The Effects of NO TURN ON RED / YIELD TO PEDS Variable Message Signs on Motorist and Pedestrian Behavior

By

Herman Huang
University of North Carolina at Chapel Hill
Highway Safety Research Center

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EXECUTIVE SUMMARY

This report evaluates the effects of variable message signs in Orlando, Florida, on motorist and pedestrian behavior. The signs display a ANO TURN ON RED@ message to motorists in the right-turn lane when they have a red signal. The signs display a AYIELD TO PEDS@ message to motorists in the right-turn lane when they have a green signal.

A treatment-and-control study design was used. Data were collected at three signalized intersections with variable message signs (treatment sites) and also at three Acontrol sites,@ *i.e.*, signalized intersections without any NO TURN ON RED or YIELD TO PEDS signs. The treatment sites were compared with the control sites to evaluate the effectiveness of the variable message signs.

The sites with the variable message signs were found to have a significantly lower incidence of motorists who illegally turned right on red, compared to the control sites. They did not have any significant differences compared to the control sites in terms of the number of right-turn-on-green motorists who yielded to pedestrians. Motorists were more likely to yield to groups than to single pedestrians at the treatment sites, but not at the control sites. The sites with the signs showed no differences in the number of pedestrians who crossed at a normal walking speed.

INTRODUCTION

In all 50 states and the District of Columbia, motorists may turn right on red at any intersection, after coming to a full stop, unless a NO TURN ON RED sign prohibits the turn during certain or all times. The only exception is New York City, where turning right on red is allowed only if a sign permits the turn. The Institute of Transportation Engineers (1984) noted that allowing right turn on red results in Asubstantial benefits in reduced energy consumption, positive environmental impacts, and reduced operational delays.@

However, right-turn-on-red can increase accident risk for pedestrians. Motorists who stop at the intersection and look left to see if the road is clear sometimes do not look right before turning right. Therefore, they may not see pedestrians coming from the right. Preusser *et al.* (1981) found that right-turn accidents comprised 1.47 percent of all pedestrian accidents before right-turn-on-red went into effect. This proportion increased to 2.28 percent after right-turn-on-red went into effect. Other studies concluded that right turn on red does not create a pedestrian safety problem (AASHTO, 1979; McGee, 1976).

The *Manual on Uniform Traffic Control Devices* (1988) identifies six conditions when the NO TURN ON RED sign may be used. Three of these conditions pertain to pedestrians: (1) where an exclusive pedestrian phase exists; (2) where significant pedestrian conflicts result from right turn on red; and (3) where there is significant crossing activity by pedestrians who are children, elderly, or handicapped.

Zegeer and Cynecki (1986) observed more than 67,000 motorists in Washington, DC; Dallas and Austin, TX; and Detroit, Grand Rapids, and Lansing, MI. About 21 percent of motorists violated NO TURN ON RED signs if given the opportunity. Twenty-three percent of right-turn-on-red violations resulted in a motor vehicle - pedestrian conflict. Countermeasures that were found to be effective in reducing pedestrian risks related to right turn on red include illuminated NO TURN ON RED signs, NO TURN ON RED signs with a red ball underneath, and offset stop bars at intersections where right turn on red is allowed. The illuminated NO TURN ON RED sign was found to be a slight improvement compared to the standard NO TURN ON RED sign, in terms of fewer violations.

Motorists turning right on green sometimes do not yield to pedestrians who are crossing parallel to traffic. Some pedestrians may fail to watch for turning vehicles while crossing on a Walk signal. Countermeasures that can reduce pedestrian risks related to turning vehicles include smaller intersection turning radii (which force motorists to turn more slowly), intersection bulbouts (which improve sight distances between pedestrians and motorists), PEDESTRIANS WATCH FOR TURNING VEHICLES signs, and YIELD TO PEDESTRIANS WHEN TURNING signs (see, for example, Zegeer *et al.*, 1982).

A new type of variable message sign is now being used in Orlando, Florida to reduce conflicts between pedestrians and turning vehicles. The signs are mounted next to traffic signals and are directed at motorists in the right-turn lane. These signs display the message, ANO TURN ON RED@ on the red traffic signal phase. Motorists who are turning right on the green light are

given the message, AYIELD TO PEDS.@ (Figure 1). These messages are displayed during each signal cycle and are not demand-actuated. This report evaluates the effects of variable message signs on motorist and pedestrian behavior.

DATA COLLECTION

No new installations of variable message signs were planned during the time frame of this study, so a Abefore@ and Aafter@ evaluation design was not possible. Instead, this study utilized a Atreatment@ and Acontrol@ design. Three intersections with variable message signs (the Atreatment@ sites) were each matched with nearby intersections that appeared to be similar but did not have any type of NO TURN ON RED or YIELD TO PEDS message, either variable message or static (the Acontrol@ sites). All intersections were in downtown Orlando, Florida, and are described in the following section.

A video camera was used to record pedestrian and motorist behavior at all six intersections. The video camera was set up on the sidewalk along the main road, approximately 23 m (75 ft) upstream from the intersecting side street. The camera faced in the same direction as traffic on that half of the main road. This position enabled the camera to record, on videotape, pedestrians in the crosswalk as they were crossing the main road and side street, and those waiting in the queuing areas on either side of the side street. The camera also recorded signal phases for traffic on the main road and pedestrian phases for pedestrians crossing the side street.

Data were collected in July of 1998. Each location was videotaped for three to six hours, during daylight hours, under dry conditions. The total number of pedestrians and right-turning vehicles (*i.e.* sample size) at each location is given in Table 1.

Table 1. Number of pedestrians and right-turning vehicles at treatment and control sites.

LOCATION	HRS OF DATA COLLECTED	PEDESTRIANS	RIGHT-TURNING VEHICLES
Orange at Central (Treatment) Orange at Washington (Control)	5 hr 50 min 3 hr 25 min	811 401	640 100
Orange at South (Treatment) Magnolia at South (Control)	4 hr 0 min 3 hr 20 min	212 53	863 80
Church at Orange (Treatment) Pine at Orange (Control)	4 hr 0 min 3 hr 10 min	989 551	464 276

SITE DESCRIPTIONS

Orange Avenue at Central Boulevard **B** TREATMENT
Orange Avenue at Washington Street **B** CONTROL
(Figures 2 and 3)

Orange Avenue is the main route through downtown Orlando. It is one-way southbound,

and generally carries three lanes of through traffic. In this part of downtown, Orange Avenue is lined on both sides with a mix of banks, restaurants, and some shops.

The east leg (on Central Boulevard) has one lane eastbound, one lane westbound, and one combined westbound through and left-turn lane. The west leg has two westbound lanes and one combined eastbound through and right-turn lane. There is a bus-only lane for right-turning buses

on Orange Avenue. All four crosswalks are brick. The variable message sign is directed at southbound traffic on Orange Avenue.

Washington Street is parallel to, and one block north of, Central Boulevard. It has one through lane in each direction, with left-turn bays on both legs. All four legs are narrowed at the intersection; away from the intersection, all four legs have on-street parking. All four crosswalks are brick. There was steady pedestrian activity at both intersections.

Orange Avenue at South Street **B** TREATMENT
Magnolia Avenue at South Street **B** CONTROL
(Figures 4 and 5)

Orlando City Hall is on the southwest corner of Orange Avenue and South Street. Orange Avenue is one-way southbound, with three lanes of through traffic. The north leg has a right-turn bay and a northbound (contraflow) bus lane. South Street is one-way westbound, with three travel lanes and a westbound bus lane which turns right onto Orange Avenue. The variable message sign is directed at southbound traffic on Orange Avenue.

Magnolia Avenue at South Street was the best control site that could be found. Magnolia Avenue is parallel to, and one block east of, Orange Avenue. The land uses here include a church, its parking lot across Magnolia Avenue, and older buildings. The north leg of Magnolia Avenue is two-way, with a separated southbound bus-only lane. The south leg of Magnolia Avenue is also two-way, with a left-turn bay. South Street is one-way westbound, with three travel lanes. The west leg consists of three travel lanes and the exclusive bus lane. Three legs

are narrowed at the intersection.

At Orange Avenue at South Street, the north crosswalk is made of brick. The other three crosswalks use continental markings. At Magnolia Avenue at South Street, all four crosswalks use continental markings. There was moderate to heavy pedestrian activity at Orange Avenue and South Street. Pedestrian activity was light to moderate at Magnolia Avenue and South Street.

Church Street at Orange Avenue **B** TREATMENT
Pine Street at Orange Avenue **B** CONTROL
(Figures 6 and 7)

Church Street is one-way eastbound. A bank is on the southwest corner of the intersection; another bank or perhaps an office is on the southeast corner. The west leg has two lanes and on-street parking on the right-hand side. Restaurants, bars, and shops line the street. The west leg of Church Street is closed to motor vehicles in the evenings, after approximately 7 PM. In effect, it becomes a pedestrian street. The east leg consists of one through lane and the exclusive bus lane. All four crosswalks are made of brick. The variable message sign is directed at eastbound traffic on Church Street. There was steady pedestrian activity during all shifts.

Pine Street is parallel to, and one block north of, Church Street. It is also one block south of Central Boulevard. Pine Street is one-way eastbound, with two lanes. There are a few offices, shops, and restaurants here. The local transit terminal is about a block west of Orange Avenue,

and many of the city buses exit the terminal onto Pine Street. All four crosswalks are made of brick. There was steady pedestrian activity during all shifts.

At these two intersections, both the north and south legs of Orange Avenue have three lanes, all southbound. The leftmost lane on the north leg of Orange Avenue at Pine Street becomes a parking lane after 6 PM, to give evening visitors to the restaurants and bars in the vicinity a place to park.

RESULTS

Each treatment was evaluated according to three measures of effectiveness (MOE-s).

1. Motorists who turned right on red
2. Right-turning motorists on green who yielded to lone pedestrians and groups
3. Normal pedestrian behavior

The results for the MOE-s are described in the following sections. The reader is advised that sample sizes vary even at the same location, because of daily fluctuations in pedestrian activity and because of the way that the MOE-s were defined. For example, the MOE involving right-turning motorists who yielded to pedestrians was only relevant in situations when a pedestrian was present at times when motorists were turning.

Motorists Who Turned Right on Red

When traffic on the main road has the red signal (and opposing traffic has the green), the variable message sign reads, NO TURN ON RED. This message prohibits motorists from turning right on red and can reduce the risk of a collision with a pedestrian who is to the right of the motorist and crossing the main road.

The chi-square statistic was used to compare the percent of motorists who turned right on red, at the treatment and control sites. As Table 2 shows, between 2.3 percent and 4.8 percent of motorists at the treatment sites made right-turn-on-red maneuvers, compared to between 11.8 percent and 30.0 percent of motorists at the control sites. Each of the three treatment sites performed better than their corresponding control sites, in that fewer motorists turned right on red at the treatment sites. The right-turn-on-red maneuvers were illegal at the treatment sites, which had NO TURN ON RED signs. The control sites did not have NO TURN ON RED signs, so right-turn-on-red was allowed.

Table 2. Percent of motorists who turned right on red.

LOCATION	TREATMENT	CONTROL	SIGNIFICANCE
Central (treatment) Washington (control)	3.3% (640)*	11.8% (102)	**T** (0.000)
South (treatment) Magnolia (control)	2.3% (861)	38.3% (81)	**T** (0.000)
Church (treatment) Pine (control)	4.8% (462)	30.0% (273)	**T** (0.000)

* Sample sizes (*i.e.*, number of motorists) in parentheses.

T Significant at the 0.10 level or better (significance levels in parentheses).

Right-Turning Motorists on Green Who Yielded to Lone Pedestrians and Groups

In this study, a group was defined as two or more pedestrians who arrived at the curb together. The pedestrians in the group may or may not be acquainted with each other. The chi-square statistic was used to determine whether motorists who turned right on green were more likely to yield to a group of two or more pedestrians than to a lone pedestrian. The study sites were combined in this analysis.

As Table 3 shows, motorists who turned right on green at the treatment sites were much more likely to yield to a group (69 percent) than to a lone pedestrian (38 percent). Overall, about 52 percent of all motorists at the treatment sites yielded to pedestrians. Perhaps a group can more easily assert its right-of-way than a single person, a reflection of a Asafety in numbers@ mentality. It may be easier for motorists to see groups than lone pedestrians, or motorists may find it harder to force the right-of-way over groups than over lone pedestrians. Also, a motorist may be more likely to heed the AYIELD TO PEDS@ message when he or she sees a group of pedestrians.

However, lone vs. group had no effect on motorist yielding at the control sites (about 64 percent of motorists yielded both to lone pedestrians and to groups). In fact, motorists were less likely to yield to lone pedestrians at the treatment sites than at the control sites. A possible explanation follows. Right-turning vehicles were more likely to arrive in platoons at the treatment sites than at the control sites. Some motorists may have decided not to yield so as to avoid being rear-ended. Each right-turning vehicle in a platoon was counted as a non-yielding vehicle until either a motorist yielded or until a gap in traffic appeared, allowing the pedestrian to cross. Thus, an intersection with a high volume of right-turning traffic and continuous pedestrian crossing activity was thought to have a lower level of motorist yielding. This effect may have persisted even with a AYIELD TO PEDS@ sign.

Table 3.
Are right-turning motorists more likely to yield to a lone pedestrian or to a group?
(Treatment locations: Central, South, Church)

LONE PEDESTRIAN	GROUP (2 or more)	SIGNIFICANCE
38.0% (205)	69.0% (171)	**T** (0.000)

* Sample sizes (*i.e.*, number of motorists) in parentheses.
T Significant at the 0.10 level or better (significance level in parentheses).

It may be that variable message signs and the presence of a group the variable message signs were effective when right-turning motorists encountered groups but not when they encountered lone pedestrians.

Normal Pedestrian Behavior

For the purposes of this study, pedestrians exhibited Anormal@ behavior if they walked across the roadway at a steady walking pace. Pedestrians were considered as not exhibiting normal behavior if they ran at any time during the crossing, if they aborted the crossing, or if they hesitated while crossing. A pedestrian aborted a crossing if he or she stepped into the roadway, and then stepped back onto the curb because of opposing traffic. A pedestrian hesitated if he or she stepped into the roadway and then waited for a gap before starting to cross, or if he or she

crossed part of the way and then waited for a gap before completing their crossing.

As motorists yield more often, it becomes less likely that pedestrians will feel a need to run, abort, or hesitate while crossing the street. As the variable message signs are intended to increase the probability that a motorist will yield, it was thought that more pedestrians would cross normally (*i.e.*, without running, aborting, or hesitating) at the variable message sign sites than at the corresponding control sites.

The chi-square statistic was used to compare pedestrian behavior at the treatment and control sites. This analysis compares all three treatment sites with all three control sites. As

Table 4 shows, there was no difference in the percent of pedestrians who exhibited Anormal@ crossing behavior.

Table 4. Pedestrians who exhibited normal crossing behavior.

TREATMENT (Central, South and Church)	CONTROL (Washington, Magnolia, and Pine)	SIGNIFICANCE
97.3% (859)*	97.1% (687)	N

* Sample sizes (*i.e.*, number of pedestrians) in parentheses.
N Not significant at the 0.10 level.

CONCLUSIONS AND RECOMMENDATIONS

The key findings of this study are as follows:

1. The variable message signs were found to be associated with significantly lower percentages of motorists who turned right on red, compared to the control sites.
2. Motorists were more likely to yield to groups than to single pedestrians at the treatment sites, but not at the control sites.
3. The signs did not have an effect on the number of pedestrians who exhibited normal crossing behavior.

Recommended Research

The present study was a behavioral evaluation of variable message signs at three locations, using a treatment and control approach. Every effort was made to select control sites that were within one or two blocks of the treatment sites, and that had the same number of lanes, the same types of land uses (such as office or downtown retail), and the same vehicle speeds as the corresponding treatment sites. However, perfectly-matched control sites do not exist in reality. For example, Magnolia Avenue at South Street had distinctly less motor vehicle and pedestrian traffic because it was one block east of Orange Avenue (the main downtown thoroughfare).

A before-and-after study is preferred, when feasible, for conducting evaluations of traffic control devices. However, a before-and-after study requires that the data collection be coordinated with local agencies: schedules for installing the devices. No new installations of variable message signs were planned during the time frame of this study. Thus, a before-and-after study design was not possible. The treatment-and-control design was considered to be acceptable to gain a better understanding of the effects of the signs.

The original intent of this study was to evaluate the variable message signs and to recommend guidelines for their use. Indeed, the signs showed promise in increasing the number of motorists who stopped on red and who yielded to pedestrians while turning. No clearly negative effects were found. Because this study was limited to evaluating three sites, using a treatment-and-control approach, no clear recommendations can be made about the conditions under which variable message signs are warranted.

Therefore, it is recommended that additional sites be tested in the future, preferably using before-and-after studies, to add to the results of this study. Such an evaluation could be conducted in stages. For example, data would be collected first at intersections with no restrictions on right-turn-on-red. Second, data would be collected at the same intersections after static NO TURN ON RED signs had been installed. Third, the static NO TURN ON RED signs would be supplemented by static YIELD TO PEDS WHILE TURNING signs. Finally, the static signs would be replaced with variable message signs. The results of these further studies could lead to the development of guidelines for using variable message signs.

Other Intersection Treatments

It is also recommended that traffic engineers consider other intersection treatments besides variable message signs. This section lists some other treatments that can improve safety and convenience for people crossing at signalized intersections.

- **Provide fixed-timing or program a WALK interval during each signal cycle:** Instead of requiring pedestrians to push buttons to get a Walk signal, the pedestrian phases may be placed on recall so that the Walk signal appears in every cycle. This option may not be practical at wide intersections with relatively low pedestrian volumes, or where there is imbalanced traffic flow at intersections of major and minor streets.

- **Provide longer WALK and clearance intervals:** At wide intersections, pedestrian crossing times often dictate green splits and cycle lengths. As a result, *minimum* Walk and flashing Don=t Walk times are commonly used. The MUTCD recommends a minimum Walk interval of 4 to 7 seconds. With such a short interval, pedestrians may only get one or two lanes across the street before the flashing Don=t Walk appears and may get confused or even panic (because they do not understand the meaning of the flashing Don=t Walk). It is desirable to provide a longer Walk interval whenever practical. Timing clearance (*i.e.*, flashing Don=t Walk) intervals to assume slower walking speeds (*e.g.*, 0.9 or 1.1 m / sec (3 or 3.5 ft / sec) instead of 1.2 m / sec (4 ft / sec)) may also be appropriate, particularly at locations with older pedestrians which cross the street regularly.

- **Use early release, exclusive, and other pedestrian signal phasing at downtown intersections:**

Most pedestrian signals use standard (or concurrent) timing, in which the Walk signal is displayed at the same time with the green light for parallel traffic. Under such a timing scheme, right- and left-turning motor vehicles may conflict with pedestrians crossing on the Walk signal (and many motorists will not yield to pedestrians when making turns at such intersections). Alternatives to standard timing are early release, late release, exclusive, and scramble timing.

An early release timing scheme displays the Walk signal for pedestrians while parallel traffic still has a red signal. That is, pedestrians are Areleased@ early and have a chance to cross before vehicles start turning right (or left) into their paths. Early release was found to reduce the vehicle - pedestrian conflict rate by up to 95 percent in St. Petersburg, Florida (IIHS, 1997). With late release, parallel traffic gets the green signal first, while pedestrians still have the steady Don=t Walk signal. This scheme holds pedestrians back before Areleasing@ them, so that turning vehicles will presumably be gone by the time that the Walk signal appears. Both early and late release may be appropriate at intersections where there is a very high volume of right- or left-turning traffic (such as Orange Avenue and South Street or Orange Avenue and Central Boulevard in Orlando).

With exclusive timing, all vehicular traffic is stopped and pedestrians are allowed to cross in any crosswalk: the Walk interval is displayed for all crosswalks at the same time. Exclusive timing has been associated with approximately a fifty percent reduction in motor vehicle - pedestrian crashes as compared to standard timing (Zegeer *et al.*, 1985). With scramble timing, all vehicular traffic is stopped and pedestrians are allowed to cross in any crosswalk or diagonally across the intersection (Figure 10).

Exclusive timing schemes are most appropriate in downtown signalized intersections with high pedestrian volumes (1,200 or more per day), and relatively low vehicle speeds and volumes. Such timing schemes do typically increase vehicle and pedestrian delay, since longer signal cycles are required, and it may be difficult to synchronize adjacent signals. Exclusive timing plans are generally impractical outside of the downtown area.

- **Educate motorists and pedestrians, coupled with enforcement**:
  Education and enforcement can help improve conditions for pedestrians. Driver education classes and drivers= license manuals should emphasize driver responsibility to yield to pedestrians when turning at intersections. Better enforcement (perhaps using red light cameras) of driver compliance to traffic signals, NO TURN ON RED signs, and TURNING VEHICLES YIELD TO PEDESTRIAN signs may also be effective in improving pedestrian safety at signalized intersections.

  Many pedestrians do not know or remember to watch for turning vehicles when crossing. They mistakenly believe that the Walk signal means that they can cross without looking for vehicles. A sign such as the one shown in Figure 11 reminds pedestrians to watch for turning vehicles.

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