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REDUCING ELEVATOR ENERGY USE: A COMPARISON OF POSTED FEEDBACK AND REDUCED ELEVATOR CONVENIENCE

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The effects of two different procedures for reducing elevator energy use were assessed using a multiple-baseline design. In the first procedure, feedback about the amount of energy consumed by the elevators each week was posted on each elevator door. Later, signs advocating the use of stairs to save energy and improve health were posted next to the feedback signs. In the second procedure, the time required to travel between floors was increased by adding a delay to the elevator door closing mechanisms. Results indicated that neither feedback alone nor feedback plus educational signs reduced the amount of energy consumed by the elevators. However, use of the door delay reduced consumption by one-third in all elevators.

A second experiment replicated the effect of the door delay on energy consumption and, in addition, demonstrated that the door delay also produced a reduction in the number of persons using the elevator. The second experiment also showed that, following an initial period during which a full delay was in effect, a gradual reduction of the delay interval resulted in continued energy conservation. Reduced convenience as a general strategy for energy conservation is discussed.

DESCRIPTORS: energy conservation, response cost, feedback, prompting, electrical energy reduction

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Elevators are often installed in small buildings to provide an alternative to stairs for handicapped or injured users as well as to assist in the transportation of freight. However, these elevators are often used by individuals who could as easily use the stairs. Unnecessary elevator use can consume large amounts of energy and can deprive an individual of an opportunity to engage in a form of routine exercise (using the stairs).

There are basically three strategies that have been used either in isolation or together to reduce unnecessary energy consumption. These are prompts, feedback, and incentives. Most studies reporting on the effects of prompting have reported very small effects. For example, Heberlein (1975) examined the effects of prompts consisting of a letter, pamphlets, and telephone calls on the residential energy consumption of apartment dwellers and found that they had no effect. Similarly, Kohlenberg, Phillips, and Proctor (1976) found that educational information and pleas produced no effect on residential electricity peaking. However, Brownell, Albaum, and Stunkard (Note 1) increased the percentage of people choosing stairs over escalators from 6.3 to 14.4% through the use of a 0.9 m $\times$ 1.1 m sign encouraging stair use. The sign read "Your heart needs exercise . . . here's your chance" and displayed a caricature of a healthy heart running up a staircase and an unhealthy heart riding an escalator.

The effect of feedback on energy consumption has also been equivocal. For example, Winett, Neale, and Grier (1979) reduced residential

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electricity use by 13% with daily written feedback and by 7% with a daily self-monitoring feedback procedure, whereas in other studies daily feedback has produced either small effects (Hayes & Cone, 1977; Zarling & Lloyd, Note 2) or no effect (Becker & Seligman, 1978). In contrast, immediate feedback provided by a warning stimulus (a buzzer and light or a flashing light) produced larger decreases than daily feedback in two studies (Becker & Seligman, 1978; Zarling & Lloyd, Note 2).

Another strategy involves providing incentives for reduced energy consumption (Kohlenberg et al., 1976; Newsom & Makranczy, 1978; Winett, Kaiser, & Haberkorn, 1977). Although this approach has produced large reductions in energy use, it has not been cost effective in most cases. For example, Newsom and Makranczy (1978) paid $180 to save $149.48 worth of energy.

An alternative strategy which could be adopted is to make energy use less convenient. For example, automobile use can be made relatively less convenient than bus ridership by providing priority lanes for buses (Rose & Hinds, 1976).

The purpose of the present study was to compare the effects of two interventions on the amount of energy consumed by three elevators. The two interventions were (a) a treatment package consisting of prompting and feedback, and (b) making elevator use less convenient by increasing the elevator door delay.

EXPERIMENT 1

METHOD

Setting

The experiment was conducted on users of three elevators located in two buildings on the campus of a small Canadian University (Mount Saint Vincent University). The first elevator (Evaristus) was constructed by the Northern Elevator Company. This was the only elevator located in Evaristus Hall, a four-story building housing the university administration, the library, and women's residences. The remaining two elevators (Seton North and Seton South) were constructed by the Otis Elevator Company. These were the only two elevators located in the Seton Academic Center, a five-story building housing classrooms, an auditorium, and faculty offices. Stairs were located in close proximity to each elevator.

Measures

Energy consumption was measured by means of individual watt-hour meters wired to the main switchbox of each elevator. Meters were type S-3 polyphase watt-hour meters manufactured by the Sangamo Company Limited, Leaside, Canada, and supplied by the Nova Scotia Power Corporation. The tolerance of these meters, as specified by the manufacturer, is less than $\pm 2\%$.

Meters on all three elevators were read between 1:00 p.m. and 1:15 p.m. Monday through Friday. Energy consumption was not measured on weekends or holidays because few people used the university buildings on these days. Therefore, only four data points were collected each week. The first data point was the difference between the Tuesday and Monday readings. The second data point was the difference between the Wednesday and Tuesday readings. The third data point was the difference between the Thursday and Wednesday readings, and the final data point collected each week was the difference between the Friday and Thursday readings.

Procedure

The experiment employed a multiple-baseline design. All experimental conditions were first introduced at the Evaristus elevator and then, a minimum of three days later, at the Seton North and Seton South elevators. Because the Seton North and Seton South elevators were located in the same building, experimental conditions were always introduced at these elevators simultaneously.

Baseline 1. No changes in elevator functioning or appearance were made during this condition. Watt-hour meter readings were taken Monday through Friday.

Posted feedback. During this condition white posterboard signs measuring 35.5 cm × 24 cm were mounted directly above the elevator call buttons located on each floor. Printed on the signs, in 2-cm high black letters, was the message: "ELECTRICITY CONSUMED BY USERS OF THIS ELEVATOR: LAST WEEK ____ kw-hr. BEST RECORD ____ kw-hr."

Numbers announcing weekly consumption were printed on 4.5 cm × 7.5 cm white index cards using a black felt-tipped pen, and were affixed to the signs using clear plastic tape. Numbers were changed every Monday at 1:30 p.m. and represented the difference between the meter readings at 1:00 p.m. on that day and the meter reading at 1:00 p.m. on the preceding Monday. Thus, for feedback purposes only, consumption values included electricty used during weekends and holidays.

Numbers announcing "BEST RECORD" consumption were constructed and affixed to the sign in the same manner as the weekly feedback numbers. However, "BEST RECORD" numbers were printed using a red felt-tipped pen and were changed only when the previous week's total consumption was lower than the previous best record.

Posted feedback plus posters. The posted feedback on energy consumption continued as during the previous condition.

In addition, three different posters requesting people to use the stairs were mounted on each elevator door at each floor. One sign, which was adapted from a model provided by Energy, Mines and Resources Canada, read "Save Energy. Use the stairs for short trips," and showed a stylized illustration of a person climbing stairs above a stylized illustration of an elevator door. Another sign, which was adapted from a poster designed by FIT Nova Scotia, read "Exercise Your Heart. Use the Stairs. A flight a day can mean the difference," and showed two anemic people standing in front of a flight of stairs leading "to your good health." Beside the stairs were two elevators leading to "the cop-out." The third sign, an original creation, read "Burn Calories. Use the Stairs," and showed a balloon-shaped woman pushing an elevator button and, beside her, a trim woman climbing a flight of stairs.

Baseline 2. All signs were absent from the elevators during this condition. The daily monitoring of energy consumption continued as during Baseline 1.

Door delay—26 sec. During this condition, operation of the elevator doors was slowed, increasing the time required to travel between floors when using the elevator. The time required for elevator door operation was measured from the point at which the door first began opening to the point at which it was again fully closed. During all previous conditions this interval was 10 sec. During this condition, this interval was increased to 26 sec by maintaining the doors in a fully opened state for an additional 16 sec. At the Evaristus elevator, this was accomplished by wiring an adjustable timer into the door opening circuit. At the two Seton elevators, this was accomplished by wiring two 1600 mf capacitors into each door opening circuit.

On the first day that this condition was in effect at the Evaristus elevator, the University received 21 complaints that the elevator was not working properly. Because of these complaints, signs announcing the reason for the change were mounted on the elevator doors at each floor on the second day of the delay condition. These signs read: "To conserve energy this elevator has been slowed." At the Seton elevators, these signs were mounted on the doors during the first day of this condition.

Delay reduced 5 sec. During this condition, the door delay was reduced from 26 sec to 21 sec. At the Evaristus elevator, this was done by adjusting the timer and at the Seton elevators, this was done by removing one 1600 mf capacitor from each door opening circuit.

RESULTS

The number of kilowatt-hours consumed by each elevator during each condition is presented in Figure 1.

Baseline 1

Energy consumption during this condition averaged 32.8 kw-hr/day at Evaristus, 29.4 kw-hr/day at Seton North, and 32.8 kw-hr/day at Seton South. Consumption by all three elevators was highly consistent from day to day.

Posted Feedback

Energy consumption during this condition remained at baseline levels, averaging 31.6 kw-hr/day by Evaristus, 29 kw-hr/day by Seton North, and 30.8 kw-hr/day by Seton South. As during Baseline 1, consumption by all three elevators was highly consistent from day to day.

Posted Feedback Plus Posters

Despite the addition of information posters to the posted feedback procedure, energy consumption did not decrease during this condition. Consumption by all three elevators remained consistently within baseline levels, averaging 31.4 kw-hr/day by Evaristus, 27.7 kw-hr/day by Seton North, and 30 kw-hr/day by Seton South.

Baseline 2

Energy consumption throughout this condition was comparable to consumption during Baseline 1, averaging 31.5 kw-hr/day by Evaristus, 26.7 kw-hr/day by Seton North, and 30.7 kw-hr/day by Seton South.

Door Delay—26 sec

Delaying door closure and posting a sign announcing the inconvenience reduced energy consumption immediately and substantially in all three elevators. Mean energy consumption was

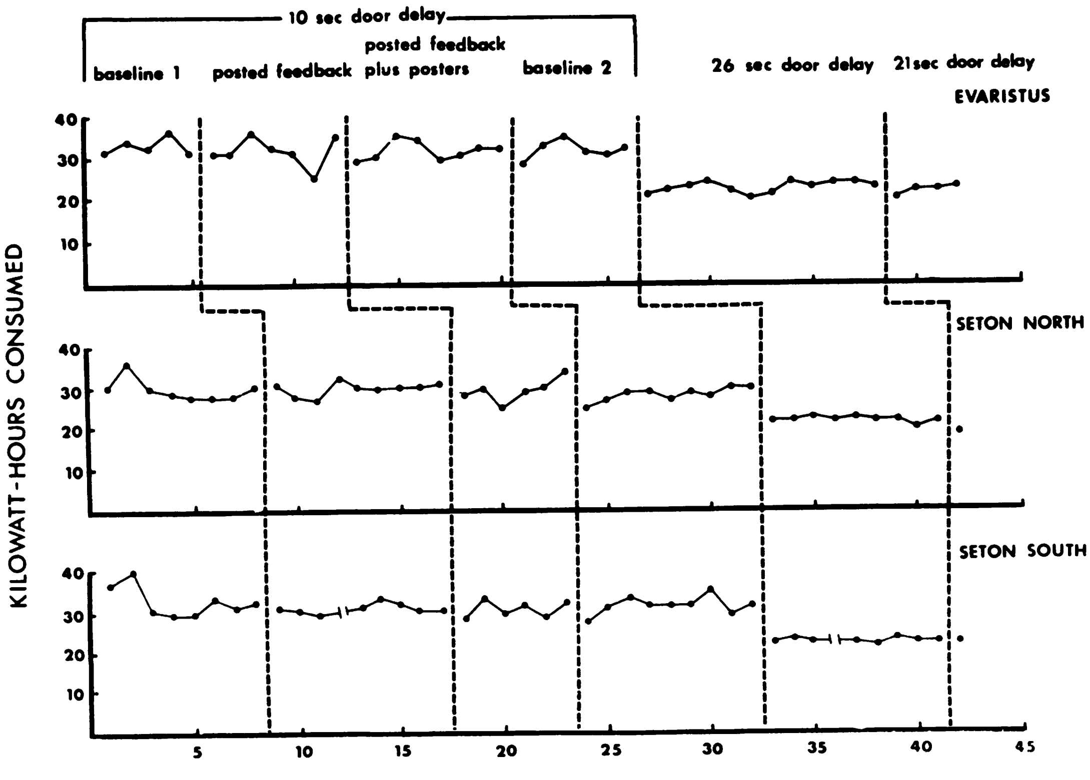

Fig. 1. Kilowatt-hours of electricity consumed by each elevator during each 24-h period during each condition of Experiment 1. The two broken lines for Seton South elevator indicate days during which data were not collected due to elevator breakdown.

22.6 kw-hr/day by Evaristus, 21 kw-hr/day by Seton North, and 22.1 kw-hr/day by Seton South. Relative to Baseline 1 levels, these averages represent reductions of 31%, 29%, and 33% respectively. Moreover, daily electricity consumption during this condition never overlapped daily electricity consumption during any of the previous conditions. It is interesting to note that this treatment produced a marked reduction on the first day that it was in effect at Evaristus, even though the signs informing people that the elevators had been slowed down had not yet been posted on the elevator doors.

Delay Reduced 5 sec

Reduction of the door delay from 26 sec to 21 sec did not result in increased energy consumption by any of the elevators. Mean electricity consumption was 21.5 kw-hr/day by Evaristus, 18.7 kw-hr/day by Seton North, and 21.8 kw-hr/day by Seton South. Relative to consumption levels during Baseline 1, these averages represent reductions of 34%, 37%, and 33%, respectively.

DISCUSSION

The results of this experiment clearly indicate that making elevator use less convenient reduced elevator use whereas providing differential feedback on the amount of power consumed did not. The results further indicate that the addition to the feedback condition of several posters which prompted reduced elevator use also failed to produce a decline in the amount of power consumed. However, it should be emphasized that although the results of this study indicate that providing weekly group feedback was ineffective, it is possible that the provision of more frequent, individualized feedback *could* have resulted in improved performance. Weekly group feedback was chosen in the present study over more frequent, individualized feedback because of its lower cost and its relative ease of implementation.

Interestingly, making elevator use less convenient by lengthening the elevator door delay reduced the power consumption of each elevator by approximately one-third. The considerable savings produced by this approach, contrasted with the absence of any effect during the feedback and prompting conditions, suggests that researchers interested in reducing energy consumption should first consider whether there is an easy way of reducing the convenience of power consumption in order to reduce the amount of power consumed.

One difficulty with this experiment was its failure to include a measure of the number of persons using the elevator during each experimental condition. The absence of these data makes it difficult to assess the true extent to which the door delay influenced the behavior of riders. For example, the percentage of passengers influenced to use the stairs instead of the elevators may have been greater than the percentage of reduction in power consumption. This is possible because the elevators usually carried several passengers on each trip. Consequently, even if four of five individuals who normally used the elevator to make a trip from one floor to the next were to cease doing so, the elevator would still be forced to make that trip in order to carry the fifth passenger and would thus consume nearly the same amount of energy as before. Large power savings would be achieved only if all five chose not to use the elevator.

An alternative interpretation might suggest that the delayed door closure conserved electricity through mechanical rather than behavioral means. Increasing the door delay automatically decreased the amount of time that was available for the elevator to travel from floor to floor. Thus, the imposition of a long door delay may have made it physically impossible for the elevators to make as many trips as they had during baseline. This would have been especially likely during periods in which the demand for the elevators was particularly high (i.e. during the 10-min intervals between classes). Energy would have been saved automatically, although the number of persons riding the elevator per day need not have changed. In fact, the number of persons riding in the elevator car at any given time may have increased.

Experiment 2 was designed to provide a clearer demonstration that delayed door closure conserved energy through behavioral rather than mechanical means. This was done by measuring the number of persons riding the elevator during the door delay and the baseline conditions. Another purpose of the second experiment was to investigate further how the choice of different durations of door delay influence energy conservation.

EXPERIMENT 2

METHOD

Setting and Measures

The experiment was conducted on users of the Evaristus elevator described in Experiment 1. Energy consumed by this elevator was measured daily using the same watt-hour meter, and according to the same schedule as in Experiment 1. Experiments 1 and 2 were conducted during succeeding academic years.

Measures of the number of persons using the elevator were obtained by an observer seated in a public lounge on the main floor of Evaristus Hall. From this position, the observer was able to obtain a clear view of all persons entering or exiting the elevator. The lounge area was used by students as a study and waiting area. Consequently, the observers employed in the present study were instructed to remain inconspicuous by displaying nonpsychological texts, novels, or newspapers and to keep their observation sheets covered. At no time was the activity of an observer questioned by passersby.

Observational sessions were conducted four times daily at 8:40 a.m., 9:40 a.m., 11:40 a.m. and 12:40 p.m., Tuesday through Friday. Each session lasted 45 min and was timed to begin 15 min before the end of a class period. Thus each observation session included the 15 min before classes were dismissed, the 10 min during which students moved between classes, and the first 20 min of the succeeding classes. This procedure ensured that behavior would be sampled during periods in which demands on the elevator were high and during periods in which such demands were low. During these observation sessions observers scored (a) the number of times the elevator stopped at the main floor (number of trips) and (b) the number of persons entering or exiting the elevator each time it stopped at the main floor. At the end of each day, results from the four observational sessions were summed in order to give (a) total number of trips per day and (b) total number of persons entering or exiting the elevator per day. Omitted from the tabulations were instances in which the elevator arrived without discharging or taking on passengers and instances in which a passenger who had just entered the elevator left it before the car proceeded to another floor.

On at least one day each week, and at least once during each condition, a second observer was also present during the observation period and made an independent tabulation of the number of passengers entering or leaving the elevator at the first floor. Interobserver argreement on the number of passengers was calculated by dividing the number of agreements on arrival or departure by the number of agreements plus the number of disagreements. Interobserver agreement averaged 98% and ranged from 95% to 100%.

Procedure

The experiment used a reversal design.

Baseline (10-sec door delay). During this condition, the elevator operated under normal conditions. No signs were posted on the elevator doors and the interval between the opening and closing of the elevator doors remained at its standard duration of 10 sec.

Increased door delay. The effect of increasing the delay between door opening and door closure was studied using several different durations of delay. The different conditions tested were: 26-sec door delay; 21-sec door delay; 16-sec door delay; 34-sec door delay. The 26-sec door delay condition was identical to the 26-sec door delay condition of Experiment 1. As in Experiment 1, a sign reading "To conserve energy this elevator has been slowed" was attached to the elevator doors on each floor. During later conditions, shorter delays of 21 sec and 16 sec were used. However, these conditions were similar to the original 26-sec delay condition in all other respects. During these conditions, the signs announcing that the elevator had been slowed remained posted on the doors at each floor.

During a final delay condition, the interval between door opening and door closure was increased to 34 sec. In addition, the signs announcing that the elevator had been slowed were absent during this condition.

Normal door plus signs. During this condition, the interval between the opening and closure of the elevator doors was 10 sec. However, this condition differed from the standard baseline conditions in that signs reading "This elevator has been returned to its normal, *fast* speed" were posted on the elevator doors at each floor.

The order of presentation of the different experimental conditions was as follows: baseline 1; 26-sec door delay; 21-sec door delay; 16-sec door delay; baseline 2; 26-sec door delay; normal door plus signs; 34-sec door delay; baseline 3.

RESULTS

The results of Experiment 2 are illustrated in Figure 2.

Baseline 1

Energy consumption was stable, averaging 34.7 kw-hr/day during this condition. The number of persons entering or exiting the elevator, and the number of trips to the first floor also were stable during this condition.

Door Delay—26 sec

Energy consumption was reduced considerably during this condition, averaging 23 kw-hr/day. The number of persons exiting or entering the elevator, and the number of trips to the first floor were also reduced during this condition. There was no overlap between the results obtained during the 26-sec door delay condition and the results obtained during Baseline 1.

Door Delay—21 sec

Energy consumption remained low during this condition, averaging 22.6 kw-hr/day. There was a considerable amount of overlap between energy consumption during the 21-sec delay condition and the preceding 26-sec delay condition. The number of persons entering or exiting the elevator per day and the number of trips per day also remained within the levels established during the preceding delay condition.

Door Delay—16 sec

Energy consumption increased slightly during this condition, averaging 24.3 kw-hr/day. However, there remained a considerable amount of overlap with preceding delay conditions. The number of persons entering or exiting the elevator per day and the number of trips per day underwent similar small increases.

Baseline 2

Energy consumption increased during this condition, averaging 27.4 kw-hr/day. However, this increase was not sufficient to bring energy consumption within the level established during baseline 1. In fact, there was a slight amount of overlap between results obtained during baseline 2 and those obtained during the preceding delay conditions.

The number of persons entering or exiting the elevator per day and the number of trips per day showed similar changes.

Door Delay—26 sec

Results obtained during this condition were similar to those obtained during the preceding 26-sec delay condition.

Normal Door plus Signs

Results obtained during this condition were

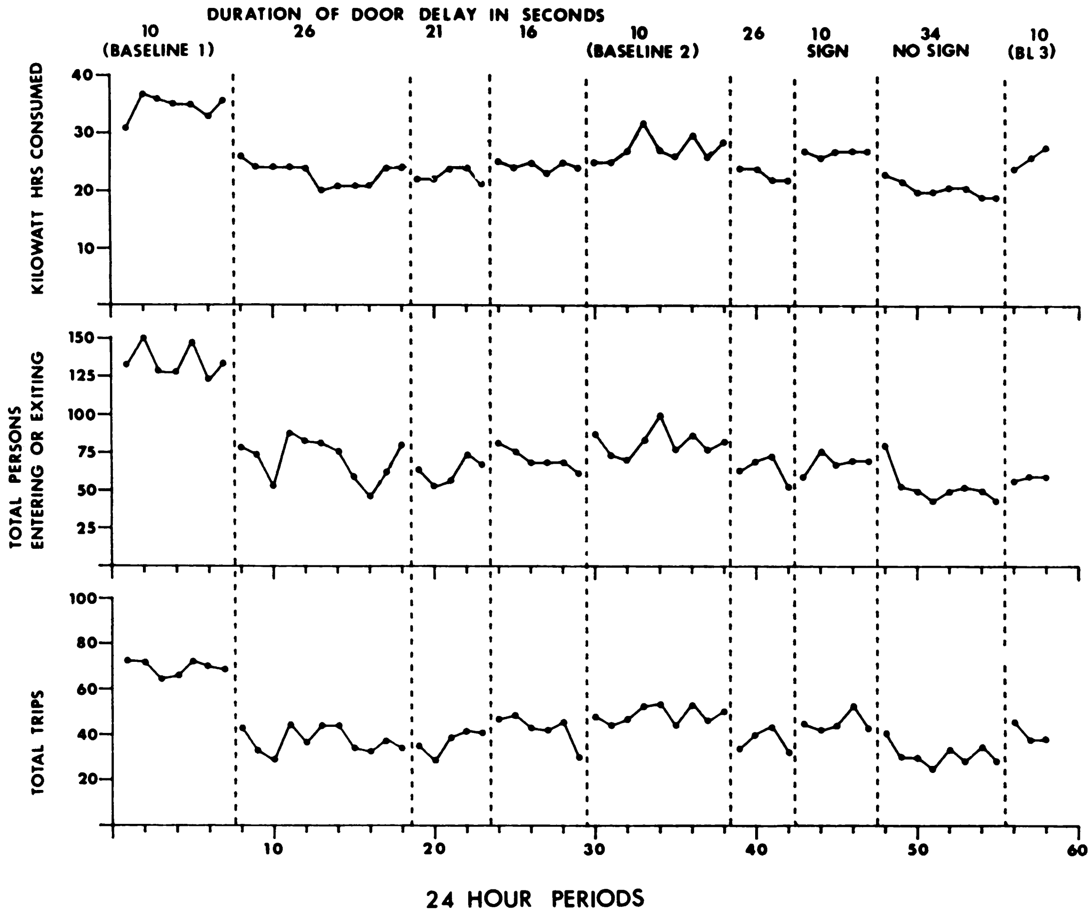

Fig. 2. Kilowatt-hours of electricity consumed, total number of persons entering or exiting the elevator at the first floor, and the total number of trips to the first floor during each 24-h period during each condition of Experiment 2.

similar to results obtained during the baseline 2 condition.

Door Delay—34 sec

Energy consumption during this condition was lower than during any preceding condition, averaging 20.6 kw-hr/day. Similar decreases were obtained in the number of persons entering or exiting the elevator per day and in the number of trips per day. However, in the cases of all three measures, there was some overlap with results obtained during the other delay conditions.

Baseline 3

Results obtained during this condition were similar to results obtained during the baseline 2 condition.

DISCUSSION

The results of Experiment 2 confirmed the results of Experiment 1 by showing that an increased delay between the opening and closing of the elevator doors resulted in significantly reduced energy consumption. The results of Experiment 2 also demonstrated that energy was saved as a result of a change in behavior and not merely through mechanical means. Observation of passengers entering and leaving the elevator on the main floor indicated that both the number of trips made by the elevator and the number of persons using the elevator decreased as a result of the increased door delay. A decreased number of trips per day might have been expected as a direct result of the increased amount of time that was required for door closure. However, the decreased number of passengers per day need not have resulted because students could have responded to the reduced availability of the elevator by crowding the elevator car with an increased number of passengers per trip. Such was not the case. Inspection of Figure 2 will show that the number of persons exiting or entering the elevator per trip remained constant throughout the experiment.

Experiment 2 also demonstrated that energy consumption remained low when the duration of the door delay was decreased gradually to its baseline value. This result is important for several reasons. First, the maintenance of reduced energy consumption throughout baseline 2 provides further confirmation that the energy savings occurred because of a change in the behavior of the elevator users. The energy savings seen here could not have been the direct result of the restricted availability of the elevator because, during baseline 2, the duration of the door delay was the same as during baseline 1.

Reduction in the duration of the door delay without a corresponding reduction in energy conservation also meant that persons who were unable to use the stairs, and thus forced to use the elevator, were not inconvenienced. During the 26-sec door delay condition, some members of the university staff who used the elevator to transport equipment and supplies complained that the elevator was too slow. However, when the delay was decreased to its normal duration, these complaints ceased. In fact, given the general decrease in elevator ridership that occurred in Experiment 2, it is likely that staff members found the elevator more convenient to use during baselines 2 and 3 than it had been during baseline 1.

It is unclear why energy savings persisted in the absence of an increased door delay. The presence of the warning signs could explain persistent energy savings during the 21-sec delay and the 16-sec delay conditions. However, these signs were absent during baseline 2 and thus could not have been responsible for the maintenance of the effect during that condition. One possibility is that many former elevator users found use of the stairs to be reinforcing in its own right. Alternatively, many former elevator users may have avoided elevator use to such an extent that they did not experience the return to baseline conditions. The 10-sec door delay plus signs condition, in which signs were posted announcing the return of the elevator to its normal speed, was an attempt to test this latter hypothesis. However, the negative results obtained during this condition make it impossible to draw any firm conclusions. The signs might have been more effective had they been posted on the stairs.

It is almost certain that the persistence of the effect in Experiment 2 depended in part on the fact that during baseline 1 is a substantial proportion of elevator users were using the elevator repeatedly. There is no other reasonable way to explain the persistence of the effect when the warning signs were removed during baseline 2. Indeed, increasing the duration of the door delay might not have been effective had it been used in an elevator that normally carried a high proportion of nonrepeating passengers. Such passengers would probably have found the elevator inconvenient to use, but, because they would never have the opportunity to use the elevator again, their behavior toward it could never change. The results of Experiment 1, in which information posters failed to reduce energy consumption, suggest that signs warning that the elevator had been slowed would not have deterred most passengers from using the elevator a first time. However, riding the delayed elevator may have changed a nonrepeating passenger's behavior toward other elevators. The Evaristus elevator was a suitable target in this case, because it served a freshman dormitory and undoubtedly carried a high percentage of repeat passengers each day. Moreover, the fact that most of Evaristus Hall's population was different each succeeding school year guaranteed that baseline levels of performance could be reestablished every 12 mo.

In order to begin to understand why the increase in door delay may have had such a marked effect on elevator use, it is necessary to consider first the contingencies that may operate to maintain elevator use. Individuals wishing to go from one floor to the next may be thought of as responding on a fixed trial concurrent schedule of reinforcement. They may make either one response (use the elevator), or an alternative response (use the stairs), in order to obtain the same potential reinforcer (movement to another floor).

One factor that has been shown to affect choice between alternative behaviors is response effort (Miller, 1968). Clearly, elevator use involves less effort, provided the elevator and stairs are situated in close proximity to each other. Still another factor that may influence choice behavior is the average amount of time required to make each response. It is reasonable to assume that if all other things are equal individuals should choose the response associated with the shortest delay of reinforcement. However, this analysis becomes even more complex when one considers that the delay associated with using the stairs can be decreased by increasing the amount of effort (i.e. walking faster or running up the stairs). Furthermore, as the distance that one must travel is increased, effort also increases for one behavior (stair use), but not for the other behavior (elevator use).

Increasing the duration of the elevator door delay was a highly cost-effective procedure, requiring only a single $40 service call and, once the delay was increased, it cost little or nothing to keep the treatment in effect. In Experiment 1, the increased delay saved the university approximately 32.9 kw-hr of electricity per day. Based on an average cost to the university of $.053/kw-hr, the amount saved by this technique was approximately $1.74/day. Thus, increasing the elevator door delay paid for itself in 23 school days. This is markedly superior to the cost effectiveness of posted feedback. This technique, had it produced a decrease in energy consumption, would have necessitated paying an assistant to read meters and post feedback (approximately 1 h per week) throughout the course of its use.

Just as elevator use can be made less convenient by increasing the duration of the door delay, it should also be possible to save energy by decreasing the convenience of other energy-consuming behaviors. One example of this approach is a study by Hirst (1976), who decreased downtown automobile use by reducing the number of parking spaces available to single drivers. A similar effect might also be obtained by limiting the use of important urban routes to mass transit systems during rush hours. In this case the use of private automobiles would be made less convenient while the use of public transportation would be made relatively more convenient. A similar approach may be used to solve many problems involving excessive energy use. One possible limitation of this approach involves the contingencies that apply to administrators and politicians responsible for making decisions of this kind. Although designating certain key roads for use by public transportation during rush hour may make bus travel relatively more convenient, it could also make the politicians who implemented such a change relatively less popular in the short run. Such considerations would clearly reduce the likelihood that such action would ever be taken.

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