinforcement). Two commands ("observing responses") each produced stimuli that were either correlated or uncorrelated with the two components. In several variations of the basic game, an S−, or bad news, was not as reinforcing as an S+, or good news. In addition, in other conditions for the same subjects observing responses were not maintained better by bad news than by an uninformative stimulus. In both choices, more observing tended to be maintained by an S− for response-independent Klingons when its information could be (and was) used to advantage with respect to other types of reinforcement in the situation (Parts 1 and 2) than when the information could not be so used (Part 3). The findings favor the conditioned reinforcement hypothesis of observing behavior over the uncertainty-reduction hypothesis. This extends research to a more natural setting and to multialternative concurrent schedules of events of seemingly intrinsic value.

Key words: conditioned reinforcement, observing behavior, uncertainty reduction, delay reduction, computer games, computer keyboard typing, college students

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Observing responses are those which produce stimuli correlated with schedules of reinforcement but which have no effect on the occurrence of reinforcement (Wyckoff, 1952). In one of the simplest cases, two equally probable schedules differing only in frequency of reinforcement alternate unpredictably, and observing responses produce stimuli correlated with the schedule in effect. For example, a variable-time schedule might alternate with extinction in the presence of a single stimulus; observing responses would produce stimuli identifying the variable-time and extinction components.

Observing behavior has been investigated extensively, and many studies have addressed the mechanism by which it is maintained (cf. reviews by Badia, Harsh, & Abbott, 1979; Daly, 1985; Dinsmoor, 1983, 1985; Fantino, 1977). In the present study, we compare two rival hypotheses that have received the greatest support and scrutiny, as discussed below. Our study also extends prior methods by assessing human observing in a considerably more complex schedule context than that of the lever-pressing procedures that have been used. In addition, the reinforcers used in prior studies were points backed with events that may be viewed as extrinsic to the experimental task (e.g., money), whereas in the present work reinforcers were an integral part of a task designed to be a realistic and entertaining simulation of naturally occurring behavior.

The conditioned reinforcement hypothesis of observing behavior holds that responding is maintained by stimuli according to their correlation with reinforcement. For example, stimuli that represent a reduction in expected time to reinforcement are predicted to be conditioned reinforcers and accordingly to maintain observing responses better than stimuli uncorrelated with reinforcers (Case & Fantino, 1981; Fantino, 1977). The uncertainty-reduction hypothesis, on the other hand, proposes that prediction, or informativeness per se, is reinforcing because of presumed unconditioned aversiveness of uncertainty. Although many findings are consistent with both, the critical test for distinguishing these views is

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whether or not an S−, or bad news, is reinforcing. The overwhelming preponderance of evidence shows that it is not (e.g., see Dinsmoor, 1983; Fantino & Case, 1983). However, in prior tests any response requirements for reinforcement were also important to the interpretation of results. This is because ostensibly bad news can become, in part, good news despite negative correlation with explicitly manipulated reinforcers. In some procedures, negative discriminative stimuli may be correlated simultaneously with improvement in response efficiency; that is, these stimuli permit improvement in one's circumstances contingent on apprisal of contingencies then in effect (e.g., ineffective, possibly effortful responses during extinction can be omitted without risk of reinforcement delay or loss).

In earlier studies, possible improvements in response efficiency were circumvented by scheduling reinforcer deliveries independently of any responding. Although this method was also employed in the present study, there is a question as to whether response-independent reinforcement provides sufficient control in more complex contexts with multiple types of reinforcement. Also, subjects may possibly believe (erroneously) that observing responses lead to reinforcement. The present procedures minimize this possibility and once again attempt to answer the question of whether bad news is reinforcing, as required by the uncertainty-reduction hypothesis, or punishing, as required by the conditioned reinforcement hypothesis.

METHOD

Subjects

Thirty-eight college students participated after being solicited with a sign-up sheet posted in a hallway of the Department of Psychology requesting volunteers for an experiment called "Star Trek." No mention of compensation was made on the sheet, although conventionally course credit or money is offered explicitly.

Three additional students completed only part of the experiment. One, who played the first version of the game, was dismissed after the first session, which was used to teach how the game worked. Dismissal was for failing to meet an a priori inclusionary criterion, which was a perfect score on a questionnaire designed to assess understanding of the game. (However, if this questionnaire contained erroneous answers when administered after experimental sessions, subjects were corrected but not dismissed—see Results.) The other 2 subjects inexplicably did not return for all sessions. Their partial data are not reported because of the within-subject design.

Twelve people who signed up did not appear even once, a larger number than usual in our albeit unsystematic experience with soliciting subjects using incentives, possibly because there was not any promised compensation. After reporting for the study, however, subjects could elect to receive money, credit towards their grade in an introductory psychology course, or both, in exchange for completing the study. Neither money nor course credit was contingent on playing performance. Compensation was not mentioned initially to encourage subjects to volunteer more out of curiosity than for concrete incentives. Money and/or course credit was subsequently provided noncontingently to encourage subjects to return for all sessions without suggesting that success in playing the game would influence payment.

Apparatus

The games were played on an Apple II+® computer equipped with two 5-in. floppy disk drives, a 12-in. Zenith Greenscreen® monitor, and a Mountain Computer real time clock. The disk drives sat side by side on top of the computer, which itself sat on a conventional typing table. The monitor was located on top of the disk drives, with its center roughly at eye level. A scrap of paper containing a drawing of a circular clock face, minus hands, was taped to the front of the monitor just to the right of the screen proper. This served as an aid in specifying directional information in the game (e.g., 6 o'clock indicated straight down).

Procedure

Subjects were taught and then played modified versions of the computer game, "Star Trek." These Applesoft Basic® programs derived from a commercial product called "Loch Ness Trek" sold by Berker Engineering. Because one strategy of the study was to capitalize on the popularity of the game, we initially attempted to modify the original as little as possible consistent with experimental objectives. As the basic game is described, brief mention of the major initial changes will be made

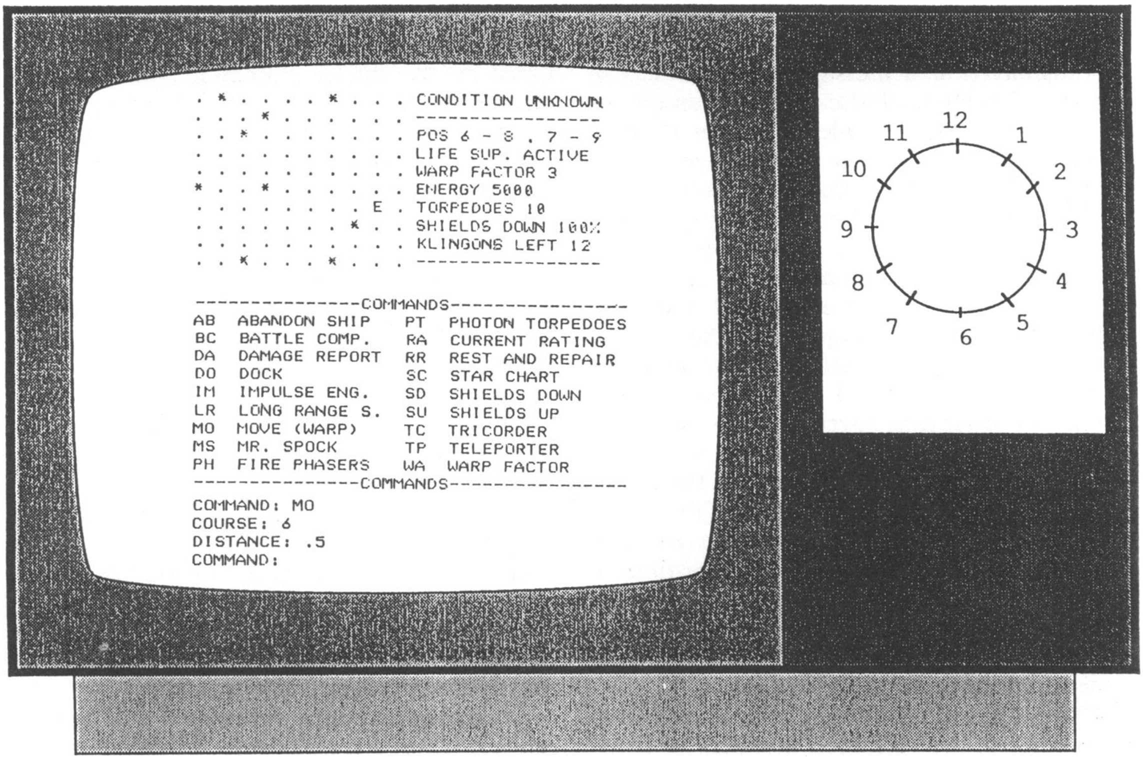

Fig. 1. Illustration of computer monitor with typical "Star Trek" display. The lower portion shows the result of entering the CO (list commands) command (response not depicted because it went out of view after upward screen scrolling in this portion), followed by a MO (move) command and then the prompt for the next response. Just before MO was selected, the location of the Enterprise (letter E in upper left portion of screen, which is the map of the immediate quadrant) had been the second row of the same column (Sector 2-9). In the upper right portion the top line contains the battle condition status message and the second line contains the current (quadrant and sector) position of the Enterprise. The clock face without hands to the right of the screen proper was a crude drawing on a scrap of paper taped to the monitor. Other details in text.

in brackets in order to suggest how well this effort succeeded and to illustrate a promising new method for exploiting game software technology in the experimental analysis of human operant behavior.

Written instructions describing the game began: "Welcome to Star Trek. The Federation is being attacked by a deadly Klingon invasion force. As commander of the United Starship Enterprise, it is your mission to destroy this invasion force. . . ." An appendix containing complete instructions is available upon request (see author note). [The original instructions were changed to the extent needed to accommodate experimental alterations; i.e., contingencies were described accurately or not at all.]

Figure 1 shows a typical display shortly after the beginning of a game and before discovery of any Klingons. An 8 by 8 matrix of "quadrants" comprised the entire (two-dimensional) "universe," and each quadrant was comprised of a 10 by 10 matrix of positions called "sectors." The immediate quadrant, occupied by the Starship Enterprise, was displayed in the upper left portion of the monitor. The upper right portion contained information on the current status of the game, and the lower half was used for entering "commands" and for displaying "messages" to the subject who played the role of commander as indicated in the instructions. Each new line in this lower portion, whether part of a message or a new command prompt and command, scrolled the entire lower portion up, the top line disappearing behind the display of the immediate quadrant and the list of status information.

A command was initiated by typing two mnemonic letters. Figure 1 shows a list of concurrently available commands in Part 1, not including the command CO that produced this listing (response had scrolled from view), which was displayed as a message to the subject in the lower portion of the screen. Commands available and their two-letter names differed in different parts of the experiment as described below under Game Variations. Additional input was required to complete some commands. For example, typing MO (move) caused prompts to be displayed for specifying the direction and distance of travel that were desired (see bottom of Figure 1). The location of the Enterprise in the universe was indicated by the letter E in one of the positions of the immediate quadrant together with the coordinates of the immediate quadrant displayed in the second line of information in the upper right portion of the video screen (Figure 1; up–down first, left–right second). On the same line, to the right of the quadrant coordinates, the sector coordinates also were given, although they were redundant with the position of the Enterprise in the display of the immediate quadrant.

The presumed reinforcing stimuli central to these studies, the "Klingon invaders" (whose location in the immediate quadrant was indicated by the letter K), were arranged to be "discovered" according to a mixed variable-time (VT) 60-s extinction (EXT) schedule of reinforcement. In a mixed schedule of reinforcement, two or more alternating component schedules are correlated with the same stimulus. In a VT schedule of reinforcement, reinforcers occur independently of any responding after random intervals. The parameter associated with the schedule is the mean time between reinforcers. An interval was drawn randomly with replacement from a constant probability distribution with 20 possible intervals according to the method of Fleshler and Hoffman (1962). No reinforcers are scheduled in an EXT schedule. [In the original version a simple variable-ratio-like schedule was used; i.e., Klingon discovery was dependent upon an unpredictable number of movement commands and was independent of time. Also, "Klingon Commanders," which were more effective invaders than Klingons and were discovered in the same manner except on a leaner schedule, were deleted from the original.]

The VT and EXT components alternated randomly, and their durations were constant and equal for a given subject (either 60 or 90 s depending upon the part of the experiment—see Game Variations). The mixed schedule was correlated with a "battle status" designated as "condition unknown"; this was indicated in the top line of information in the upper right portion of the screen (Figure 1). To make this stimulus more salient, the words were displayed in reverse video (i.e., dark characters on light, individual character surround; not shown in the figure). [In the original, this line of information was buried in the middle of the list of status information and displayed in normal video, i.e., light characters without a distinguishable character surround. Also, the occasions for its change to a different battle condition were different, as described below in the section on observing response contingencies. Finally, two lines of information in the original were deleted: a digital clock showing time elapsing in units of "star dates" and a count-down timer showing time remaining for play. These were deleted to prevent clock-assisted timing of events and to minimize changes in responding towards the end of games due strictly to dwindling time remaining.]

Observing response commands and contingencies. Two commands were added to the game; these constituted observing responses patterned after level-pressing tasks (cf. Dinsmoor, Sears, & Dout, 1976; Perone & Baron, 1980). Their names and functions were counterbalanced across subjects (see Design), and of course the instructions were modified accordingly. For conditions in which the TC (Part 1) or TR (Parts 2 and 3) "tricorder" command produced a stimulus correlated with the EXT component (S−), for example, the instructions read,

> [The tricorder] is a scanning device that uses language to report its readings, like a robot. Occasionally the tricorder is able to establish that no Klingons are nearby (which you might like to know). If it is able to determine this, the battle condition is set to "GREEN," which means there is no chance that Klingons will attack. However, often the tricorder cannot establish one way or the other about the chances of encountering a Klingon soon.

For conditions in which the MS ("Mr. Spock") command produced a stimulus correlated with the VT component (S+), the instructions read,

> Occasionally Mr. Spock is able to establish that Klingons are approaching for a possible attack. If he is able to determine this, the battle con-

> dition is set to "RED," which means the chances are twice as great as normal that Klingons will attack. However, often Mr. Spock cannot establish . . . (same as the tricorder command).

As explained below in the section on game variations, the name of this command was changed in Parts 2 and 3 to BC (battle computer). Corresponding minor changes in instructions are omitted for brevity.

For conditions in which the MS command produced the battle status stimulus uncorrelated with Klingons, the instructions read,

> Occasionally Mr. Spock is able to establish that there is a chance Klingons are nearby. If he is able to determine this, the battle condition is set to "YELLOW," which means that although Klingon attack is possible, the chances are no better or worse than normal. However, often Mr. Spock cannot establish . . . (same ending sentence as above).

[The battle status in the original game changed to "red alert" only, sometimes independently of any responding, under a variety of perilous circumstances including just after a Klingon began attacking the Enterprise. Interestingly, such stimulus change did not correlate with circumstances in which a Klingon was nearby and its imminent discovery likely.]

If one of these commands was issued after the battle condition had already been changed from the default "unknown" status, a message was displayed at the bottom of the screen that read, "battle condition already established." If the appropriate component was not in effect or the schedule of stimulus change reinforcement, described below, had not yet arranged for an observing response to be effective, the message, "Command not available—try again later," was displayed. Effective observing responses changed the battle status in the upper right part of the screen appropriately and displayed an appropriate message at the bottom of the screen (e.g., Spock: "Captain, my instruments suggest that Klingons are approaching. Beware!").

Observing responses produced stimuli according to a variable-interval (VI) 10-s schedule (i.e., the observing response schedule) that was operative in 50% of each of the VT and EXT components. A VI schedule of reinforcement is identical to a VT schedule except that the programmed event is contingent upon a response after a random interval elapses. The VI contingency was used to prevent an unchanged (unknown) battle status following an observing response from being discriminative for the components. That is, because most responses in a VI schedule are typically ineffective, this procedure makes it virtually impossible to detect whether an observing response lacked an effect because the stimulus change (which in appropriate components was contingent upon that response) was inappropriate to the present component or because of the intermittent consequences in the VI schedule. If the cause were detectable, an ineffective observing response might itself become as informative as an observing response that produced a stimulus change (Dinsmoor, Browne, & Lawrence, 1972). The 50% constraint was imposed to equate opportunity for producing a change in the battle status across observing choices within an experimental condition and across conditions (see Design), given that one stimulus change was uncorrelated with the VT and EXT components (condition yellow). That is, in principle an uncorrelated stimulus change contingent on observing could occur regardless of the present component (as long as it is not correlated with the components) and thus in all components. However, if this were possible in the present study the opportunity for stimulus change would be double that of the observing response maintained by S− (condition green) because the latter stimulus change must be restricted to EXT components that comprise half the total. Although an observing schedule could operate in as many as 66% of components (33% for each observing response) and still permit equal opportunities, the percentage used was the same as in the study by Fantino and Case (1983).

After an observing response changed the battle status, the stimulus remained in effect until the end of the component. The words flashed twice per second between normal and inverse-video display modes to increase salience (e.g., flashing "condition red"). At the end of the component, the battle status reverted to "unknown" in continuous, reverse-video display. A Klingon still present when the VT component ended was eliminated to maintain the correlation between battle status and Klingons; this was accompanied by the message, "Klingon escapes from galaxy."

Other commands, instructions, and messages. Subjects were able to destroy Klingons directly using the PH and PT "weapon" commands (refer to Figure 1) or indirectly if the Klingons

Table 1

Representative sample of potential messages (used throughout unchanged from original game).

1. That does not compute
2. Unit hit on the Enterprise from Klingon at sector . . .
3. Klingons attack—starbase shields protect Enterprise
4. ***Emergency automatic override attempts to hurl the Enterprise safely out of quadrant
5. All devices functional
6. Device . . . repair time:
7. Starship blocked by object at sector . . .
8. ***Red alert! Red alert! The Enterprise has stopped in a quadrant containing a supernova
9. Phasers can't be fired through base shields
10. Shields must be down to fire phasers
11. Very small hit on Klingon
12. ***Starbase destroyed. Congratulations!
13. ***Starship buffeted by nova
14. Torpedo missed
15. Engineer Scott: "Aye, sir, but our engines may not make it"
16. Engineer Scott: "Aye, sir we'll try it"
17. Shields already up
18. Ensign Chekhov to captain: "Excuse me, sir, but we are already docked. Are you sure you want to move?"
19. Lieutenant Uhuru to captain: "Communications report: attempting teleportation of Enterprise to distant starbase"

Note. A complete list of messages and other events is available upon request (see Author Note).

were adjacent to a destroyed "star." Commands SU and SD were used in defending against Klingon attack on the Enterprise ("shields" had to be down in order to use PH, which was otherwise an easier means of destroying Klingons because it did not have to be aimed like conventional weapons). All commands were available concurrently in multialternative choice except for the interdependency of the PH and shield commands (and the observing response commands, as described in that section). Commands BC, DA, LR, RA, and SC provided information unrelated to probability of discovering a Klingon; that is, the information was unrelated to that obtained by observing responses. Command AB gave subjects a second chance to play if the Enterprise was about to be destroyed. Commands DO, IM, MO, TP, and WA were involved in movement of the Enterprise in various ways. Command TP also was used, along with RR, to restock depleted ammunition and energy, and/or to repair "damage" to the Enterprise (e.g., repair of damaged "life support systems"—see the third line in the upper right portion of the screen, Figure 1). To illustrate game complexity and realism, which undoubtedly contribute to playing enjoyment, Table 1 lists a small but representative sample of potential messages in the original version that were retained throughout.

The TP (Part 1) or TE (Parts 2 and 3) "teleporter" command and the RR "rest and repair" command are important in explaining certain results (see Game Variations, Results, and Discussion), so we give verbatim instructions for them here:

> The teleportation unit aboard the Enterprise transmits a secret signal to a random starbase which activates the starbase's teleportation equipment when the command TP [TE—Parts 2 and 3] is given by the captain. The ship is then teleported to the distant starbase and docked automatically. The unit aboard the ship may become damaged and rendered useless for a period of time.

As soon as this command was executed, the Enterprise was restored to its fully functional state.

Instructions for command RR were: "There is a command to maintain position. One can specify the length of time to rest. This allows one to repair damaged devices. To find out how much time is needed to repair a specific device, ask for a damage report (DA)." [Six commands were removed from the original because of potential irrelevant disruption and because their removal probably would not markedly reduce the complex naturalistic character of the game: (a) quit game; (b) save game parameters for later continuation; (c) recall game parameters; (d) self-destruct; (e) death ray, a weapon with a nonzero probability of self-destruction; and (f) captain's log.]

Game variations. Table 2 summarizes variations in the game and procedure that were used in different parts of the experiment. All subjects were studied in two observing choice conditions using one of these variations (see Design). The games were identical in Parts 1a and 1b; the procedure differed only in that Part 1b used a criterion for dismissing confused subjects after the training session (see Subjects). All game versions used after Part 1 differed in three respects from the first one: (a) infrequently used commands AB, BC, DO, IM, LR, RA, and WA were eliminated and MO (move) was simplified to make the game easier to learn and play, (b) the "Mr. Spock" observing response command was changed to

BC ("battle computer") to reduce the tendency of bias towards the former (which is the name of a particularly appealing character from the "Star Trek" television show and movies; note that BC was not an observing response command in Part 1 and that its original function had been eliminated in these later versions, as just indicated); and (c) the two-letter names of two commands were changed to make them more distinctive and memorable (TC, "tricorder," became TR; TP, "teleporter," became TE). Corresponding changes in instructions and messages were made.

The versions used in Part 3 differed from the earlier ones in three respects. First, Klingons were inserted differently. When a Klingon was scheduled to be discovered in Parts 1 and 2, it was inserted into an unoccupied sector randomly selected from the immediate quadrant, whereas in Part 3 it was inserted similarly into a randomly selected quadrant bordering the immediate quadrant. This was accompanied by a message, "Klingon entered quadrant . . . ," that gave the relevant coordinates. Thus, subjects had a last-minute opportunity to prepare for battle or to avoid it. Second, sessions were structured slightly differently. The number of Klingons that needed to be destroyed to finish a game was the same for each game (12), two games always were played per test session, and a 20-min time limit was placed on each. In Parts 1 and 2 a random number of Klingons, ranging from 3 to 20, needed to be destroyed to finish a game and no limits on the number or length of games per session was imposed (aside from total session length). Third, the TE (teleporter) command was operative only if the battle condition was unknown (i.e., only during the mixed schedule).

Similarly, in Part 3c the less frequently used RR (rest and repair) command also was operative only at these times. The restrictions on TE and RR were made to prevent replenishing resources and making repairs if observing produced ostensibly bad news (condition green), thus precluding such improvement in one's circumstances (but, to equate contingencies, these restrictions were imposed identically regardless of which battle status was produced by observing). Component duration was increased to 90 s in Parts 3b and 3c from the 60-s value used previously because the results of Part 3a showed that subjects had greater difficulty than before in destroying Klingons in time before the components alternated (the Enterprise had to move to the Klingon's quadrant before attacking it).

Table 2

Summary of game variations.

Variation	Applicable part of experiment					
	1a	1b	2	3a	3b	3c
Criterion for participation		X				
Infrequently used commands eliminated; others changed[a]			X	X	X	X
Klingons inserted into adjacent quadrants; session format changed; teleporter restriction[b,c]				X	X	X
Component duration of 90 s[d]					X	X
Rest and repair restriction[c]						X

[a] Commands AB, BC, DO, IM, LR, RA, and WA were eliminated (see Figure 1 and text). Commands MS (BC), TP (TE), TC (TR), and MO (simplified) were changed (later version in parentheses). Command BC in Part 1 was unrelated to the observing response command BC in Parts 2 and 3.

[b] Klingons were inserted into either the immediate quadrant or adjacent quadrants. New session format had constant number of Klingons to be destroyed to finish a game, fixed number of games per session, and time limit imposed on each.

[c] Restricted commands were operative only during the mixed schedule (battle status unknown).

[d] Components were either 60 or 90 s in duration.

Design. Two experimental conditions were studied in each part of the experiment. Preference for observing S+ (condition red) or S− (condition green) was assessed in one condition, and preference for observing S− or a stimulus uncorrelated with the VT and EXT components (condition yellow) was assessed in the other. All subjects were studied in both conditions. Subjects in each part were counterbalanced in terms of the order of testing and the correlation of observing response commands with the Klingon schedules (Table 3). The same observing response command that produced the S+ battle status in the condition assessing preference for S+ versus S− also produced the battle status uncorrelated with Klingons in the condition assessing preference for the uncorrelated stimulus versus S− (i.e., the observing response that produced S− was the same across conditions). Subjects were

Table 3

Design and results.

Subject	Testing order[a]	S− observing response[b]	S+ versus S− Choice	S+ versus S− Observing rate S+	S+ versus S− Observing rate S−	S+ versus S− Questionnaire errors	S− versus uncorrelated Choice	S− versus uncorrelated Observing rate S−	S− versus uncorrelated Observing rate Unc.	S− versus uncorrelated Questionnaire errors
Part 1a										
1	A	TC	.60	26	17	1	.36	6.1	11	1
2	B	TC	.49	27	28	0	.46	26	30	0
3	B	TC	.86	57	8.9	0	.39	37	58	0
4	A	MS	—	—	—	0	.50	2.3	2.3	0
5	B	MS	.43	9.9	13	0	.66	13	6.7	0
6	A	TC	.51	19	18	0	.50	11	11	0
7	B	MS	.67	20	9.7	0	1.0	13	0	1
8	A	MS	.55	34	28	1	.64	57	32	0
Part 1b										
9	A	TC	.74	20	7.0	0	.31	12	27	0
10	B	TC	.54	30	26	0	.47	22	25	0
11	B	MS	.74	20	6.9	0	.20	7.4	30	0
12	A	MS	.53	19	17	0	.39	26	41	0
13	B	MS	.64	23	13	0	.67	8.7	4.3	0
14	A	TC	.81	27	6.5	0	.29	23	57	0
Part 2										
15	A	TR	—	0	0	0	.67	8.5	4.2	0
16	A	BC	.42	23	32	1	—	—	—	0
17	B	TR	.50	6.0	6.0	0	.95	25	1.3	0
18	B	TR	.61	47	30	0	.35	29	53	0
19	A	BC	.44	9.4	12	0	.32	79	171	0
20	A	TR	.80	26	6.5	0	0	0	45	0
21[c]	B	BC	.57	47	35	0	.57	24	18	0
22	A	TR	.68	134	62	0	.44	33	42	0
23	B	BC	.45	14	17	0	.54	13	11	0
Part 3a										
24	A	TR	.84	294	56	0	.40	40	60	0
25	A	BC	.15	6.0	34	2	.38	8.0	13	2
26	B	TR	.80	18	4.6	0	.22	2.7	9.8	0
27	B	BC	.89	67	8.6	0	.23	12	40	0
Part 3b										
28	B	TR	.78	20	5.6	0	.53	28	25	0
29	A	BC	.69	42	19	0	.28	14	36	0
Part 3c										
30	A	TR	.72	36	14	0	.15	5.2	30	0
31	B	BC	.70	44	19	0	.36	21	37	0
32	A	BC	.85	57	10	0	.33	31	62	0
33	B	BC	.51	90	85	0	.52	97	90	0
34	B	TR	.61	50	32	0	.28	9.5	25	0
35[d]	A	BC	.63	30	18	1	.24	13	42	0
36	B	TR	.60	31	21	0	.71	7.5	3.1	0
37	B	TR	.46	33	38	1	.70	63	27	0
38	A	TR	.78	69	19	0	.20	24	97	0

Note. Dashes indicate missing or insufficient data for calculating the choice proportion. Observing rates are expressed in responses per hour.

[a] Order A = S+ versus S− first; Order B = S− versus uncorrelated first.

[b] TC or TR = Tricorder; MS = Mr. Spock; BC = Battle Computer.

[c] Due to experimenter error, observing was extinguished and Klingons did not attack in the first game of the first condition.

[d] Due to experimenter error, subject was trained under the contingencies of the second condition rather than the first.

studied in only one session per condition, not counting the training session, because (a) instructions explicitly described the observing contingencies, (b) questionnaire results suggested that comprehension was adequate, (c) pilot observations in the S+ versus S− condition did not reveal systematic changes in preference as a function of number of sessions, and (d) earlier lever-pressing studies similar to ours were conducted successfully in this manner.

Specific session protocols. Subjects participated in three sessions on different, usually consecutive, weekdays; each session lasted about 50 min. The first was devoted to learning to play the game, and the other two involved assessment of observing preferences in each of the experimental conditions. In the first session, after informing the subject of the rights of experimental participants, a written description of the game was presented along with instructions to read it. Subjects finished this in about 10 min in Part 1 and in about 5 min in Parts 2 and 3. Next, the game was started and the operation of all the commands was demonstrated, generally from first to last according to their order in the list of commands produced by the CO (command list) command. The experimenter instructed the subject which commands to make, and events that occurred while this went on were explained and responded to as one might respond in actual playing.

When this demonstration was completed, all remaining questions about the game were answered. The final 10 to 15 min of the session were allocated to unhindered practice but with the experimenter present to answer questions. Although all questions were answered, the experimenter did not suggest commands or strategies and did not initiate other verbal exchanges. At the conclusion, a questionnaire assessing understanding of the game was administered.

In the second session (the first test session) the same observing alternatives were used as in the practice session. A few minutes were allocated at the beginning to review the written instructions. (The instructions were available throughout testing, but training was usually sufficient to make rereading unnecessary, especially in Parts 2 and 3.) The experimenter left the room when the game was started, returning as necessary to start another game when one ended or when the time limit had elapsed. A game ended automatically if all Klingons were destroyed; it was terminated by the experimenter after the time allowed for playing had elapsed. The last game of a session was terminated with ample time remaining to administer the same questionnaire before the subject's hour of participation ended.

The third session was conducted like the second. The instruction period at the beginning was devoted mainly to explaining the change in observing contingencies correlated with the alternate experimental condition. A brief, general explanation of the purpose of the experiment, as required by the rules for human subjects was provided at the end of this session after the questionnaire was administered a final time.

Data analysis. Statistical analysis is based on responding in only those sessions for which subjects did not give an erroneous answer on questionnaires administered immediately afterward. Errors were considered indicative that playing may not have been controlled by contingencies intended to be operative, because subjects apparently were confused about the way the game worked. Those results are difficult to interpret without collecting more data; the reasons for the errors would likely be independent of the hypotheses under investigation. However, for the sake of completeness, identical analyses of the data for all sessions were conducted. No changes in conclusions were necessitated by these results so they will be omitted in the interest of brevity. Relative rates of observing behavior were calculated by dividing the rate of the indicated observing response by the total rate of both observing responses in a session. Absolute observing response rates were found by dividing the number of observing responses by the time spent in the mixed schedule (condition unknown). Significance was defined conventionally at the .05 level, but for convenience significance at the .01 level also will be reported. When assuming the applicability of parametric statistical analyses in analyzing choice, we used one-tailed t tests because specific ordering of preferences was predicted. Nonparametric tests also were conducted.

RESULTS

Consistent with the instructions for playing the game, subjects as a rule spent most of the time moving the Enterprise around the universe, attacking Klingons when discovered. Subjects also defended against Klingon attacks, repaired damage to the Enterprise incurred in these attacks, and replenished weapon and fuel resources expended, but they used the other commands rarely. The battles always resulted in destruction of Klingons or at least continued viability of the Enterprise. The relative incidence of commands was consistent with the conclusion that (a) moving the Enterprise in search of Klingons, and (b) stimuli predictive of their discovery were principal events controlling choice between commands: 36% of the total number were MO moves and 27% were observing response commands (all results are from test sessions only). The relative frequency of the other commands ranged from 1.5% (SD shields down) to 6.3% (SC star chart); this excludes seven rarely used commands unique to Part 1 and invalid (i.e., mistyped) commands, which together summed to 4.8% of the total.

The mean rate of responding, summed over all commands, was 237 per hour (4.0 per minute). This does not include additional input required by some commands after being initiated (e.g., the distance and direction specifications of the MO move command—see Figure 1). Also, the time base for the calculation consisted of the entire duration of games, including relatively substantial periods spent either entering additional required input or waiting for a command to be executed before another could be selected. Mean latencies, beginning at the display of the command prompt and lasting until the next command was initiated, were estimated from response rates and the typical length of time spent (in pilot studies) entering additional required input and waiting for a command to be executed. These latencies were considerably shorter than 15 s. Mean rates of total responding did not differ significantly across the major parts of the experiment. Mean game duration was 21 min, and Klingons were discovered 9.0 times and destroyed 3.8 times per game on average. Postsession questions about the function of observing responses were answered accurately in most cases (Table 3, Columns 7 and 11).

Principal results. Relative and absolute rates of observing response commands are shown in Figures 2 and 3 (group means) and Table 3 (individual means for each session). Overall mean rate of total observing behavior was 63 per hour. Mean total rates in the major parts of the experiment did not differ reliably, nor did total rates in the two choice conditions, although the latter means are in the order predicted by both the conditioned reinforcement and uncertainty-reduction hypotheses (64 vs. 61 per hour, higher in the condition arranging choice between S+ and S−). However, S+ maintained more observing than S− in each part (Figure 2, open bars) and overall (mean choice proportion was .65, $t = 6.2$, $p < .01$). Nonparametric analysis of the percentage of subjects showing this preference (i.e., a binomial test using the normal distribution as an approximation because of a large sample) also was significant (25 "successes" out of 31 possible subjects, 1 of which was a tie, and excluding Subject 15, who did not observe in this condition, and the 6 subjects who made questionnaire errors as discussed above; $z = 3.9$, $p < .01$; see Table 3).

By contrast, in choice between observing S− and a stimulus uncorrelated with Klingons, mean rates of observing maintained by the uncertainty-reducing S− stimulus were lower in each part than the rates maintained by the uninformative control stimulus, although they were significantly lower only in Part 3 (Figure 2, hatched bars). The mean choice proportions did not differ reliably in the different parts, however. Overall the mean choice proportion expressed in terms of S− was .43, which is significantly less than indifference ($t = 2.2$), and only 11 of 34 subjects who observed and who answered questionnaires without error preferred S− (2 of which were ties; binomial test, $z = 1.8$).

Mean rates of observing maintained by S− did not differ reliably between choice conditions. The means were averaged (22 per hour) and then compared simultaneously with the overall mean rates maintained by S+ (45 per hour) and the Klingon-uncorrelated stimulus (38 per hour; Figure 3, set of bars on left). One-factor analysis of variance revealed significant differences between them, $F(2, 58) = 4.2$. Specific comparisons revealed that mean observing rate maintained by S+ exceeded that maintained by S− averaged over conditions, $F(1, 29) = 7.3$, as did mean observing rate maintained by the uncorrelated stimulus ($F = 10$); this is consistent with the preference data within conditions.

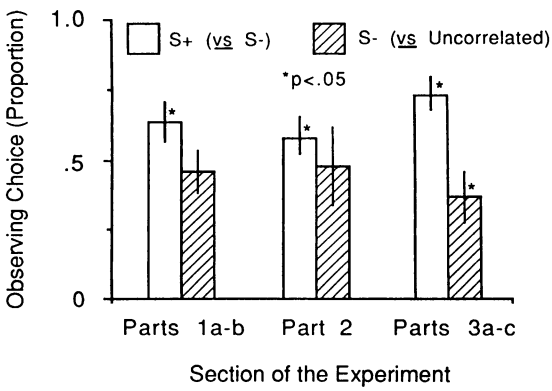

Fig. 2. Mean observing response command choice proportions in each condition for each of the main parts of the experiment. Open bars depict choice for observing condition red (S+) relative to condition green (S−); hatched bars depict choice for observing condition green relative to a stimulus uncorrelated with Klingons (condition yellow). Error bars are one standard deviation in length. Asterisks indicate significance (one-tailed) assuming a null hypothesis of indifferent choice (proportion = .5).

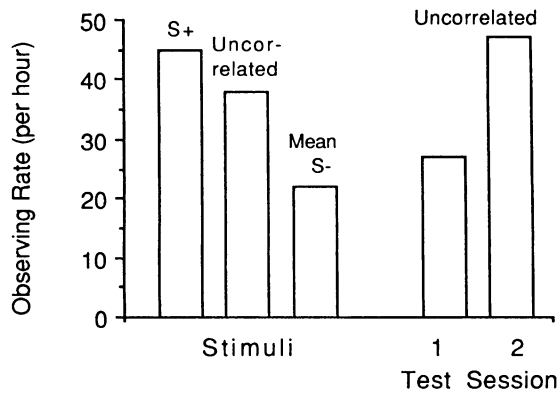

Fig. 3. Mean rates of observing response commands averaged over all parts of the experiment. The left set of bars shows the mean rates maintained by battle condition red (S+), yellow (uncorrelated), and green (S−, average rate in both conditions). The right set of bars shows mean rates maintained by a Klingon-uncorrelated stimulus for each order of conditions: Test Session 2 result is the mean rate maintained when the same observing response command had produced S+ in the preceding condition (Order B in Table 3).

Plotted with the set of bars on the right of Figure 3 are the overall mean rates of observing maintained by the uncorrelated stimulus for each order of conditions (i.e., data for Test Session 1 comes from subjects studied in Testing Order B as indicated in Table 3). Mean rates of observing were significantly higher in the second test session, which followed the session in which the same observing response had produced S+ (47 vs. 27 per hour on average, $t(32) = 1.8$, one-tailed). The same carryover effect appeared in the choice data: mean S− proportions in choice between the S− and an uncorrelated stimulus were .49 and .36 in Test Sessions 1 and 2 ($t = 2.0$). Thus, the overall mean S− observing choice proportion, .43, was significantly lower than indifference only because the command producing the uncorrelated stimulus in the same sessions had had a history in half the subjects that resulted in a higher mean observing response rate maintained by it. By contrast, mean rates of observing maintained by S+ did not differ reliably depending upon existence of an immediate history with the same response having had produced the uncorrelated stimulus.

Open-ended questionnaire items and other comments. Subjects were asked to describe their playing strategy and to make other comments. Replies that referred to putative reinforcers were examined the most carefully, especially the discovery and destruction of Klingons and production of the battle status stimuli. Subjects' evaluations of the game also received attention. The discovery and destruction of Klingons were implicated most often as reinforcers. For example, Subject 31 reported attempting "to destroy all the Klingons possible." Subject 22 wrote, "I simply move from quadrant to quadrant looking for ships (Klingon ships)." This subject also destroyed Klingons when they were discovered rather than "simply looking" for them, however, as did all subjects. As a final example, Subject 38 combined the two aspects of Klingon reinforcement by reporting the strategy: "Move from one sector to the adjacent sector on a search and destroy mission."

Only two replies suggested that Klingons were not always a welcome discovery. In one, for example, Subject 30 wrote, ". . . when all these Klingons start coming around I start punching buttons and getting myself out of the galaxy. . . . spread the Klingons throughout the game for the next poor soul!" By chance, more than once for this subject the VT schedule for inserting Klingons arranged short interreinforcement intervals in succession and more than one Klingon was present. Subject 30 also typed a question at the computer terminal during a game, "Where are the stupid Klingons?" suggesting that discovering Klingons remained reinforcing at least some of the time despite such occasional irregularities.

Most subjects described Klingon reinforcers in a way that implied response-independent scheduling. For example, Subject 3 wrote, "I would just move about the galaxy and wait for a Klingon to show up. . . ."

Subjects appeared to view observing response commands as predictors of Klingon discovery. Subject 27 indicated preference for S+, for example, "because this is what I wanted to know . . . 'Green' [S−] means no Klingons—boring." Subject 29 also wrote, "Green is boring." Subject 22 wrote, "I moved to find Klingons, using BC [which produced S+]." Subject 31 asked somewhat rhetorically after receiving instructions about the observing responses, "Then TR [observing command that produced condition yellow, which was uncorrelated with Klingons] is actually better [than the observing command that produced S−]?" The experimenter replied by repeating the instructions.

"Star Trek" was evaluated as fun, very enjoyable, and interesting (Subjects 9, 27, and 36). However, disagreement is suggested by comments that "Star Trek" was "a slow game" (Subject 24) with "not enough action" (Subject 20), and Subject 32 asked, "Is this a learner's program?" The game also was evaluated as "complicated" (Subject 30), "pretty complex" (Subject 34), and "a little hard for a video game" (Subject 36), and using the coordinate system was described as difficult, "not like Space Invaders" (a computer game in which quick reaction time is a major requirement for successful play; Subject 30).

DISCUSSION

Observing behavior was studied in a modified popular computer game. "Star Trek" was selected because of its popularity (Malone, 1981), complexity (cf. Nelson, 1980), and modifiability (programming of original commercial version in Basic computer code), and because it gave players access to various sources of information about the current status of the game, together with putative reinforcing events (e.g., Klingon destruction). Critical features of prior lever-pressing methods were incorporated while minimizing modifications needed to make the game a suitable tool for experimental investigation of observing behavior. Given that the opportunity to destroy enemy Klingon invaders was reinforcing in this context, observing-behavior preferences were maintained as predicted by the conditioned reinforcement hypothesis and counter to predictions of the uncertainty-reduction hypothesis. In each major part of the experiment, S+ (condition red) was preferred over S− (condition green), although each stimulus reduced uncertainty about Klingon availability. In addition, S− was preferred less than an uninformative stimulus uncorrelated with Klingons (condition yellow) both in Part 3 and overall. A caveat is that the latter result depended upon a history with the same observing-response command currently maintained by the Klingon-uncorrelated stimulus, a history that had the effect of increasing response rate. This effect presumably came from prior association of response-correlated stimulation and S+, a separate but quite possibly related conditioning effect. This suggests an obscuring "floor effect" in detecting S− avoidance with these methods in the absence of such a history.

Laboratory studies of human observing behavior have been vulnerable to criticism. The present study began to address these concerns. Unchallenging and arbitrary lever-pressing tasks have been posed in spare, unfamiliar surroundings similar to chambers typically used in studies of nonhumans. Although this may have increased experimental control and produced greater comparability of results across species, it may be correspondingly less likely for uniquely human features to emerge, such as purported information-processing abilities and sensitivity of behavior to verbal control (Bentall & Lowe, 1987; Perone & Baron, 1980). A degree of external validity is sacrificed by these methods in order to strengthen internal validity (Fantino, 1985; Fantino & Logan, 1979). Computer games such as "Star Trek" present a considerably more complex contingency space than do prior methods because subjects can choose from many response alternatives and consequences. There were also other events and messages too numerous to report (see Table 1). Although "Star Trek" is not perfectly faithful to the realistic fictional dramas upon which it is based, this complexity makes the task realistic quite apart from the static resemblance of specific stimuli and responses to extralaboratory events. Playing games on computers is also more commonplace than typical arbitrary lever-pressing tasks and apparatus that have been used. Using an office setting in the present study, rather than a barren cubicle, was an additional step towards improved external validity.

Another related criticism is that reinforcers usually have been points backed by money or other events extraneous to the task, rather than events of intrinsic value in context. Although there is little doubt that monetary backing or instructions can be effective in making points themselves reinforcing (Case & Fantino, 1989; Navarick, 1985), there may be different properties between reinforcing stimuli established in this manner and those that are well-integrated into a realistic simulation. Discovering and destroying Klingons apparently were intrinsically reinforcing within the context of the game. Points typically used in lever-pressing tasks, in contrast, have more of a discriminative or informational feedback character, somewhat like the scores obtainable in the "Star Trek" game by issuing the rarely used RA (rating) command.

A final concern is that response-independent reinforcement, used to remove interpretational ambiguities (Fantino & Case, 1983), is thought to increase the chances of learning inadvertent response–reinforcer contingencies (Skinner, 1948). However, Klingons attacked the Enterprise as well as being the target of attack. Because of such simulated antagonism and the Klingons' ostensibly aversive rather than reinforcing nature, it is less likely that subjects would inadvertently learn that their behavior produced response-independent Klingons. Subjects are more likely to view their strategy as one of reacting to an invasion initiated by autonomous agents, an invasion that occurs whether or not defensive actions (locating and destroying Klingons) are taken.

The Klingon attacks could conceivably lead to Klingon discovery being considered more a punisher than a reinforcer. However, shields could be raised to reduce inflicted damage, ample fuel and weapons were available, replenishing resources was accomplished readily (though rarely necessary and done infrequently), the Enterprise always survived attacks, and subjects' comments overwhelmingly suggested that Klingon discovery and destruction were more welcome than their discovery and attacks on the Enterprise were threatening. Follow-up investigations should test this interpretation by determining whether comments change appropriately and observing preferences reverse when the Enterprise is stripped of its weapons and shields, permitting only temporary escape and damage repair.

As already discussed, S− was observed less than was an uninformative control stimulus (i.e., S− was avoided) in Part 3 but not in Parts 1 and 2. Avoidance of S− tended to be less in Parts 1 and 2 considered together than in Part 3, but the difference in the means failed to reach statistical significance (mean choice proportions were .47 and .37; $t(32) = 1.4$, $p < .1$). The result depends upon unusually high variance in Parts 1 and 2, approximately one quarter of which was due to two extreme preferences. Reanalysis, after excluding Subjects 17 and 20 with choice proportions of .95 and .00, leaves the mean unchanged after rounding while yielding a significant difference despite fewer analyzed data, $t(30) = 1.7$. Also, S+ was preferred over S− significantly less in Parts 1 and 2 combined than in Part 3 (mean choice proportions were .61 and .73; $t(28) = 2.4$).

It may be worthwhile to speculate briefly on the differences between parts of the experiment in accounting for these tendencies, although additional research will be required to better establish the reliability of the former finding. Future research also will need to experimentally dissociate variables, because Part 3 differed from the others in several ways (Table 2). In any event, in considering the various procedural differences, the one that is most likely relevant is that, in Part 3, subjects were not able to use S− to advantage for restocking the Enterprise at times when Klingons were unavailable. Research in simpler and better controlled lever-pressing tasks suggests that S− may be preferred over an uninformative stimulus if it is correlated with improved efficiency of responding required for primary reinforcement (Case, Fantino, & Wixted, 1985; Perone & Baron, 1980). According to a conditioned reinforcement analysis, the value of S− as a conditioned reinforcer/punisher controlling choice should be a combination of negative value (from being negatively correlated with reinforcement) and positive value (from being positively correlated with improved efficiency of responding required for reinforcement; this is a different kind of reinforcement).

In the present study there is an important methodological difference in the different situations to which response efficiency considerations pertain. Because Klingons were inserted independently of responding throughout the study, S− did not permit improvement in efficiency of responding required for Klingon-related reinforcement, previously an acceptable method of eliminating all considerations of response efficiency in accounting for preference. But in Parts 1 and 2, S− could be used to advantage with respect to other responses and reinforcers, most notably those that restocked the Enterprise. Analysis of resource-replenishing teleporter and rest and repair commands in those parts suggests that subjects did indeed tend to use the opportunity to improve circumstances in this way. Eight subjects used these commands more often during S− than during the other observing-contingent stimuli, compared with 2 subjects who used them more during S+ (i.e., 8 "successes" out of 10 possibilities, $p = .055$, binomial test) and 1 subject who used them more during condition yellow (i.e., 8 of 9, $p < .05$); the remaining subjects showed no differences. It seems that scheduling reinforcers independently of responding will eliminate considerations of response efficiency only if the situation does not include other important types of reinforcers. For more complex (more realistic) situations, other methods of controlling response efficiency improvements may need to be used (such as restricting opportunities for obtaining alternate reinforcers, as in Part 3).

Two previous studies employed games similar to that used in the present research (Baum, 1975; Leung, 1989). In both studies, the games were created by the researchers rather than being modified from a commercial product. Game popularity was not assessed, and they were much simpler than "Star Trek"; the earlier one, which antedated personal computers, was programmed electromechanically. Nevertheless, there are similarities in that subjects produced stimuli in the presence of which attacking "enemy missles" or "aircraft" appeared that had to be destroyed. Both studies were also investigations of choice. Subjects were required to produce stimuli to obtain access to reinforcers, as in chain schedules of reinforcement (although Baum used different terminology). In observing-behavior research, reinforcers with which the contingent stimuli are correlated are delivered independently of observing behavior. Neither study used one of the two most comparable nonobserving operant procedures, namely a simple changeover between signaled and unsignaled events and choice between equivalent mixed and multiple schedules in the terminal links of concurrent-chains schedules. As a method of investigating conditioned reinforcement, observing behavior has an advantage over chain schedules because of the separation of responding maintained by primary and secondary events (Dinsmoor, 1983). The simplicity of the earlier games also makes them less suitable for addressing concerns that motivated this study, even if they had been designed to investigate observing behavior.

Theoretical analyses in both studies were nevertheless similar to that of the present study. Control of choice by contingent conditioned reinforcers was emphasized, in Baum's (1975) study according to the relative rate of reinforcers scheduled in their presence (i.e., Herrnstein's, 1964, matching relation), and in Leung's (1989) study according to the signaled reduction in average delay to reinforcers (i.e., Fantino's, 1969, delay-reduction hypothesis). A symmetrical extension of Fantino's original delay-reduction hypothesis has been proposed to account for observing avoidance of S− (Case & Fantino, 1981), and evidence suggesting its predictive superiority to the matching hypothesis has been found in studies of observing behavior in pigeons (Case, 1981; Kendall, 1975). Unfortunately, the present study of human observing was not designed to contrast the accuracy of these or other competing theories (e.g., Daly, 1985), although the symmetrical extension of the delay-reduction hypothesis again found support.

In summary, an elaborate computer program developed as an entertainment device with commercial value was modified slightly and used effectively as a tool in the investigation of human observing behavior in college students. Our findings support the conditioned reinforcement hypothesis of observing behavior over the uncertainty-reduction hypothesis. The results therefore extend human lever-pressing research to a realistic game context. The results also suggest a general condition under which receipt of ostensibly bad news may be reinforcing: Negative discriminative stimuli for one type of reinforcing event can become partly good news if they permit improvement in one's circumstances. To control for this possibility in prior research on observing behavior that was embedded in simpler schedule contexts, it was sufficient to schedule reinforcers independently of responding, because only a single reinforcer of significance was involved. Additional constraints may be required in more complex situations that arrange additional types of reinforcers.

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