Howarth. The Exposure of Young Children to Accident Risk as Pedestrians. Ergonomics, Vol. 17, No. 4, 1974, pp. 457-480.
12. H. Marks. Child Pedestrian Safety: A Realistic Approach. Traffic Engineering, Vol. 25, 1957, pp. 13-19.
13. S. Sandels. Young Children's Ability to Understand Traffic Education. International Federation of Pedestrians, Bulletin 8, 1969.
14. S. Sandels. Young Children in Traffic. British Journal of Educational Psychology, Vol. 40, 1970, pp. 111-116.
15. E. M. Backett and A. M. Johnston. Social Patterns of Road Accidents to Children: Some Characteristics of Vulnerable Families. British Medical Journal, Feb. 14, 1959, pp. 409-413.
16. J. H. Read and others. The Epidemiology and Prevention of Traffic Accidents Involving Child Pedestrians. Canadian Medical Association Journal, Vol. 89, Oct. 5, 1963, pp. 687-701.
17. W. J. Conover. Practical Nonparametric Statistics. Wiley, New York, 1971.

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Abridgment

Pedestrian Signal Displays: An Evaluation of Word Message and Operation

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In 1974, a study was initiated by the Federal Highway Administration to define the problems associated with pedestrians crossing at urban intersections and to evaluate remedial measures aimed at reducing or eliminating these problems. The results of the problem identification phase of the study (1, 2) indicated that pedestrian signal displays were the source of several problems and that certain improvements in the displays could result in a higher level of compliance, safer pedestrian behavior, and better user understanding.

Two problem areas are addressed in the research described here. One problem involved the display of the pedestrian clearance interval. Pedestrians complained that there was not enough WALK (W) time to complete their crossing. They did not understand that a clearance interval was provided for them to complete their crossing before traffic was released. Additionally, some 15 percent of pedestrians hit by vehicles at signalized intersections were crossing against the signal. At 71 percent of 38 site pairs (intersections) that were matched by high and low occurrence of pedestrian accidents in Washington, D.C., the percentage of pedestrians who started crossing during the clearance display was greater than that at the high-accident location. Finally, 40 percent of the pedestrians observed crossing against the pedestrian signal started on the clearance indication, which is the flashing DONT WALK (FDW).

The second problem area centered on the effectiveness of flashing the W indication to warn pedestrians that vehicles might be turning through their crosswalk. A study by D'Angelo in 1973 (3) showed that pedestrians did not understand the intended meaning of flashing WALK (FW) and that an educational campaign produced no change in pedestrian crossing behavior. Observations in the earlier phase of this project confirmed that there was no significant difference in compliance between locations with FW and locations with steady W. The accident data indicated that turning vehicles represented a serious safety hazard to pedestrians. Approximately 25 percent of pedestrian accidents at intersections involved turning vehicles.

STUDY METHODOLOGY

Three experimental conditions were devised to address these two problem areas. In all cases, the experimental condition was compared to the current recommended Manual on Uniform Traffic Control Devices (MUTCD) standard. Experiment 1 compared a steady DONT WALK (DW) clearance indication to the standard FDW clearance indication. The hypothesis was that, if pedestrians were not shown a distinct clearance-interval indication, compliance would increase, undesirable behaviors would decrease, and the need to understand the clearance interval would be eliminated, i.e., W means it is safe to cross, and DW means it is not safe to cross. However, this hypothesis contained a possible flaw. Would the pedestrian understand what to do if he started on the W and the signal changed to DW while he was still in the street?

Experiment 2 was designed to address this question and consisted of a DONT START (DS) message in place of the DW message. The operation was the same as the experimental condition in experiment 1, i.e., a steady DS indication during the clearance and prohibited intervals. The hypothesis was that, when the DS message was displayed, pedestrians already in the street would continue their crossing while those still on the curb would not start their crossing.

Experiment 3 dealt with the second problem area and compared steady W to FW. The objective was to determine whether pedestrians understood the intended meaning of FW and steady W and whether pedestrians behaved differently with the two displays. Figure 1 shows the experimental design.

All three experiments were conducted simultaneously in Buffalo, New York, and Phoenix, Arizona. A before and after study design was employed. Each experiment was conducted at two different test intersections (one central urban and one suburban) in each of the two cities, i.e., 4 intersections/experiment. A 2-month acclimation period was allowed after installation of the experimental condition. One exception was that experiment 3 in Buffalo was reversed in the before and after sequence because the normal operation in Buffalo was a steady W. All of the test sites operated on two-phase, fixed-time control, and turning movements were permitted at all sites.

The three types of variables measured were observed pedestrian behavior, pedestrian compliance, and user understanding. In phase 1 of the project, a set of hazard-related pedestrian behaviors was developed. These behaviors occurred more frequently at high-accident intersections than at similar low-accident intersections and included the following:

1. Backup movement (B)—Pedestrian momentarily reverses his or her direction of travel in the traffic lane or the pedestrian hesitates in response to a vehicle in a traffic lane;
2. Moving vehicle (MV)—Through traffic is moving through the crosswalk while a pedestrian is in a traffic lane;
3. Turning vehicle (TV)—Pedestrian is in the path and within 6.1 m (20 ft) of a turning vehicle;
4. Vehicle hazard (VH)—Pedestrian enters a traffic lane when a through vehicle that is unrestricted by a traffic control device is approaching in that lane within one block of the pedestrian;
5. Running vehicle hazard conflict (RVH)—Pedestrian runs in a traffic lane in response to a VH; and
6. Running turning vehicle conflict (RTV)—Pedestrian runs in a traffic lane in response to a TV or TV potential.

The second type of variable measured was the pedestrian compliance observed at the signal display. In addition to recording the number of pedestrians starting on the clearance interval, starting on the prohibited interval, and anticipating the signal, the distribution of these occurrences was also recorded.

The third type of variable measured was the user's understanding of the signal display. A survey was made of pedestrians who used the crossings when the above described observations were taken. Three days were spent at each site pair for each experimental condition during the before and after study in each of the two cities.

The evaluation of each experimental signal display, when compared to the base condition, was based on the following criteria:

1. A significant change in the occurrence of one or more of the observed pedestrian behaviors;
2. A significant difference in the types of pedestrian violations and the distributions of those violations over time; and
3. Responses from the user survey with respect to the meaning of the indications and perceived actions required by the indications.

DATA ANALYSIS

The analysis of data was designed to reflect the three evaluation areas of understanding, compliance, and behavior. Within each of these areas, a statistical comparison that contrasted the experimental and standard signal was performed. These analyses were based on standard psychometric procedures, and all statistical tests were evaluated at the 0.01 level (two-tail). The analysis of data on signal understanding consisted of a series of Z-tests that were used to compare the percentage of pedestrians who correctly identified the meaning of the various signal displays under investigation.

The analysis of the compliance data consisted of two sequential steps. First, an overall test of the compliance distributions that were obtained under different signal conditions was performed by using χ^2 with a 2 $\times$ n design, where n = the number of intervals timed. Second, the results of this test determined if there was a significant difference between the distribution of crossings under different signal conditions. In the event that such a difference was detected, a series of Z-tests was conducted to isolate the particular time interval in the cycle that showed a significant shift. The behavioral data were analyzed by comparing the proportion of pedestrians involved in each of the target behaviors. The proportions of each behavior occurring under the different signal displays were tested by using the Z-test.

Experiment 1: FDW Versus Steady DW

The results of experiment 1 are given in Table 1. Almost no behavioral differences were found. In Phoenix, the three behaviors showing a slight significant difference occurred in less than 2 percent of the 3000 observed crossings.

The compliance data were summarized in two ways. First, the proportion of pedestrians leaving the curb during the W indication (in compliance with the signal) was noted. Highly significant differences were found at one intersection in each of the two cities. In Buffalo the before case (FDW) was favored (compliance was 10.5 percent higher), while in Phoenix the after case (DW) was favored (compliance was 8 percent higher). No significant differences were found at the other intersections for each city. Combining the two sites in each city resulted in the same trend but a lower level of significance. Thus, the improvement shown by steady DW in Phoenix appears to be offset by the findings in Buffalo. In general, compliance ranged from 8 to 32 and from 65 to 89 percent in Buffalo and Phoenix respectively.

Second, the compliance data were summarized and tested by comparing the proportion of pedestrians leaving the curb during the clearance interval. The hypothesis was that fewer pedestrians would leave the curb during the DW clearance then during the FDW clearance. At one site in Buffalo, the hypothesis proved correct at the 0.05 level of significance (a reduction of 9.1 percent). At the remaining sites, there were no significant differences. In general, pedestrians leaving the curb during the clearance interval ranged from 10.0 to 20.4 and from 3.7 to 20.7 percent in Buffalo and Phoenix respectively.

Some 400 pedestrians were surveyed to obtain user-understanding data (50 pedestrians/site/before and after condition). The questions asked pertaining to the clearance interval are given in Table 1. No significant differences were found in the responses to question 1 for either city. Of the responses to question 1, an average of 91 percent were correct across both cities. In other words, most pedestrians understood that they should not leave the curb on either FDW or DW. The answers to question 2 (what would the pedestrian do if after he or she left the curb the clearance indication changed to FDW or DW) produced mixed results. In Buffalo, the combined correct responses (i.e., to continue across) for both sites were significant at the 0.05 level in favor of the FDW clearance indication (59.1 percent before compared to 42.6 percent after). In Phoenix, the correct responses at one site and at both sites combined were significant at the 0.05 level in favor of the steady DW clearance indication. At the one site, correct responses ranged from 74 to 90 percent for the before and after cases respectively. With both sites combined, the correct responses went from 79 to 91 percent for the before and after cases respectively.

The differences between cities were considerable. In Phoenix, pedestrians exhibited both a higher compliance

Figure 1. Displays for experiments 1, 2, and 3.

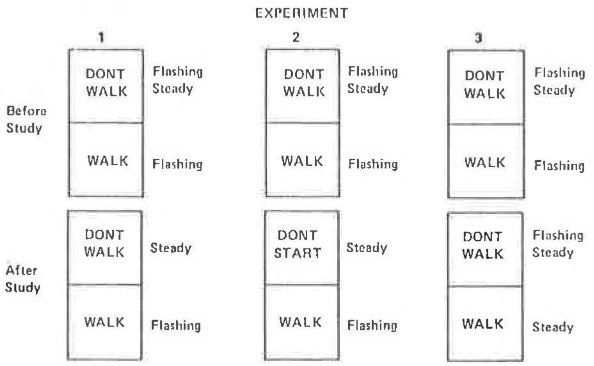

Table 1. Summary of results for experiment 1: steady DW (after) versus FDW (before).

Item	Buffalo			Phoenix		
	Site 1	Site 2	Sites 1 and 2	Site 5	Site 6	Sites 5 and 6
Behavior						
B	nc	nc	nc	A*	nc	nc
RTV	nc	nc	nc	nc	nc	B*
MV	nc	nc	nc	nc	nc	nc
TV	nc	nc	nc	nc	nc	nc
RVH	nc	nc	nc	nc	nc	nc
VH	nc	nc	nc	nc	A*	nc
Compliance						
Leaving curb on walk	B**	nc	B*	A**	nc	A*
Leaving curb on clearance	nc	A*	nc	nc	nc	nc
Understanding						
Question 1[a]	nc	nc	nc	nc	nc	nc
Question 2[b]	nc	nc	B*	nc	A*	A*

Note: A = significant difference in favor of after (experimental) condition; B = significant difference in favor of before (MUTCD standard) condition; nc = no significant difference between before and after conditions; * = significant at the 0.05 level; and ** = significant at the 0.01 level.

[a] If you are at the curb, what should you do if you see the FDW or DW indication?
[b] If you had just started to cross the street and you saw the FDW or DW indication, what should you do?

Table 2. Summary of results for experiment 2: steady DS (after) versus FDW (before).

Item	Buffalo			Phoenix		
	Site 3	Site 4	Sites 3 and 4	Site 1	Site 2	Sites 1 and 2
Behavior						
B	nc	nc	nc	nc	nc	nc
RTV	nc	nc	nc	nc	nc	nc
MV	nc	nc	nc	nc	nc	nc
TV	nc	nc	nc	nc	A**	A*
RVH	nc	nc	nc	nc	nc	nc
VH	nc	nc	nc	nc	nc	nc
Compliance						
Leaving curb on walk	nc	nc	nc	nc	A*	nc
Leaving curb on clearance	nc	nc	nc	nc	nc	nc
Understanding						
Question 1[a]	nc	A**	nc	nc	nc	A*
Question 2[b]	nc	nc	nc	nc	nc	nc

Note: A = significant difference in favor of after (experimental) condition; B = significant difference in favor of before (MUTCD standard) condition; nc = no significant difference between before and after conditions; * = significant at the 0.05 level; and ** = significant at the 0.01 level.

[a] If you are at the curb, what should you do if you see the FDW or DS indication?
[b] If you had just started to cross the street and you saw the FDW or DS indication, what should you do?

with and a better understanding of pedestrian signal indications. In Buffalo, the number of significant differences was fewer than in Phoenix. Pedestrians did not react differently to the change in clearance indications. The responses to a question about when it would be safe to leave the curb (the correct answer is on the W indication) implied that some 21 percent of the respondents either do not understand pedestrian signals or do not bother to use them as an aid in crossing the street.

Experiment 2: FDW Versus Steady DS

The results of experiment 2 are given in Table 2. No significant differences in behaviors occurred in either city except at one site in Phoenix. At that site, TV conflicts were reduced from 23.5 to 14.5 percent, which favored the DS display. This difference was significant at the 0.01 level and contributed largely to the difference for the combined data from both Phoenix sites to be significant at the 0.05 level. TV conflicts were approximately 8 percent higher in Phoenix than in Buffalo, even though the proportion of TVs in Phoenix was about 2 percent lower than that in Buffalo.

Only one significant difference was found in the compliance data. At one site in Phoenix, the compliance increased from 80.9 to 87.8 percent (significant at the 0.05 level), thus favoring the DS message. This difference was not sufficient to cause the combined data from both sites to be significantly different. No significant difference was found in the proportion of pedestrians (approximately 11 and 8 percent in Phoenix and Buffalo respectively) leaving the curb during the clearance interval. In general, compliance ranged from 39 to 49 and from 81 to 88 percent in Buffalo and in Phoenix respectively. Thus compliance was greater at the experiment 2 sites than at the experiment 1 sites in both cities.

The survey questions in experiment 2 were the same as those asked in experiment 1, and again 400 pedestrians were surveyed. A highly significant (at the 0.01 level) increase in correct responses to question 1 (82 to 98 percent) was found at one site in Buffalo, thus favoring the after case. In Phoenix, the difference was not significant at either site, but was significant at the 0.05 level for the two sites combined, which also favored the

Table 3. Summary of results for experiment 3: steady W (after) versus FW (before).

Item	Buffalo			Phoenix		
	Site 5	Site 6	Sites 5 and 6	Site 3	Site 4	Sites 3 and 4
Behavior						
B	B**	B**	B**	nc	nc	nc
RTV	B*	nc	B**	nc	nc	nc
MV	nc	nc	nc	nc	nc	nc
TV	nc	B*	B**	nc	nc	nc
RVH	nc	nc	nc	nc	nc	nc
VH	nc	B**	B**	nc	nc	nc
Compliance						
Leaving curb on walk	B**	nc	B**	A**	nc	A**
Leaving curb on clearance	nc	nc	nc	A*	nc	A*
Understanding						
Question 3[a]	nc	nc	nc	nc	nc	nc
Turn expectancy, percent[b]	49.5	41.4	45.5	35.0	44.0	39.5

Note: A = significant difference in favor of after (experimental) condition; B = significant difference in favor of before (MUTCD standard) condition; nc = no significant difference between before and after conditions; * = significant at the 0.05 level; and ** = significant at the 0.01 level.

[a] At some intersections, the W signal flashes, at some, it does not. What does the flashing (nonflashing) W signal mean at this intersection?
[b] The percentage of pedestrians that would expect vehicles to be turning into their crosswalk if they started their crossing on the W indication.

after case (an increase in correct responses from 84 to 91 percent). No significant differences were found in the responses to question 2 in either city; thus the hypothesis that DS would be better understood as a clearance display was not sustained. As in experiment 1, the differences between cities were great at the experiment 2 sites. Compliance in Phoenix was nearly twice as high as that in Buffalo. The pedestrian understanding of signal indications also remained higher in Phoenix than in Buffalo.

Experiment 3: FW Versus Steady W

The results of experiment 3 are given in Table 3. As given in that table, a number of differences were found in the Buffalo behavioral data, whereas no significant differences were found in the Phoenix behavioral data. All of the differences in the Buffalo data favored the before (FW) case. The most significant results were that hesitations, vehicle hazards, and turning vehicle conflicts were reduced by 13, 6, and 4 percent respectively.

Significant differences were also apparent in the compliance data. As in experiment 1, the differences in pedestrians leaving the curb on the W indication were offsetting. In Buffalo, the before case was favored (compliance decreased 19 percent) and in Phoenix the after case was favored (compliance increased 8 percent). The same trends held when data from both sites in each city were combined. Compliance at these sites ranged from 21 to 40 and from 78 to 93 percent in Buffalo and Phoenix respectively. The proportion of pedestrians leaving the curb during the clearance indication (FDW) was not expected to change because the indication was the same in both the before and after cases. This expectation held true except at one site in Phoenix where a difference at the 0.05 level was found.

The most significant finding in this experiment was from the understanding data. Of the 400 pedestrians surveyed, only 2.5 percent understood the intended meaning of FW and steady W. Less than half of the pedestrians in both cities said that they would expect vehicles to be turning into the crosswalk during the W interval, even though turning vehicles in both cities made up one-fourth of the total traffic passing through the intersection when all turns were permitted. As mentioned earlier, turning vehicle conflicts dropped in Buffalo (4.0 to 0.4 percent) and remained the same for both the before and after cases in Phoenix (approximately 16 percent).

The trends in compliance differences between cities remained consistent with the trends in experiments 1 and 2. The behavioral differences found in Buffalo are not easily explained. The before and after sequence was reversed in Buffalo for this experiment, but there was a 2-month acclimation period to reduce or eliminate the novelty effect. There was no novelty effect apparent in the behavioral data for the other two experiments, and they were conducted simultaneously with this experiment.

CONCLUSIONS

1. A steady DW clearance display appears to have the same effectiveness as an FDW clearance display. There is not sufficient evidence to say that a steady clearance is better than a flashing clearance.
2. The DS message offers little or no improvement over the current DW message.
3. FW is not an effective means of warning pedestrians about turning vehicles.
4. Based on pedestrians' stated expectancy in regard to TVs, there is a need to make pedestrians more aware of TVs.
5. Pedestrians' observance of pedestrian signals varies somewhat from intersection to intersection and greatly from city to city.
6. The pedestrian behaviors used may be sensitive enough to reflect the responses of pedestrians to the subtle changes made in these experiments.

ACKNOWLEDGMENT

The conclusions stated here are mine and do not necessarily reflect the opinions of the Federal Highway Administration or the U.S. Department of Transportation.

REFERENCES

1. H. D. Robertson, W. G. Berger, and R. F. Pain. Urban Intersection Improvements for Pedestrian Safety. Volume II: Identification of Safety and Operational Problems at Intersections. BioTechnology, Inc., Falls Church, Va., May 29, 1975.
2. H. D. Robertson. Urban Intersection: The Problems of Sharing Space. Traffic Engineering, Arlington, Va., Feb. 1976.
3. J. D. D'Angelo. The Effects of a Flashing Walk Education Program on Pedestrian Crossing Characteristics. Department of Civil Engineering, Univ. of Pennsylvania, College Park, June 1973.

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Abridgment

A Method for Estimating Pedestrian Volume in a Central Business District

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In the past decade, significant efforts have been directed toward improving the accessibility and revitalization of the central business district (CBD) in many large metropolitan areas. The ingenious concepts that emerged