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Evaluation of the Paddle Pal, a Device for Increasing the Visibility of Flagger Paddles	
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Supplemental Notes	
Abstract The Paddle Pal consists of a black plastic case and four arrays of three flashing LED's, two red arrays on one side and two amber arrays on the other side. The Paddle Pal can be easily mounted on the handle of a flagger paddle and is intended as a way of increasing the visibility of a paddle. The Paddle Pal was evaluated in an outdoor, laboratory-like setting by 68 persons: employees of WisDOT and retired persons from the surrounding community. The weather was cold, overcast and foggy with visibilities as low as 0.25 miles. Evaluators were asked to make pair-wise choices between all combinations of four paddle configurations, of which three involved lights displayed 495 feet away. It was found that flaggers should use lighted paddles if low-visibility, daytime conditions are anticipated. The Paddle Pal is recommended over a standard paddle. The MUTCD should be modified to allow paddles lighted with LEDs, as these paddles perform better than standard paddles and at least one white-light paddle in low visibility, daytime conditions.	

Evaluation of the Paddle Pad, a Device for Increasing the Visibility of Flagger Paddles

Alan J. Horowitz and Thomas Notbohm

1. TECHNOLOGY

The Paddle Pal is a product of Safe-T-Proof (31143 Via Colinas, # 502, Westlake Village, CA 91362). The product consists of a black plastic case and four arrays of three flashing LED's, two red arrays on one side and two amber arrays on the other side. The actual color of the LED's is obscured by red and amber lenses on their respective sides. The case has a round hole about 1.5 inches in diameter, allowing the device to be slipped onto a paddle handle of between 0.75 and 1.125 inches in diameter. Within the hole is a soft rubber part that provides sufficient friction to keep the device in place. An on-off button is mounted below the device. The device is designed to have the LED's oriented such that the red array is parallel with the STOP side of a paddle, and the amber array is parallel with the SLOW side of a paddle. The Paddle Pal is intended as a way of increasing the visibility of a flagger paddle.



Figure 1. Paddle Pal from the Red Side

The Paddle Pal is powered by four standard AA batteries. The battery compartment is accessed by removing six small Allen-head screws from the bottom of the case. The device used in the tests was a prototype, not a production unit.

Similar Studies

There have been only a few prior systematic studies of flagger paddles, all of them anecdotal in nature. In a study for the Kentucky Transportation Cabinet, Agent and Hibbs (1996) distributed six designs of lighted paddles to work zone crews. Comments from the crews allowed the authors to conclude that lighted paddles were preferred over nonlighted paddles. Sutton and Baher (1997) evaluated two designs of radar-activated lighted flagger paddles. Interviews with flaggers and motorists at a single site revealed both good and bad aspects of the paddles, so no recommendation was made. A Michigan study (not dated) displayed five paddle designs to a group of 35 highway safety specialists at a distance of 285 feet. A conclusion of the group, reached by consensus, was that the halogen lighted paddle was best able to draw the attention of a motorist. An article on the FHWA web site describes a South Dakota study that evaluated a single design of a lighted paddle. After deploying the device in several work zones, South Dakota recommended use of lighted paddles.

2. STUDY SITE:

The Paddle Pal was tested in a laboratory-like setting on the grounds of the Wisconsin Department of Transportation (WisDOT), District 2, Pewaukee Road office in Waukesha, Wisconsin. Tests were performed on a service drive that was oriented almost perfectly north and south. Evaluators were located at the south end of a service drive and flagger paddles were displayed to the evaluators at the north end of the same service drive. Evaluators were seated

in a new, luxury-class automobile, so they could view the paddles through a windshield. The windshield had a slight tint. The automobile was stationary. The distance between the evaluator's eyes and the paddles was 495 feet, corresponding to the AASHTO stopping sight distance for a vehicle traveling at 55 mph on a road with 0% grade. This distance is somewhat longer than the MUTCD-suggested distance of 335 feet between the flagger station and the work zone on 55 mph roads. The longer distance was chosen in order to make the task more challenging for the evaluators.

The Paddle Pal was evaluated by employees of WisDOT and by retired persons from the surrounding community. WisDOT employees were recruited from among the whole staff at the Pewaukee Rd. office (including technicians, managers, engineers, and clerical staff), not just specialists in traffic control. Retired persons came from two community groups (a breakfast club and an exercise class). All evaluators had valid driver's licenses. All evaluators signed an informed consent form (see Appendix A) and all community evaluators were paid \$20 for their services. WisDOT employees were not compensated. The age distribution of evaluators is shown in Table 1.

Table 1. Age Distribution of Evaluators

<i>Age Range</i>	<i>Count</i>
Less than 26	2
26 to 45	22
45 to 65	27
Over 65	17

None of the evaluators reported having any eye diseases or medications that affected their vision, but 16 reported having less than 20/20 vision (corrected) and two evaluators reported being slightly colorblind. There were a total of 68 evaluators.

The test was conducted between 8:30 am and 3:30 pm on a weekday in early April. The weather was cold (temperatures between 33 and 38 degrees F), overcast, foggy and moderately windy (average wind speed of 15 mph). At no time during the day were shadows observed. Visibilities ranged between about 0.25 and 1 mile throughout the day. The fog did not obscure any of the paddles completely, but the red color of the faces of the paddles was considerably muted. Although the reflective sheetings on the paddles were not identical, given the fog, the absence of any direct light and the distance, the faces of the paddles were indistinguishable from each other. The only discernable difference related to lights on three of the four paddles.

Flaggers wore orange safety vests and orange hard hats. The headlamps of the automobile were off.

3. DATA COLLECTION:

The Paddle Pal evaluation was accomplished using the classical psychometric technique of paired-comparisons. Three comparison paddles were used. The four paddles were shown to each evaluator in six pairs, covering all possible combinations. Each paddle of the pair was held by a separate flagger, spaced 5 feet apart. In order to eliminate order bias, paddles were alternately reversed left-to-right and the pairs were shown in different orders to different evaluators. The following statement was read to each evaluator:

“Please put on glasses or contact lenses that you use when driving. We will show you pairs of stop signs for a few seconds each. Tell us which one you believe would be easiest to recognize as a stop sign when driving an automobile under all conditions. Raise your right hand (or say right) if you believe the sign on the right is easiest to recognize and raise your left hand (or say left) if the sign on the left is easiest to recognize. Raise both hands (or say same) if you cannot distinguish between the signs.”

Paddles were displayed until the evaluator could make a decision. This was always accomplished within 10 seconds.

Only the STOP side of the paddles was displayed. All of the paddles were 18” across and measured 79” from the road to the top of the octagon. The four paddles were:

- A. Paddle Pal: This paddle consists of the octagon, a staff and the Paddle Pal. The Paddle Pal was mounted just below the octagon. The retail price of this device is unknown.
- B. White-Light Paddle: This paddle is manufactured by Detronics and contains two flashing white halogen lights, aligned vertically above and below the STOP legend. The configuration is described in Section 6E.03 of the MUTCD. The two lights alternately flash for 12 seconds before automatically switching off. The device has rechargeable batteries. A short piece of 1.5 inch PCV pipe was affixed to the end of the handle to match its length to the other paddles. The retail price of this paddle is between \$500 and \$550.
- C. Blinkerstop Paddle: This paddle has eight red LEDs, one LED at each vertex of the octagon. All LEDs flashed together in two user-selectable sequences. One sequence is a single short flash and a longer pause. The second sequence, used in the test, is multiple short flashes and a longer pause. This model had a short handle, which was retrofitted with a 1.5 inch PVC pipe to match its length to the other paddles. The retail price of this paddle is between \$100 and \$150.
- D. Standard Paddle: This paddle has no lights and was otherwise identical to the Paddle Pal. The retail price of similar paddles range from \$30 to \$70, depending upon the sheeting.

All paddles were in new condition and in conformance with the MUTCD without their lights. All batteries were replaced or fully charged just prior to the beginning of the test. The flaggers were told to orient the paddle directly at the evaluator; however, the actual orientation would vary slightly from evaluator to evaluator, between pairs, or during the display of a pair because of wind or human error. An imprecise orientation would have the greatest effect on devices with LEDs, because of their more limited cones of vision.

Figure 2 shows the setup at the south end of the site. Three people were required to process each evaluator. One person read the paired-comparison questions and recorded answers. Another person allowed the evaluators to see the signs only when the flaggers were ready, kept the windshield free of mist and communicated with the flaggers via radio. The third person checked-in the evaluators, obtained signatures on the “informed consent form”, and asked preliminary questions. Each evaluator spent about 10 minutes on the site.



Figure 2. Setup at South End of Site

4. DATA ANALYSIS

Paired-Comparisons Data: Two scales were constructed from the data: (1) the average number of times a device was preferred and (2) a Thurstone scale. A Thurstone scale is a standard method of analyzing paired-comparison data. It is constructed from probability theory and is intended to exhibit an equal-interval property. That is, if A is preferred to B and C is preferred to D by the same amounts, then the difference between A and B on the scale is the same as the difference between C and D on the scale. The units of a Thurstone scale are standard deviations of a normal distribution. The Thurstone scale ignores responses that said a pair of paddles were the same.

Batteries: The battery life of the Paddle Pal was tested by installing new alkaline batteries and leaving the device on until the LEDs were no longer visible. The test was terminated after 40 hours. During the test, the illumination provided by the LEDs became less and less as the voltage from the batteries dropped. Apparently, the device has no voltage cut-off, so it will continue to operate even when the light is too dim to be effective.

The batteries were difficult to change on the Paddle Pal, taking about 10 minutes, and requiring a small Allen wrench. The batteries were in the bottom of the device and the lights were in the top of the device. With the bottom removed, wires between the two halves were stretched and could have easily been broken.

Other Reliability Issues: Considering that the Paddle Pal provided for the test was an expensive prototype, it was not deliberately subjected to conditions that might have damaged it. The parts of the case are well-fitted, although the case would probably not be water tight, if submerged. The rubber piece that holds the device on the staff looks like it might be subject to wear and tear. The device was not dropped or otherwise subjected to the type of abuse that it would experience in actual flagger operations.

5. RESULTS

Numerical Results: A straight preference scale was created by averaging the number of times a paddle was preferred over another paddle. A score of 1 was given to the most preferred paddle of a pair, and a score of -1 was given for the least preferred paddle of a pair. A score of 0 was given to both paddles of a pair for the few cases where the evaluator thought they were the same. Since each paddle was involved in three comparisons for a single evaluator, the maximum score is 3; the minimum score is -3; and the average score is 0. The average scores are shown on Table 2 and the Thurstone scores are shown on Table 3.

Table 2. A Straight Preference Scale of Paddles

Device	Average Preference
A. Paddle Pal	0.10
B. White-Light Paddle	-0.50
C. Blinkerstop	1.78
D. Standard Paddle	-1.40

Table 3. A Thurstone Scale of Paddles

Device	Thurstone Scale
A. Paddle Pal	0.10
B. White-Light Paddle	-0.20
C. Blinkerstop	0.68
D. Standard Paddle	-0.58

Overall the two scales are consistent. The Paddle Pal performed about average in the group – slightly more preferred than the white-light paddle but considerably less preferred than the Blinkerstop paddle. The Paddle Pal was preferred over a standard paddle without any lights.

Subjective Observations: Many of the evaluators offered reasons for their opinions and these reasons are consistent with the observations of the research team.

The white-light paddle had two problems. First, the brightness of the lights made it very difficult to see the octagon, and it was virtually impossible to make out the color of the sheeting or see (much less read) the STOP legend. Second, many evaluators did not agree that the white lights (the only really visible part of the device) connoted “stop”.

The LEDs from the Blinkerstop seemed brighter than those from the Paddle Pal and were easily visible through the fog. A reason for the difference in apparent brightness could be related to the lenses over the LEDs on the Paddle Pal. One evaluator saw the pattern of Blinkerstop lights as a circle, not an octagon.

Age Effects: Age was correlated with some of the preferences. Table 4 shows correlation coefficients for each pair. The correlation coefficients indicate that older evaluators tend to prefer the white-light paddle and tend to prefer any lighted paddle over the standard paddle. The data suggest that older drivers need lights to improve visibility and bright lights are better.

Table 4. Age Effect on Preferences

Pair	Correlation Coefficient
Paddle Pal > White Light	-0.23
Paddle Pal > Blinkerstop	-0.12
Paddle Pal > Standard	0.19
White Light > Blinkerstop	0.36
White Light > Standard	0.37
Blinkerstop > Standard	0.24

Other Observations: The flaggers complained about the relative heaviness of the white-light paddle. The rubber part that held the Paddle Pal on the handle was not rigid. The Paddle Pal could rock back and forth, and it could be easily displaced. The Paddle Pal’s allowable range of diameters for the paddle staff is too thin; we had difficulty locating standard paddles that had staffs that were thin enough to insert into the Paddle Pad without damaging it.

6. CONCLUSIONS

The weather conditions were among the severest possible for testing the paddles. Without any direct light and the fog, the standard paddle and the flaggers were very difficult to see. It is likely that an even denser fog would necessitate a suspension of flagger operations at an actual work zone, as the use of any paddle (illuminated or otherwise) would be unduly hazardous.

The original design of the experiment anticipated a sunny day, with the sun behind the evaluators. This situation would have given maximum illumination to the face of the paddles and would have reduced the visibility of the lights due to glare. Although a sunny day may have also been a good test of the lights on the paddles, it would not have simulated a particularly hazardous weather condition. Another possible weather scenario would have been nighttime, but this situation would have benefited from the retroreflectivity of the paddles, safety vests, barrels, pylons, etc.

The Paddle Pal was evaluated as inferior to the Blinkerstop paddle, but was better than having no lights at all.

The relatively poor showing of the white-light paddle was a surprise. Although the white halogen lights were bright, they obscured other parts of the sign and confused some of the evaluators. The white-light paddle may not be the best choice for low-visibility situations, which are the most hazardous to flaggers and construction workers. Other designs should be considered for inclusion into the MUTCD.

The results of this test depended on the instructions given to the evaluators. Slight wording differences could produce different results. For example, some evaluators reported that the white-light paddle was the most “visible”. Had the word “visible” been used in the instructions, the white-light paddle may have fared better.

7. RECOMMENDATIONS

Flaggers should use lighted paddles if low-visibility, daytime conditions are anticipated. The Paddle Pal is recommended over a standard paddle. The MUTCD should be modified to allow paddles lighted with LEDs, as these paddles perform better than standard paddles and at least one white-light paddle in low visibility, daytime conditions.

8. REFERENCES

Kenneth R. Agent and John O. Hibbs, “Evaluation of SHRP Work Zone Safety Devices”, Kentucky Transportation Center, Research Report KTC-96-30, December 1996.

Thomas Sutton and Paul Baher, “Flashing Stop/Slow Paddle”, Department of Transportation, Western Lands Division, February 1997.

“Lighted Paddle Improves Flagger Visibility”, www.fhwa.dot.gov/winter/roadsvr/CS035.htm (undated).

“Michigan Compares Various Models of Flashing STOP/SLOW Paddles”, Weekly Event Article, Michigan Division (undated).

Appendix A. Informed Consent Form for Community Participants

Informed Consent Document Traffic Sign Study

I am Alan Horowitz of the Civil Engineering and Mechanics Department at the University of Wisconsin – Milwaukee. I am conducting a study of traffic signs. We would appreciate your participation in this study, as it will help us make recommendations about the safest type of sign.

We expect that your participation in the study will take no more than 10 minutes, once you have reached the site, which is near a parking lot for the Wisconsin Department of Transportation. You will be asked a few general questions about your eyesight, about any medications you may be taking that could affect your eyesight, and about your age. Then you will sit in an automobile that is not moving to observe and give your opinion about some traffic signs. Some of the signs have flashing lights, which have less brightness than a standard traffic light or an automobile taillight. The signs will be 500 feet away. We have invited about 80 other people to participate in this study.

You are not allowed to participate in this study if you have any medical condition that would cause a problem by viewing flashing lights, if you are under 18 years of age, if you do not hold a valid Wisconsin driver's license or you are unable to sit in the driver's seat of an automobile.

You will be paid \$20 for your full participation in this study. If you do not complete the requested tasks, then you will not be paid.

Information that you give us will be retained in a way that it will be impossible to identify you once all data has been collected. Only summaries of the information obtained from all participants will be included in my research reports. We will retain the information indefinitely and may make the information (without any personal identifiers) to other researchers and our sponsors. The data sheet will be filled out by me and one of my assistants.

We will only be asking you to do things that you might normally do while driving. Your participation is completely voluntary and you may withdraw from the study at any time, in which case I will destroy any information you may have given me.

Once the study is completed, I would be glad to give the results to you. In the meantime, if you have any questions, please contact me at:

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If you have any complaints about your treatment as a participant in the study, please call or write:

Jeanne M. Kreuser, JD
Human Protections Administrator
Institutional Review Board for the Protection of Human Subjects
Graduate School, University of Wisconsin – Milwaukee
PO Box 340
Milwaukee, WI 53201
414-229-3173

Although Ms. Kreuser will ask your name, all complaints are kept confidential.

I have received an explanation of this study and agree to participate. I understand that my participation in this study is strictly voluntary.

Name

Date

You should sign two copies of this form and keep one of them.

This research has been approved by the University of Wisconsin Milwaukee's Institutional Review Board (IRB) for a one year period.