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Yielding Behaviors of Right-Turn-on-Red Drivers to a White Cane User

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Abstract

This study tested the null hypothesis that drivers turning right-on-red will not yield (defined as declining to turn during an acceptable gap) more often when a pedestrian who used a cane was present. The researchers recorded and evaluated drivers' gap acceptance (N=93) under three conditions: with and without a pedestrian presence at the crosswalk, and with a pedestrian present using a flagging cane strategy. Results: When there was no pedestrian present, drivers did not accept the gap (yielded) 46.7% of the time; when a pedestrian was present 25%, and when the pedestrian flagged with a cane was at the corner, significantly more at 90.3% (p < .001). Discussion: The findings indicate that even when drivers are monitoring for a traffic gap to their left side at a red signal, pedestrians who are blind using a cane with movement may increase the likelihood of vehicles yielding as they prepare and initiate a crossing.

Keywords

Blind, O&M, cane, crossing, yielding

Introduction

A series of published studies between 2011 and 2023 examined pedestrian behaviours and drivers' yielding responses. These studies found a consistent pattern of increased yielding to pedestrians who presented particular cane and body movements, indicating the ability to mitigate risk at street crossing by increasing the likelihood that the driver would slow down or stop. Before the current study, only roadways without traffic controls and drivers making right turns on a green signal were examined. This study tested the null hypothesis that drivers turning right-on-red will not yield (defined as turning during an acceptable gap) more often when a pedestrian who used a cane was present. Methods: The researchers recorded drivers' gap acceptance (N = 93) in a right-turn-on-red situation under three conditions: with and without a pedestrian presence at the crosswalk, and with a pedestrian present using a flagging cane technique. Results: When there was no pedestrian present, drivers did not accept the gap of sufficient length (i.e., yielded) 46.7% of the time and when a

pedestrian was present 25.0%. When the pedestrian flagged with a cane at the corner, drivers yielded significantly more at 90.3% ($p < .001$). Discussion: The findings indicate that even when drivers at a red signal are visually monitoring their left side for a gap in cross-traffic, pedestrians who are blind using a cane with movement may substantially increase the likelihood of drivers yielding as the pedestrian prepares to initiate a crossing.

Yielding Behaviors of Right-Turn-on-Red Drivers to a White Cane User

Since 1980, drivers in most places throughout the United States have been allowed to turn right at a red signal after stopping, unless otherwise prohibited by local posted signage (Compton & Milton, 1994; National Highway Traffic Safety Administration [NHTSA], 1995), referred to hereafter as RTOR. Orientation and Mobility Specialists, blind pedestrians, engineers, and others have long been concerned about risks for pedestrians posed by RTOR drivers (Compton & Milton, 1994; Day et al., 2023; Fazzi & Barlow, 2017; Jacobson, 2013, Xu et al., 2015; Zador et al., 1982). For example, early studies found a significant increase in crashes after RTOR was introduced (Compton & Milton, 1994; Xu et al., 2015; Zador et al., 1982), including a 40% increase in crashes for pedestrians in New York State reported by Preusser et al. (1981).

Concerns for pedestrian safety at crosswalks with RTOR are often expressed in terms of drivers' attention and where it is focused. For example, the National Academies of Sciences, Engineering, and Medicine says, "The RTOR maneuver requires drivers to look to the left for oncoming traffic, but a pedestrian could be coming from the right, and drivers do not always remember to look to the right before starting to turn" (Day et al., 2023, p. 4). The concern for pedestrians who are blind and who rely on drivers to yield is that if drivers do not see and notice them, then the strategies that have been found to be effective for blind pedestrians to increase drivers' yielding (Bourquin et al., 2011, 2014, 2017, 2018, 2024) will not be effective for also prompting RTOR drivers to yield.

Literature Review

Blind Pedestrians and Drivers' Yielding

There is a substantial corpus of literature regarding drivers' yielding to blind pedestrians, (for example: Bourquin, et al., 2011, 2104, 2017, 2018; De Marco, 1990; Geruschat & Hassan, 2005; Harrell, 1992, 1993); however, it is unknown whether drivers when preparing and executing a RTOR would notice and yield to a typical pedestrian or one who is using a white cane.

Cane Techniques at the Crosswalk

The practical effectiveness of various cane techniques used at crosswalks has been studied in the O&M literature to determine what causes drivers to yield. Flagging a white cane is a standard or alternate technique to improve drivers' yielding at crosswalks in various O&M textbooks (e.g., Fazzi & Barlow, 2017; Jacobson, 2013, Paprural, 2012). Data at a roundabout showed that the static display of a long cane created higher driver yielding than a person without a cane (Geruschat and Hassan, 2005). However, in later studies, for example, with drivers intending to turn right at a green traffic signal, a displayed cane garnered no more driver yielding than a pedestrian without a cane or at a crosswalk with no pedestrian presence at all (Bourquin, et al., 2014). The authors concluded, "The standard practices taught by O&M specialists [a cane display] may not result in substantial yielding by drivers" (p. 173). Likewise, in two studies at roundabouts, data analysis revealed that there were no significant differences between a cane display versus a pedestrian without a cane at both entrance and exit crosswalks (Bourquin, et al. 2016, 2018). In studies that compared the two techniques, the flagging technique gained practical and statistically more drivers' yielding than a simple display (Bourquin, et al., 2014, 2018, 2024) and was therefore used in this study.

Drivers' Attention

Literature about where drivers place their visual attention in RTOR situations is scarce. While there is a substantial amount of research regarding drivers' attention, there is a smaller amount of research directly regarding right-turns. Researchers have found that areas of interest (AOIs), where drivers place their attention, are highly selective (Hristov, 2019, in Abstract section). Factors impacting drivers' attention may include surrounding traffic, intersection geometry, signal status, conflicting traffic, and conflicting pedestrians (Xu, 2015). Drivers make errors by attentional failure (Bao & Boyle, 2009; Preusser et al., 1981; Ringhand et al., 2022). Put succinctly, "Motorists are so intent on looking for traffic approaching on their left that they may not be alert to pedestrians on their right" (Federal Highway Administration, 2009, in section RTOR).

Drivers have opportunities to notice pedestrians at various stages: approaching, stopping or rolling to yield, and turning. Regarding drivers turning right, Xu et al. (2015) reported that right-windshield observation frequency was lower at a red traffic signal. Wu and Xu (2017) found in a naturalistic driving study, that right turners demonstrated low observation frequency at RTOR, checking more for conflicting traffic from the left. Ringhand et al. (2022) reported similar findings, especially under low-demand situations. Interestingly, Ringhand found that fixations to the left were more strongly reduced the nearer to the intersection the driver was, and that more attention was paid to pedestrians when they were in groups. However, other research findings imply that drivers' attention can be amplified and can frequently be to the right and towards pedestrians as AOIs. Hristov (2019) found that drivers' stress during curved traffic movements increased drivers' attention. When there were intersecting roadways, drivers did scan them often using multiple fixations (Lappi et al., 2017). Drivers' "visual exploration (horizontal gaze eccentricity) increased at intersections requiring the driver to give way compared to intersections where the driver had the right of way" (Ringhand, p. 117). Kito et al. (1989) found that drivers' eye movements were frequent when approaching an intersection and that attention was focused to the intended path when turning. Werneke and Vollrath (2012; 2014) studied drivers in a simulator at three legged (T) intersections, looking for gaps in traffic into which they could turn. In situations with two AOIs (cars and pedestrians) drivers did shift attention between both and had more gazes to high-value secondary information to their right. Further, the researchers found that in the stopped phase of the turn pedestrian presence was an important value factor. Upon acceleration, pedestrians on the right were a priority for drivers and drivers' gaze and behaviors change according to task-relevant information in the environment. Finally, in a master thesis study, Girgis (2021) found that when turning right at a red signal, drivers attended to traffic on the left 18% of the time and 29% of the time to pedestrians on their right and left. While drivers turned right the same percent of opportunities whether there was a pedestrian or not, the presence of a pedestrian reduced incidences of RTOR-without-stopping by 14%, indicating drivers' awareness.

Gap Acceptance

The authors reviewed the literature regarding gap acceptance, the average time or distance between two successive vehicles before a merging driver makes a maneuver such as turning or changing lanes (Karthika & Koshi, 2014; Sahraei, 2023). In traffic manuals, Ryus et al. (2010) stated that a right-turning driver is assumed to need a critical gap of 6.2 seconds, and AASHTO (2011) indicated that at stop-signs the gap acceptance is 6.5 seconds. Reported historical findings at stop-controlled crosswalks found acceptable gaps of right-turners were between 6.73s and 7.47s, critical gaps for right turning vehicles were between 5.20 and 7.47, and in an extensive study the average of critical gap was 4.51s (Fitzpatrick, 1991; Karthika and Koshi (2014); Sahraei, 2023). For RTOR, Dabbour (2015) found the gap acceptances of 5.5s to 5.9s. Although there is variability within gap acceptance measurements, looking at the literature over time and conditions, we found a general consistency without practical differences clustering around 5 to 6 seconds.

Data for the pedestrian-present-only (no cane) condition was collected when the temperature was an average of approximately 17 C [30 F] degrees lower. Therefore, we performed a review of the literature and found no evidence that this would impact drivers' turning behaviors.

Methods

A university Institutional Review Board determined that approval was not required because the study was observational and there were no human subjects; a researcher fulfilled the role of pedestrian. The researchers recorded data in an initial collection for two conditions: a crosswalk with no pedestrian presence and with a pedestrian with a white cane. In a second collection, they returned five months later and collected further data in a pedestrian-present-only (no cane) condition at the same location. Traffic signals and patterns were the same, as was the pedestrian's presentation, that is, clothing, approach, placement, and body movements were consistent with the first collection. The only difference was outdoor temperatures which were approximately 17 C [30 F] degrees lower.

I. Study Site

The site for data collections was an intersection located in a suburban county outside of a major urban center in northeastern United States. According to the Department of Transportation database, the most recent statistics (2019) indicate the directional design hourly volume (DDHV) is 448 vehicles/hour. The average speed of vehicles on the roadway is 29 mph. The intersecting roadway has a DDVH of 2,269 vehicles/hour (NYSDOT, 2023). The crosswalk of the intersection traversed a turn lane where RTOR was permitted (see Figure 1).

Figure 1

Intersection overview

Figure 1. Suburban intersection (Google Maps). Measurement lines: line A - drivers approach, 100 feet; line B – pedestrian intended path, 146 feet; line C intersection with vehicles approaching from the drivers' right, 157 feet.

The site was observed through more than 50 signal cycles before collection began. The researcher sampled the vehicles speeds (with a Bushnell Velocity Gun, 20 to 29 mph mid-intersection) on the parallel roadway to the intended path of the pedestrian. Using the length of the intersection to calculate the time for a driver to cross, it was computed that when the intersection was clear of traffic, we could be certain that the drivers waiting at the perpendicular red signal always had an acceptable gap which was 5 to 7 seconds long or longer. During the observations, drivers regularly performed a RTOR during these gaps. The pedestrian phase for the crossing, when the pedestrian detector was actuated, was always a 6 second Walk interval and a 31 second clearance time.

II. Definitions

Acceptable gap was defined as a condition when there was no vehicle present within the intersection approaching from the drivers' left (157 feet, see Figure 1) equaling a gap in traffic of approximately 5 to seven seconds of drive time, or greater.

Gap acceptance (a non-yield) was defined as the occurrence of an acceptable gap, when a driver at or approaching the red signal and the stop bar, then completed a RTOR.

Gap non-acceptance (yield) was defined as the occurrence of an acceptable gap, when a driver at or approaching a red signal and the stop bar, then did not make a RTOR.

Cane flagging was performed when the pedestrian positioned at the crossing location began with a cane displayed to the left, then swung the cane to the right effecting an arc that peaked near waist level, then swung the cane left with a similar movement, allowing the cane tip to rest until the end of the trial.

III. Participant for Data Collection

The pedestrian, one of the researchers, was a 6-foot male, wearing dark clothing, a cap, and dark sunglasses. He used a 54-inch folding mobility cane, white with a lower red stripe and roller tip. Another researcher collected data, remaining in a location to observe trials undetected by drivers. Because substantial research indicated that a static cane technique often did not produce significant driver yielding under various intersection geometry and signal schema, the researchers used the standard flagging cane method outlined above to measure drivers' attention, turning, and yielding behaviours.

IV. Protocols for the Pedestrian for Data Collection

The researchers observed when an acceptable gap occurred and recorded the drivers' actions during late morning and afternoon daylight hours.

No Pedestrian
For the trials when there was no pedestrian presence at the corner, the researchers recorded drivers' RTOR behaviors when there was an acceptable gap. When a pedestrian was present, he did the following:

Pedestrian Without a Cane.
1) The pedestrian began walking along the sidewalk perpendicular to the drivers making a RTOR (at the top of Figure 1) toward the intersection, from where he was not initially visible to drivers.

2) The pedestrian walked to arrive at the detectable warning surface at the crosswalk ahead of him 2s to 6s before the beginning of the Walk interval (see Figure 1). Sometimes drivers were already present, stopped at the red signal, because of the opposing traffics' left arrow protected-turn signal.

3) The pedestrian pushed the pedestrian detector button, positioned himself at the detectable warning surface within the crosswalk lines. Trials began at the onset of the pedestrian's Walk signal and were abandoned if there were no vehicles stopped or approaching in the turn lane after 16 seconds.

Pedestrian with a Cane
Using steps 1 to 3 immediately above, in the cane condition the pedestrian flagged at the onset of the Walk signal interval. Also, if he detected a car approaching, and there was at least 16 seconds of drivers' red signal remaining, he flagged the cane a second time a few seconds before the driver arrived at the stop bar (from approximately 50 to 100 feet, see Figure 1).

Results

Data were analyzed to look at the 1) potential effect that the presence of a pedestrian with and with a cane had on whether the driver took the next available acceptable gap, and 2) whether the position of the vehicle when the pedestrian began flagging a cane had an impact on whether the driver turned at the next available acceptable gap. Data were categorical so chi square analyses were used.

Looking at the impact on drivers' gap acceptance, with no pedestrian present at the crosswalk (n = 30), drivers yielded 46.7% of time overall: 55.6% of the times that they were at the crosswalk, and 33.3% of the times when they were approaching. The crosswalk and approaching conditions were not statistically significantly different $\chi2(1) = 1.43$, $p = .23$. When a pedestrian who flagged the cane was present (n = 31), drivers yielded 90.3% of the time overall: 93.8% at the stop bar and 86.7% as they approached. Again, the crosswalk and approaching conditions were not statistically significant different, $\chi2(1) = .44$, $p = .51$. The difference between having a pedestrian-cane present or not was statistically significant, ($\chi2(1) = 13.55$, $p < .001$).

Analysis of drivers' acceptance or non-acceptance (yield) at acceptable gaps when there was a pedestrian-only presence at the crosswalk (n = 32) found that drivers yielded 25.0% of the time overall: 35.0% at the stop bar and 8.3% as they approached. The crosswalk and approaching conditions were not significantly difference $\chi2(1) = 2.84$, $p = .09$.

Comparing the three pedestrian conditions collapsed across the drivers' yielding location (at the crosswalk and approaching the crosswalk), drivers yielded 25.0% of the time for a pedestrian with no cane, 46.7% of the time for no pedestrian at all, and 90.3% of the time for a pedestrian with a cane. A comparison of the pedestrian with a cane to both no-cane conditions was statistically different, $\chi2(1) = 13.55$, $p < .001$, as was the pedestrian with a cane to the pedestrian-only condition, $\chi2(1) = 27.44$, $p < .001$. Notably, a pedestrian without a cane and no pedestrian presence at the crosswalk resulted in no statistical difference, $\chi2(1) = 3.18$, $p = .08$.

Discussion and implications for O&M practitioners and pedestrians

Situations when drivers are waiting to make a RTOR present an obvious concern for pedestrians wanting to cross the street. In the first data collection we compared the pedestrian-cane to a no-pedestrian condition, finding a practical and highly significant effect; upon reflection, the researchers decided it would be valuable to also be able to compare pedestrian conditions, with and without a cane, to measure and clarify the influence of the cane.

Previous studies at right-turn-on-green and uncontrolled intersections consistently indicated that pedestrians using a flagging white cane technique could have a substantial impact on drivers' yielding. This study did not attempt to reconduct that research comparing a static displayed cane and flagging. Rather the researchers sought to determine whether drivers' yielding behaviors could be increased in favor of the pedestrian using an effective cane technique, even when drivers monitored the traffic away from the pedestrian's location.

Drivers yield when they notice and understand the intent of a pedestrian at a crosswalk. Previous studies in the field on O&M consistently reported result that are explained by the work of psychologists in the field of vision cognition (Bourquin, et. al, 2011, 2014, 2016, 2018). Studies about the phenomenon of 'attentional capture' have found that drivers and others responded with involuntary immediate visual focus (attention) when presented with items that they understood and that had meaning (Mack, Pappas, Silverman, & Gay, 2002; Most & Astur, 2007; Most et al., 2001). As well, when there is a sudden onset of an object in the visual field, attention is driven to the source of movement. Researchers speculate that a mobility cane, a well-known symbol of vision loss along with the sudden movement of the cane, efficiently captures the awareness of drivers and increases the likelihood of yielding.

The results of this study fill a gap in the research. The researchers note the practical and highly significant statistical difference between the pedestrian-only and no-pedestrian-presence, and pedestrian-cane condition, and they conclude that the presence of a pedestrian using a flagging cane can draw the notice of the driver and alert them to pedestrians at the crosswalk, therefore more often prompting yielding. Travelers who are blind and O&M specialists can incorporate appropriate pedestrian behaviors such as a flagging cane strategy to increase the likelihood that drivers will wait for them to cross, including when drivers are preparing and executing a right turn at a red traffic signal.

The researchers further note that appropriate and practical application of flagging a cane is one aspect of standard practices and techniques included in the O&M curriculum for street crossings. This includes clearing the space in front of the traveler before stepping off the curb (not part of this study's methodology).

Limitations and future research

The current study, although highly statistically significant, used a relatively small number of trials. Although we selected a conventional suburban intersection, we examined only one location. Various intersection geometries, roadway regulations, and signal schema may result in different results. The researchers would have preferred to collect all the data at the same session, rotating among the three conditions, to control for any unidentified variables.

This study was completed in a single setting. The researchers cannot claim that the percentage of drivers' yielding at other RTOR locations is strictly predicted by this study. Generalizations should be considered carefully. Future studies are needed to confirm these results and examine other circumstances and protocols.

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