JOURNAL OF APPLIED BEHAVIOR ANALYSIS 1977, 10, 665-671 NUMBER 4 (WINTER) 1977

AN EXPERIMENTAL ANALYSIS OF ELECTRICITY CONSERVATION PROCEDURES[1]

MICHAEL H. PALMER, MARGARET E. LLOYD, AND KENNETH E. LLOYD

DRAKE UNIVERSITY

Daily electricity consumption of four families was recorded for 106 days. A reversal design, consisting of various experimental conditions interspersed between repeated baseline conditions, was used. During experimental conditions, daily prompts (written conservation slogans attached to front doors) and/or daily feedback (daily kilowatts consumed and daily cost information) were in effect. Maximum consumption occurred during the initial baseline; minimum consumption occurred during different experimental conditions for different families. The mean decrease from the maximum to the minimum for all families was 35%. Reversals in consumption were demonstrated in three families, although successive baselines tended to decrease. No clear differences in effectiveness between prompting and feedback conditions were apparent. The procedures used resulted in considerable dollar savings for the families.

DESCRIPTORS: electricity conservation, reversal design, prompts, feedback, cost information, daily kilowatt hour consumption, suburban families

Environmental problems have been the subject of recent behavioral analyses, *e.g.*, littering (Burgess, Clark, and Hendee, 1971; Kohlenberg and Philips, 1973), destructive lawn walking (Note 1), and recycling (Geller, Farris, and Post, 1973). The energy shortage is an environmental problem that has recently become critical. Seaver and Patterson (1976) increased fuel-oil conservation by providing consumption feedback plus social commendation for lowered consumption levels. Behavioral procedures have also been used to delay the use of some electrical appliances until nonpeak times of the day (Kohlenberg, Phillips, and Proctor, 1976). With decreased peaking, more electrical demands can be met without increasing plant capacity.

The electrical energy shortage is, however, a result both of the limited capacity of electrical plants to meet daily peaks in consumption and the limited supply of primary energy sources from which electricity is manufactured. To conserve primary energy sources, an overall electrical reduction is desirable. The present study is an experimental analysis of procedures designed to reduce the total daily electricity consumption of residential consumers.

METHOD

Subjects

Four families living in a suburb of Des Moines, Iowa were selected from 253 families who were identified by the utility company's files as having outside gas, water, and electric meters. Every tenth file card was pulled to select potential subject families. Thirteen of these families were excluded because they used electric heat, or because they did not have school-age children. The remaining 12 families were notified by letter that they might be invited to participate in an energy conservation program. The first four families to be invited

[1]This study was based on a thesis submitted by the first author to the Department of Psychology, Drake University, in partial fulfillment of the requirements for the MA degree. Special thanks are due Ron Hanson for his assistance with this research. The authors would also like to thank Gene A. Lucas for his comments on the manuscript and Maurice Van Nostrand of the Iowa Commerce Commission for his assistance. Reprints may be obtained from Michael H. Palmer, Department of Psychology, Drake University, Des Moines, Iowa 50311.

agreed to participate. Three families included two adults and two elementary or secondary school children (Family 2 had four children). Families 1 and 3 had one and two children, respectively, who returned home from college at various times during the experiment.

Pre-experimental Instructions

Families were told that their outside gas, water, and electric meters would be read by experimenters daily, and that messages would occasionally be taped to the inside of their storm doors. An adult in each family was asked to make sure that family members read and initialled the messages on the day they were received. They were requested to save the messages in a 7.5 by 12.5 cm index card file that was provided. They were asked to note on these cards any conservation behavior they attempted. The index cards were collected at the end of the experiment.

Procedure

Data were collected from February 2, 1974, through May 19, 1974, for a total of 106 days. Meters were read at each home between 10:00 and 10:30 each night. Electric meters were read to the nearest half-kilowatt hour. The units dial of the meter was read as a whole number only when the hand of the dial covered any part of a number. When the white background of the meter could be perceived between the hand of the units dial and the last number that the hand passed, a half-kilowatt hour was recorded. The difference between each night's reading and the preceding night's reading defined the electricity consumption for that day.

Reliability

Once each week, a second observer read the electric meters independently of and concurrently with the first observer. In all cases agreement was 100%.

A second index of reliability was provided by the power company's monthly meter readings. During this research, the power company read the meters four times. In all cases, power company readings were greater than experimental readings of the previous night and less than experimental readings of the subsequent night.

Baselines

During baseline conditions, electricity consumption was measured daily for each family.

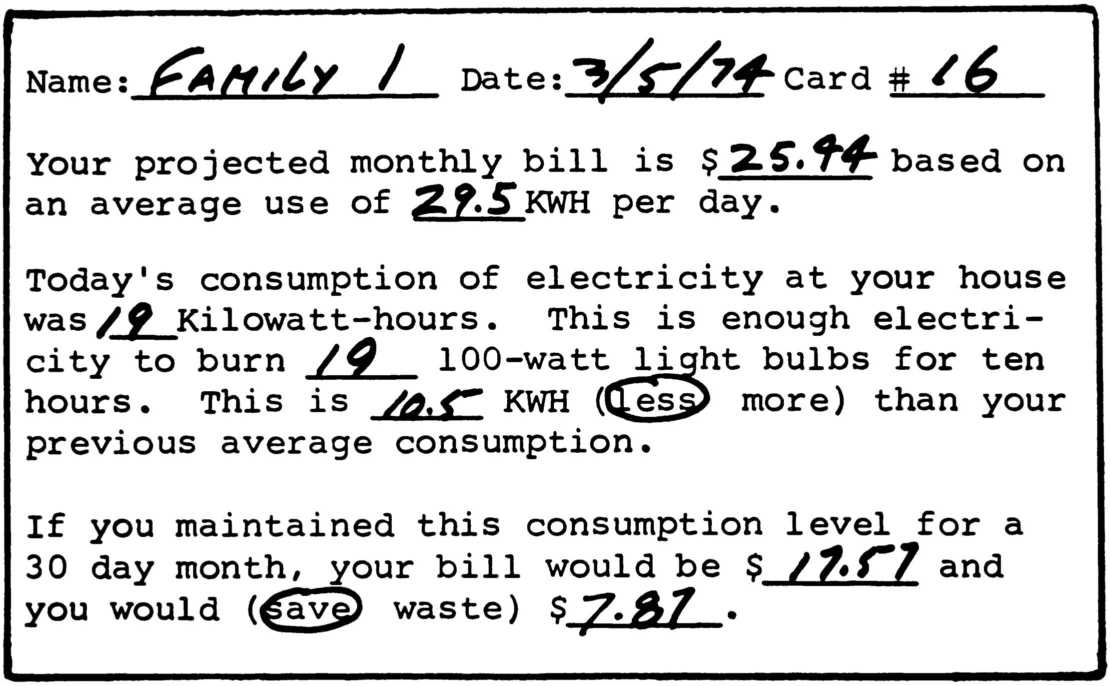
Experimental Conditions

Conditions were changed when consumption was relatively stable or when the trend of the last 10 days of one condition was opposite the change expected in the next condition.

Feedback condition. Each night, a card showing the consumption of electricity for that day, compared to the mean daily consumption for the previous baseline period, was taped to the inside of the front storm door of the family's home. The difference in kilowatt hours was also indicated.

Cost-information condition. In addition to the information provided in the feedback condition, the expected monthly bill projected from the mean baseline consumption (calculated by multiplying the mean baseline consumption by 30 and determining the monthly cost from the power company's rate table) was compared with the expected monthly bill projected from that day's consumption (calculated by multiplying that day's consumption by 30 and determining cost as above). The difference between the two projections was identified as the amount of money that would be saved or wasted if that day's consumption were maintained for 30 days. A sample card is shown in Figure 1.

Daily prompt condition. Each night, one of a series of eight typewritten prompts (*e.g.*, Kill-a-Watt, Conserve Electricity!) was taped to the inside of the storm doors of each family following the nightly meter reading. Families were instructed to save the cards until the end of the experiment. The cards were always removed when the experimenter returned the next night.



Name: FAMILY 1 Date: 3/5/74 Card # 16

Your projected monthly bill is $25.94 based on an average use of 29.5 KWH per day.

Today's consumption of electricity at your house was 19 Kilowatt-hours. This is enough electricity to burn 19 100-watt light bulbs for ten hours. This is 10.5 KWH (less more) than your previous average consumption.

If you maintained this consumption level for a 30 day month, your bill would be $ 17.57 and you would (save waste) $ 7.87 .

Fig. 1. Sample cost-information card.

Prompt plus Feedback condition. Each night, a feedback card with one of the prompts from the prompt series typed on the back was taped to the inside of the storm doors.

Government prompt condition. A personal letter was mailed to the families from the Director of the Iowa Office of Energy. The letter discussed the instability of electricity supplies and included a request for a 20% reduction of electricity consumption. Although the letter was sent only once, this condition was assumed to be in effect from the day that the letter was received until the onset of the next condition. All families receiving this letter indicated that they had read (or had some recollection of) the letter, in a postexperimental interview.

RESULTS

Figures 2 and 3 show each family's daily electricity consumption during each condition and the median consumption for the last 10 days of each condition. Medians were calculated for the entire condition when conditions lasted less than 10 days. Figure abscissas were plotted in seven-day units indicating Sundays of consecutive weeks.

Family 1: During the last 10 days of the initial baseline condition, median consumption was 29 KWH per day. After cost information was introduced, consumption was reduced to 23 KWH per day. Although consumption did not return to its original level during the second baseline condition, when cost information was reintroduced, the median decreased further to 14 KWH and the daily consumption pattern became less variable than in any of the preceding conditions. When cost information was no longer available, consumption increased to 18 KWH per day and variability increased.

Family 2: the daily consumption pattern of Family 2 was extremely variable throughout all conditions. Family 2 consumed approximately 33 KWH per day during the initial baseline condition. Consumption decreased to 29 KWH per day when the cost-information condition was introduced and returned to its original level when cost information was sub-

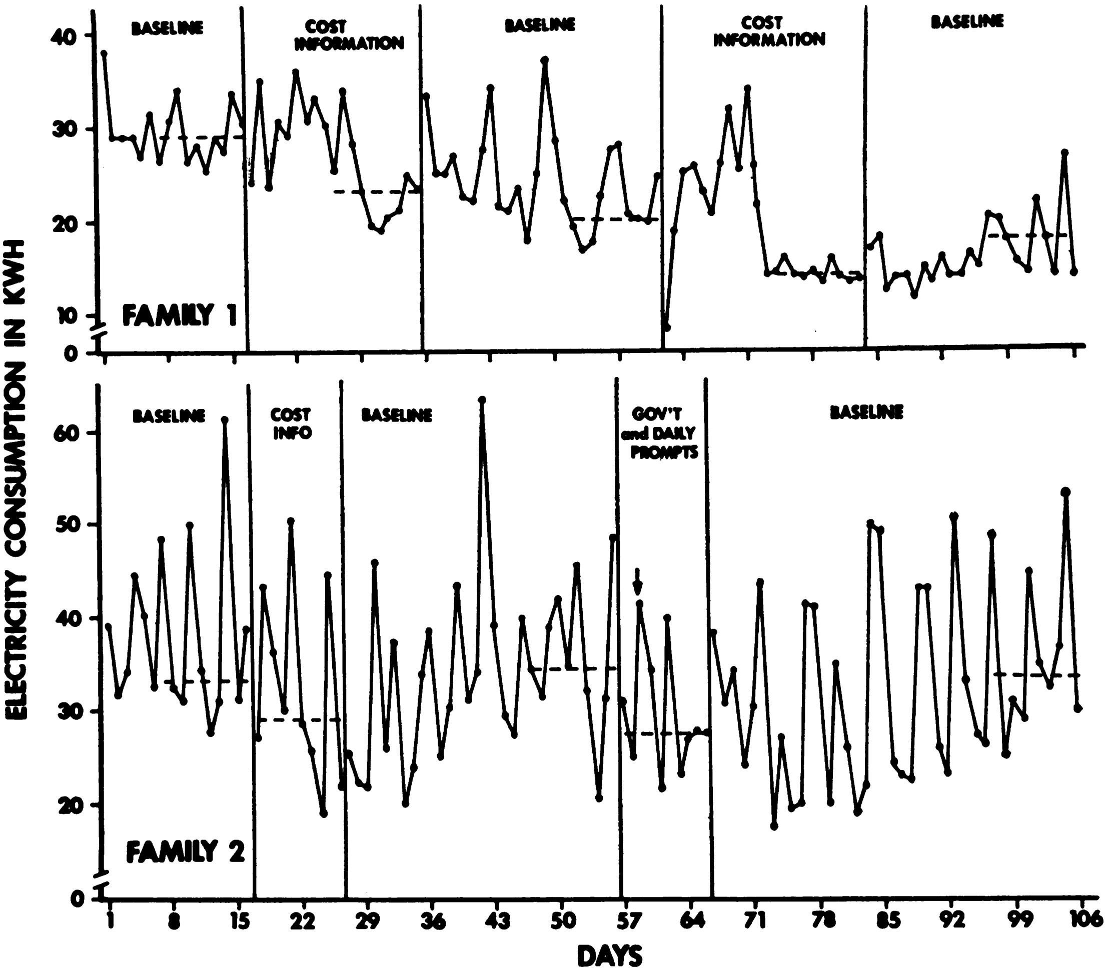


Fig. 2. Daily electricity consumption for Families 1 and 2 for all days of baseline and experimental conditions. Dotted lines indicate median consumption for the last 10 days of each condition. Numbered days are Sundays. For Family 2, the arrow indicates the first daily prompt.

sequently withdrawn. When government and daily prompts were introduced, consumption decreased again to 27 KWH. Consumption increased to 34 KWH per day when prompts were discontinued. Day-to-day variability did not decrease as it had with Family 1.

Family 3: Family 3 consumed approximately 22 KWH of electricity per day during baseline. After the government prompt, consumption decreased to 18 KWH and remained at approximately that level when daily prompts were added. Consumption decreased further to 14 KWH per day with prompts and feedback; increased to 19 KWH per day when these were no longer available; and decreased again to 14 KWH per day when prompts and feedback were reintroduced.

Family 4: during the last 10 days of baseline, Family 4 consumed approximately 29 KWH of electricity per day. Consumption decreased after the government prompt, during the daily prompts, and the second baseline condition. Consumption did not change appreciably when feedback was introduced.

Table 1 presents the electricity consumption as recorded by the power company for each of the families for a three-month period during the same season of the pre-experimental, ex-

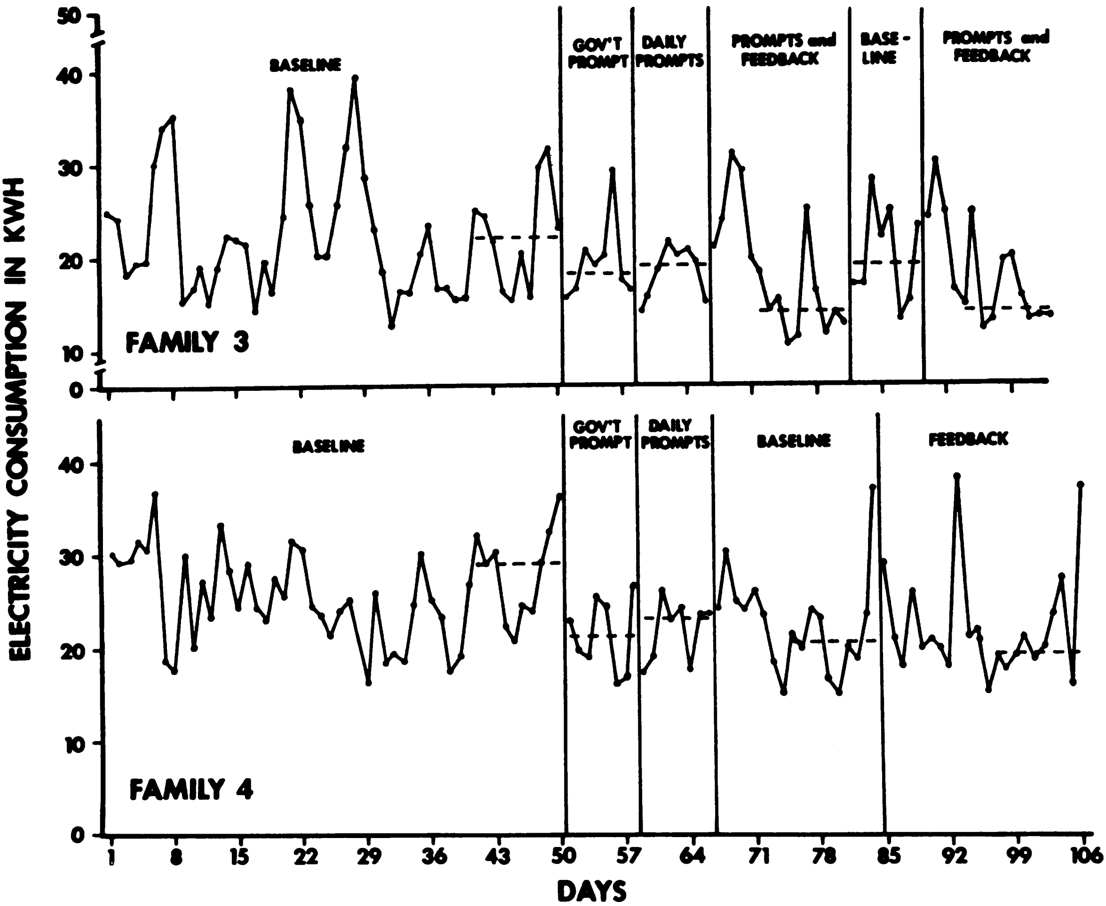


Fig. 3. Daily electricity consumption for Families 3 and 4 for all days of baseline and experimental conditions. Dotted lines indicate median consumption for the last 10 days of each condition or for the entire condition if the condition lasted less than 10 days. Numbered days are Sundays.

Table 1

Electricity consumption and temperature data of pre-experimental, experimental, and postexperimental years.

Family	*Year*	*Dates*	*Days*	*Mean Temperature*	*Total KWH Consumption*	*$\overline{X}$ Daily KWH Consumption*	*% Pre-experimental Year*
1	pre-experimental	2/10-5/11	91	44.6	2738	30.0	100%
	experimental	2/11-5/13	92	44.7	2016	21.9	73%
	postexperimental	2/11-5/10	89	37.9	1804	20.3	68%
2	pre-experimental	2/10-5/11	91	44.6	3264	35.9	100%
	experimental	2/11-5/10	89	44.3	2859	32.1	89%
	postexperimental	2/11-5/10	89	37.9	3312	37.2	104%
3	pre-experimental	2/10-5/11	91	44.6	2050	22.5	100%
	experimental	2/11-5/10	89	44.3	1794	20.2	90%
	postexperimental	2/11-5/10	89	37.9	2040	22.9	102%
4	pre-experimental	2/10-5/11	91	44.6	2490	27.4	100%
	experimental	2/11-5/10	89	44.3	2052	23.0	84%

perimental, and postexperimental years. The dates of the first and last monthly meter readings and the corresponding number of days are indicated, as well as mean temperatures for the three-month periods based on the mean of the highest and lowest temperature for each day.[2] Total consumption, mean daily consumption, and per cent of pre-experimental year consumption are also presented for experimental families for each year.

In all cases, consumption of the experimental year was lower than during the pre-experimental year. Families 2 and 3 returned to above pre-experimental year levels during the post-experimental year. Family 1 did not recover initial year consumption. No postexperimental data were available for Family 4 because they moved from the area.

DISCUSSION

This study demonstrated that both prompting and feedback techniques were effective in reducing daily electricity consumption in three of four suburban families. Since data were collected from February through May, some of the decrease in consumption was related to both increases in duration of daylight and in outside temperature. Heating degree-day medians decreased from 44.5 degrees during the first 10 days of data recording to seven degrees during the last 10 days; the median hours of sunlight increased from 10.4 to 14.7 during the same time period. In all cases in which reversals in consumption occurred, reversals were directionally opposite to the changes in daylight and temperature. The seasonal changes cannot account for the reversals in the consumption data. Further, as Table 1 indicated, the consumption of all families was reduced during the experimental year and recovered during the post-experimental year in two of three cases, while temperature data were similar for all years. Changes in daylight hours were constant for all years, since data were presented for about the same dates each year. Seasonal changes cannot account for the overall electrical reduction that occurred during the experimental year.

The patterns of electricity consumption varied greatly among families. The range of day-to-day variability in Family 4 was about 23 KWH (38 KWH to 15 KWH); the range for Family 2 was 46 KWH (63 KWH to 17 KWH). High-consumption days for Family 2 were frequently on weekends and on Wednesdays. Family 2 attributed this to clothes washing (Family 2 was the only family that used an electric hot-water heater). High-consumption periods for Families 1 and 3 occurred when their children were home during college vacation periods. Vacation periods occurred on Days 19 through 29 and on Days 68 through 72 for both families. During these two vacation periods, Family 1 was on cost information; Family 3 was on baseline and prompts plus feedback.

Relatively long periods of time were required to demonstrate experimental effects. One possible reason for this is that experimental conditions were applied to behavioral outcomes (daily electricity consumption), rather than to specific behaviors that could have decreased consumption. The families were not given any instructions on ways of conserving electricity. Reductions in electricity consumption may have occurred more quickly if behaviors, rather than outcomes, had been consequated.

Previously, wives have been reported to be largely responsible for changes in appliance use resulting in reductions of electrical peaking (Kohlenberg *et al.*, 1976). In the followup interview, Families 1, 2, and 3 in the present study also reported that the wives' behavior was important. They reported that they tried to turn off light bulbs more often. Family 1 switched their furnace blower off continuous use to partial use; they also used an electric fry pan more often than they used their electric range. Family 2 said they had used their elec-

[2]Local climatological data were obtained from the National Weather Service Forecast Office, Municipal Airport, Des Moines, Iowa.

tric rotisserie on days of high consumption. Family 4, which reported that no one took an interest in the study, was the only family that was inconsistent in initialling the card messages.

Since electricity consumption decreases when families have daily knowledge of consumption and cost, a simpler means of providing this knowledge might be devised. Decorative electric meters indicating both consumption and cost (as gasoline pumps do) could be installed in conspicuous locations in kitchens or living rooms.

A considerable saving in both electrical power and money was obtained by the families. For example, the projected monthly bill for Family 1 during the last 10 days of the second cost information feedback condition was $13.18, compared with the second baseline projection of $21.89, a saving of $8.71 and 315 KWH. If all of the 77,303 residential consumers in the Des Moines metropolitan area saved this amount, the resulting saving would be $673,309.13 and 24,350,445 KWH per month.

The local power company seems to encourage high rates of electrical power consumption because the rate charged per KWH decreases with increased usage. Large reductions in electricity consumption therefore result in a proportionately smaller money savings. If conservation of electrical power is desired, it would be more efficient to reverse these billing procedures, *i.e.,* to charge increasingly more for greater consumption levels.

A typical approach to the energy problem taken by the government consists of requesting consumer conservation of energy, *i.e.,* providing stimulus control. The results of the present research, as well as those of Seaver and Patterson (1976) and Kohlenberg *et al.* (1976) have indicated that consequence control (largely overlooked by government programs) also has utility for changing consumer behavior in a direction favorable for energy conservation.

The conditions in this study were effective during relatively brief experimental periods. Long-term effectiveness cannot be determined from these data. Additional research is needed to assess the relative effectiveness of prompts and feedback, to identify family variables that may affect outcome, and to evaluate the practicality of behavioral procedures for large-scale energy conservation programs.

REFERENCE NOTE

1. Hayes, S. C. and Cone, J. D. *Decelerating environmentally destructive lawn-walking behavior.* Paper presented at the meeting of the American Psychological Association, New Orleans, Louisiana, September 1974.

REFERENCES

Burgess, R. L., Clark, R. N., and Hendee, J. C. An experimental analysis of anti-litter procedures. *Journal of Applied Behavior Analysis,* 1971, **4,** 71-75.

Geller, E. S., Farris, J. C., and Post, D. S. Prompting a consumer behavior for pollution control. *Journal of Applied Behavior Analysis,* 1973, **6,** 367-376.

Kohlenberg, R. and Phillips, T. Reinforcement and rate of litter depositing. *Journal of Applied Behavior Analysis,* 1973, **6,** 391-396.

Kohlenberg, R., Phillips, T., and Proctor, W. A behavioral analysis of peaking in residential electrical-energy consumers. *Journal of Applied Behavior Analysis,* 1976, **9,** 13-18.

Seaver, W. B. and Patterson, A. H. Decreasing fuel oil consumption through feedback and social commendation. *Journal of Applied Behavior Analysis,* 1976, **9,** 147-152.

Received 1 May 1975.
(*Final acceptance 24 January 1977.*)