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USE OF REWARD-PENALTY STRUCTURES IN HUMAN EXPERIMENTATION

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SUMMARY

This paper reviews the use of motivational techniques in human performance research and presents an example study employing a reward-penalty structure to simulate the motivations inherent in a real-world situation. The influence of motivation on human performance has been an issue since the beginning of behavioral science. Most often, motivation is controlled through procedures designed to minimize its influence as an uncontrolled variable. Driver behavior in a decision-making driving scenario was studied.

The task involved control of an instrumented car on a cooperative test course. Subjects were penalized monetarily for tickets and accidents and rewarded for saving driving time. Two groups were assigned different ticket penalties. The group with the highest penalties tended to drive more conservatively. However, the average total payoff to each group was the same, as the conservative drivers traded off slower driving times with lower ticket penalties.

INTRODUCTION

Reward-penalty structures have existed since the beginning of experimentation, and the effects of such structures have evolved into a separate area of research. As early as 1922, A. M. Johanson observed the effects of rewards and penalties on reaction times. These classic results (cited in Ref. 1) are shown in Fig. 1. Researchers have examined the motivational aspects (Refs. 2-6), looked at rewards' distracting effects (Refs. 7-10), and looked at the positive effects of rewards (Refs 11 and 12). What does this experimentation mean, and how can the researcher of today utilize the efforts of others?

Subject motivation is a primary concern in any experiment. "We want the subject motivated to come back for 12 experimental sessions;" or "we want the subject motivated to respond as quickly as possible;" or "we want the subject motivated to respond in a manner consistent with his or her normal behavior." Rewards and penalties play an important part in this motivation.

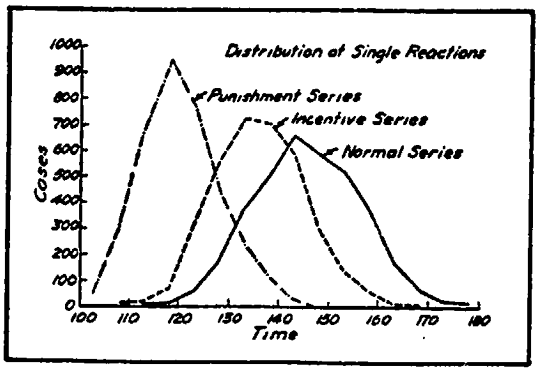

Figure 1. Change in the Distribution of Reaction Time Under the Influence of Incentives. Auditory stimulus. In the "incentive series" O was informed of his last RT; in the "punishment series" he received a shock in the finger when the reaction was at all slow. Each curve shows the distribution of 3600 single reactions obtained from three Os whose times were nearly the same. (Adapted from Ref. 1)

To assess reward-penalty structures with regard to their consequences, and to develop a structure for a given experiment, requires a basic knowledge of the literature, terminology, and present methodologies. This paper is a review of the present body of knowledge with an emphasis on reward-penalty design consequences for human performance research.

PREVIOUS RESEARCH

Definitions

The distinction between intrinsic and extrinsic motivation should be an important consideration when designing a reward-penalty structure. If a person chooses to work a series of complex mathematical problems because of personal enjoyment, then the "perceived locus of causality" (Ref. 6) is internal, and the task is intrinsically motivating. If, however, the person chooses to work the problems to gain an external reward, and the "perceived locus of causality" is external, then the task is extrinsically motivating (Refs. 3, 4, 6, 13-15).

Deci (Refs. 2 and 3), Deci, Benware, and Landy (Ref. 4), and Edwards (Ref. 16), all point out that reward-penalty structures can be designed to be either extrinsically motivating or neutral. If the experimenter chooses to have the structure of neutral influence on the subject, and at the same time achieve high subject motivation, it becomes necessary to use a task that has been, or can be, shown to be intrinsically interesting to the subject population. If the choice is to have a structure that makes the reward or penalty contingent on performance, or in some other way extrinsically motivating, then the choice of experimental task is of secondary consideration. It has been shown by Lepper and others (Refs. 3, 4, 13, and 14) that subjects performing tasks of high intrinsic motivation, receiving extrinsic rewards, perceive the locus of causality to be external, and show low intrinsic motivation.

Purpose of Rewards and Penalties

As pointed out by Edwards (Ref. 16), rewards and penalties can serve three purposes: 1) motivators, 2) information givers, and 3) instructions. If the subject is rewarded only for participation in an experiment, then the reward serves as a motivator; the subject will perceive the locus of causality as internal, and the experimental task will be intrinsically motivating. If the reward-penalty structure is changed, and task performance is rewarded the reward or penalty will serve as information, in addition to any motivating influence it has. If the experimental task is solving complex mathematical problems, and the subject is paid hourly for experimental participation, then task performance is unrelated to the reward, and the reward's purpose is that of a motivator. If the reward is increased as a function of problem completion time, or number of problems solved, the reward takes on the additional quality of an information giver. In this case it is important to note that correct response is not required.

If correct response is required for a reward increase, or incorrect response is punished, the reward also serves as an instruction. In this case the reward not only provides motivation and information, it now tells the subject the relative desirability of a specific response. Withholding the reward until the completion of the experiment does not alter its motivational or instructional qualities. Because the reward is performance related, withholding payment (or information about the reward "earned") only eliminates the informational feedback quality.

Form of Rewards and Penalties

Rewards and penalties can take many forms, and the type of reward or penalty chosen by the experimenter should be an important part of the reward-penalty design. The overall effect of the reward or penalty needs to be assessed prior to its introduction in the experiment. For example, Deci (Ref. 2) found that monetary rewards caused a decrease in intrinsic motivation, while rewards by use of verbal reinforcement caused an increase. McCloskey (Ref. 17), in her work with staff turnover rates, found that psychological rewards such as recognition, help from peers, and educational opportunities were more important in keeping an employee than salary or job benefits; and that money alone would not keep an employee. Viesti (Ref. 18) found that on an insightful learning task pay made no difference in performance.

One of the most commonly used rewards is money. Many researchers have examined the advantages and pitfalls of this reward form, and their findings can be of great assistance in developing a reward-penalty structure.

Money seems to provide the best balance between response and error rate. Daniels, et al.(Ref. 11), found that response speed remained constant, but a drastic reduction in error rate was observed when real instead of imaginary money was used. Slovic, Lichtenstein, and Edwards (Ref. 19) found that subjects employed simpler decision strategies in an imaginary incentive design than with real payoffs. Also Slovic (Ref. 20) found that when subjects made hypothetical choices, they maximized gain and discounted losses; however, when their choices had real consequences, the subjects were considerably more cautious.

The researcher should be cautioned by the work of Greenberg (Ref. 21) and Leventhal and Whiteside (Ref. 22), however. They have shown that monetary reward can be used to motivate performance, but that overreward is frequently employed. In some cases the overrewarding tendency was so strong that higher rewards were given to lower performing workers. Furthermore, Spence (Refs. 8 and 9), Miller and Estes (Ref. 10), and McGraw and McCullers (Ref. 7) point out that increased rewards may draw attention from the experimental task.

EXPERIMENTAL STUDY

The above research findings clearly show the need for appropriate reward-penalty designs, both in form and magnitude. The following examples, part of a study on alcohol-driver interaction, show how this information can be used to create a reward-penalty structure.

In a study concerning the effects of alcohol on drivers' decision making behavior, two separate experiments were conducted. The first was run in our fixed-base driving simulator (Ref. 23) and the second in an instrumented vehicle designed for the National Highway Traffic Safety Administration (Ref. 24).

In both experiments the subject was required to complete a driving scenario in both sober and intoxicated states. The following is a brief discussion of the requirements, design, and effects of variations in a motivational reward-penalty structure.

Reward-Penalty Structure

Driving in the real world is motivated by a variety of counteracting incentives. Drivers wish to minimize trip time but avoid tickets and accidents. Driving behavior is influenced by these motivations, particularly in risk-taking/decision-making tasks. In order to encourage real-world-like behavior we must attempt to simulate the real-world incentives. The problem with simulating typical driving incentives is that they include some difficult-to-quantify variables, such as the subjective value of time gained by driving faster and the subjective fear of low probability events such as auto crashes. Negative reinforcement with electric shock is a classical experimental technique and might serve to simulate the pain of an accident, but this technique is difficult to quantify and recent subject welfare guidelines make it unattractive. In a recent aircraft landing experiment involving pilot decision making (Ref. 25), the experimenters went so far as to inform their pilot subjects that they would be eliminated from the experiment in the event they crashed in order to make them as averse to crashes as they would be in real life. However, this approach would be logically awkward in this study because we would lose selected and trained subjects and, furthermore, the majority of driving accidents do not involve fatalities.

The traditional method of quantifying incentives for experimental control is to relate them to some well-defined variable with interval properties by measuring indifference curves (Refs. 26 and 27). The most well-defined, widely studied, and widely used norm is money, primarily because of its interval properties and interchangeability. Money has some limitations; for example, the decision-making behavior has been shown to be confounded by the subject's financial status. However, this can be experimentally controlled by controlling the knowledge of results (Ref. 28). In general, the additional experimental effort required to scale other disincentives (e.g., shock, loud noises, etc.) has led to widespread use of money for rewards and punishments in decision-making experiments.

In both experiments the reward-penalty structures had multiple requirements. A major concern was that the subject complete the driving scenario in a normal manner, with a reasonable motivation for timely progress and a desire to avoid tickets and accidents; that is, we wanted the subject to drive as if the driving situation were being experienced in the real world. A second requirement was that the subjects return for participation in six full-day experimental sessions. Finally, we chose to alter the penalty structure in the experiment to determine the behavioral effects of increased ticket penalty on the driver.

With the exception of ticket penalties, the reward-penalty structure for both experiments was the same. In order to provide a basic motivation to remain in the study, the subjects were paid an hourly wage. This payment was received by the subject irrespective of performance. To facilitate completion of the driving scenario, and to encourage normal driving behavior, we used an additional reward-penalty structure scaled to real world occurrences.

Rewards consisted of $10.00 for completing the driving scenario, and $2.00 for every minute of total elapsed driving time under 20 minutes. Assuming a real world situation of leaving a bar intoxicated, this rewarded the subject for making it home and for driving with the flow of traffic, thus avoiding detection.

In both experiments, crashes (i.e., hitting an obstacle or adjacent car, or running off the roadway) were penalized $2.00.

Tickets were given for running a red light or for speeding. Again to simulate a real world driving experience, the traffic police were present only 30% of the time. In experiment 1 (the simulation), tickets were either $1.00 or $2.00, depending on the group to which the subject was assigned. In experiment 2 (full-scale), tickets were either $1.00 or $4.00.

Subjects received immediate feedback if they crashed (buzzer), or received a ticket (siren and red lights), but total rewards and penalties were withheld until the completion of the experimental day. Again this simulates the real world, because the cost of a ticket or crash is rarely known when the incident occurs.

RESULTS AND DISCUSSION

To determine the suitability of our reward-penalty structure to the experiment, two criteria can be used. First, did all the subjects complete the experiments? In both experiment 1 and experiment 2 the answer was yes, indicating that we were able to keep the subjects sufficiently motivated to return. Second, to correlate our results with real world driving statistics, we compared our simulator and field test results with epidemiological data of over 7000 alcohol related traffic accidents. As evidenced in Fig. 2, the simulator results and the field results compare favorably with the actual accident data, thus indicating drivers motivated to take comparable risks.

Finally, in our investigation of the behavioral effects of a change in penalty structure, we found in experiment 1 no significant difference between the $1.00 ticket group and the $2.00 ticket group. Experiment 2, however, did show a significant difference between the $1.00 ticket group and the $4.00 ticket group.

In Fig. 3 we see that the high penalty group in the field study had on the average of one-third less tickets, with speeding tickets showing a greater sensitivity than signal light tickets. These results are statistically significant as shown in Table 1. Driving time differences between the two penalty groups were marginally significant (Table 1) and consistent with the ticket results, e.g, larger time and fewer tickets. Payoff was <u>not</u> significantly different between the penalty groups, however (Table 1), which indicates a compensatory tradeoff between driving time and ticket rate.

TABLE 1. ANALYSIS OF VARIANCE SUMMARY FOR OVERALL SCENARIO PERFORMANCE IN THE FIELD VALIDATION STUDY

SOURCE	ERROR TERM[a]	DEGREES OF FREEDOM	F RATIOS					
			PAYOFF	DRIVING TIME	ACCI- DENTS	SIGNAL TICKETS	SPEEDING TICKETS	ROUTE ERRORS
Day	DS(P)	1	19.33***	2.92	12.71**	2.09	13.96**	1.50
Penalty	S(P)	1	2.37	4.20†	1.92	10.80**	5.47*	1.33
Trial	TS(P)	2	10.44**	2.27	13.56**	4.72*	3.71*	1.41
DP	DS(P)	1	0.33	0.42	1.08	0.52	2.67	1.50
DT	DTS(P)	2	13.71***	1.0	11.55**	2.15	4.10*	1.26
PT	TS(P)	2	0.59	2.02	0.40	1.13	0.53	1.33
DPT	DTS(P)	2	1.40	1.65	1.27	2.08	0.90	1.49

Level of Significance: †$p < 0.10$; *$p < 0.05$; **$p < 0.01$; ***$p < 0.001$.

[a]Error term degrees of freedom: S(P) - 12, DS(P) - 12, TS(P) - 24, DTS(P) - 24.

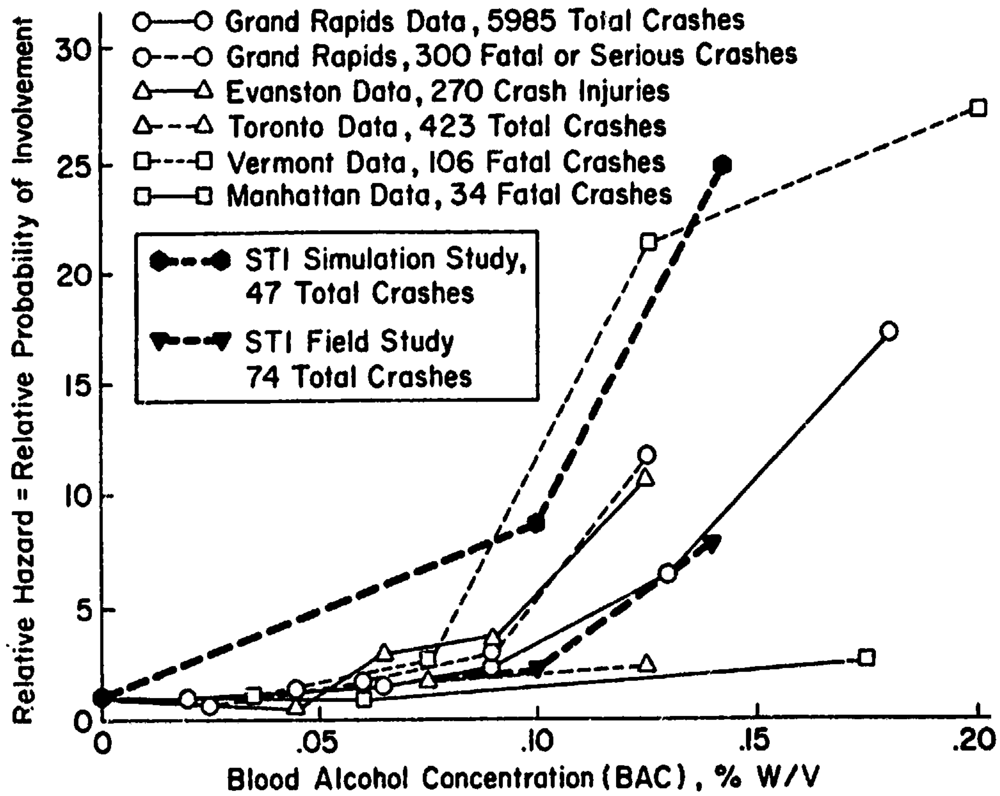

Figure 2. Relative Probability of Crash Involvement as a Function of BAC Where 1.0 = Relative Probability at Zero Alcohol (Adapted from Ref. 29)

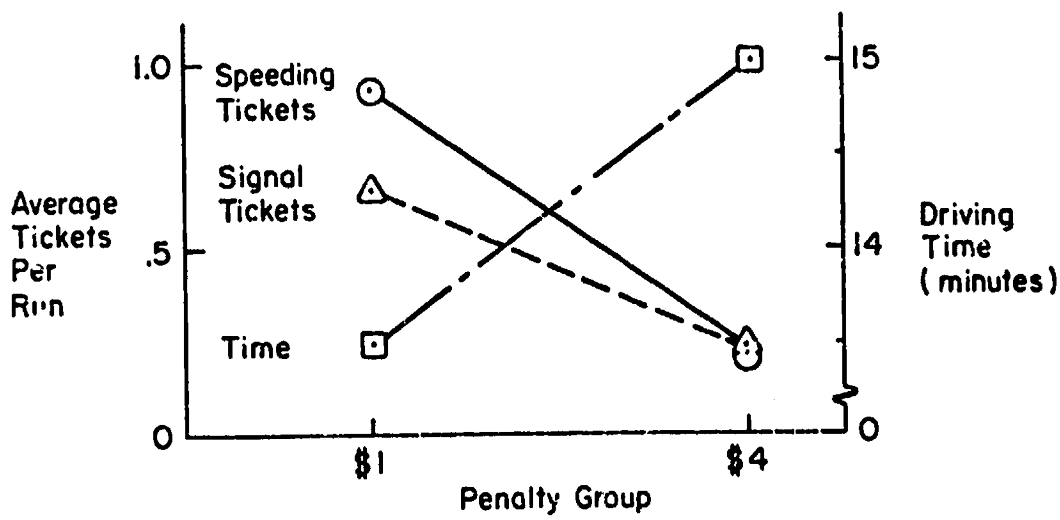

Figure 3. Penalty Effect on Ticket Rate and Total Time to Complete the Driving Scenario

Some insight into the ticket reduction with increased penalty can be gained from the signal light risk acceptance plot shown in Fig. 4 (Ref. 30). Here we see that the high penalty group perceived higher risks in signal failures (i.e., running the red light) and was willing to go less often. The combined effect was much more conservative behavior for the high penalty group, leading to better driving performance. The P(G) and SP(F/G) differences in Fig. 4 were statistically significant, but the SP_c difference was not. No group differences were observed for accident data in the experiment, and because of the magnitude of the ticket and P(G) group differences it is assumed that these are true penalty effects and not just between-group differences.

CONCLUDING REMARKS

The following conclusions were drawn with respect to the reward-penalty structure in our experiments:

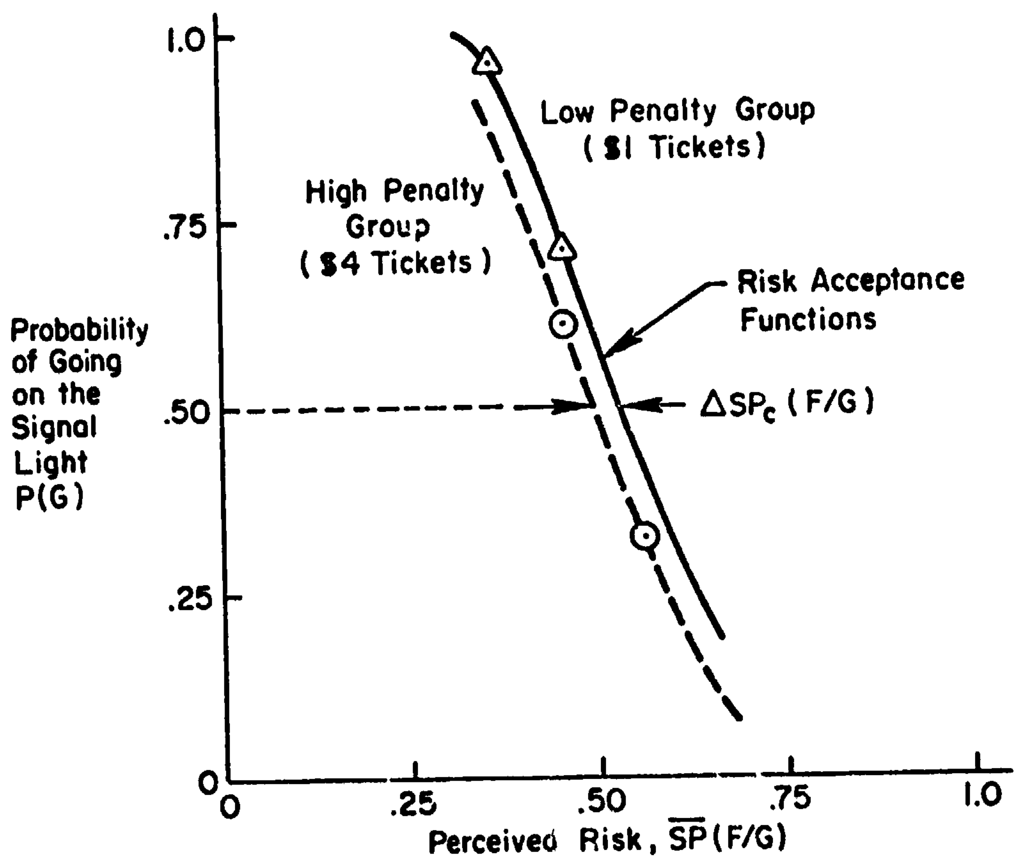

Figure 4. Mean Subjective Probability of Failure to Make It Through the Light If It Were Attempted

* Driving is not intrinsically motivating to the majority of the population, and in experimental tasks is even less so. Real-world Motivation incentives such as accidents, tickets, and desire to safe time, are extrinsic.

* Rewards and penalties must be tangible. Imaginary rewards and/or verbal reinforcement are not sufficient.

* Rewards and penalties should serve as general motivation, but not direct feedback in the driving scenario.

* Between runs in an experimental session, overall performance payoffs should be withheld in order to avoid feedback or reinforcement which might modify behavior on subsequent runs.

* Our results show that employing a specifically designed monetary reward-penalty structure provides sufficient extrinsic motivation to duplicate a "real world" driving situation.

These results on reward/penalty effects on driver risk taking might be extrapolated to real-world driving behavior. Perhaps drivers would drive more conservatively with increased and more evenly applied penalties for traffic violations.

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