

## Bicycle intersection collisions: Proceed with caution

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### 1 INTRODUCTION

Traffic laws treat bicycles as vehicles in terms of the rules of the road. For example, bicycles are legally entitled to a full share of a travel lane, must ride in the same direction as motor vehicular traffic, and must obey traffic signal lights and other traffic control devices in the same way as (motor vehicle) drivers. However, there are several important practical realities that make bicycles significantly different from automobiles, particularly in accident reconstruction, human factors and injury biomechanics analyses. First, bicycles typically travel at speeds significantly slower than posted speed limits. Second, bicycles are significantly smaller and lighter than automobiles, and often are not as conspicuous. Third, bicycles do not provide any significant structural protection against injury.

Our prior work on intersection collisions proposed mathematical definitions of immediate hazards and studied the conditions under which most red-light running collision occur (1,2). In our analyses, we focused for simplicity on 4-way intersections with vehicles traveling at the posted speed limits. Red-light running intersection collisions between automobiles occur in two generally broad categories: 1) Egregious red-light running, when one vehicle that has stopped at a light gets a green and enters the intersection, and a second vehicle enters the intersection from the side 4 or more seconds after its light turns red; and 2) A vehicle approaching a red light fortuitously gets a green light and enters the intersection without needing to decelerate or stop, and a vehicle, travelling at or around the posted speed limit, in the cross direction enters the intersection less than 2 seconds after its light turns red.

Most red-light violations do not result in collisions. In fact, based on estimates of intersection crashes involving at least one red-light violation (on the order of 100,000 annually in the U.S.) and of the frequency of vehicles running red lights (on the order of one billion annually in the U.S.) (1), it appears that the rate of injurious collisions per red-light violation may be as low as 1:10,000. This may be because the two conditions that tend to result in collisions (according to our timing analyses) are relatively uncommon: 1) vehicles that run red lights are least likely to do so after the light has been red for more than a few seconds (e.g.,10); and, 2) drivers approaching a red light can enter the intersection without braking only if their light fortuitously turns green when they are at or farther away from the location where they would have started their deceleration. Thus, the timing of normal driving at signalized intersections tends to make collisions rare compared with red-light violations by motor vehicles.

The situation changes, however, when one of the vehicles is a bicycle (or other human-powered vehicle). In urban and suburban settings (where signalized intersections are most common), posted speed limits may range from 25-45 mph, but most cyclists are traveling at significantly lower speeds. The difference in speed between motorists and cyclists affects the timing of intersection collision analyses, as described in the next section.

## 2 INTERSECTION TIMING ANALYSIS

The details of our analytic framework can be found in our prior report (1). In brief, for a driver (westbound, for example) entering an intersection at the start of the green signal, we consider a typical perception-reaction time for green light onset, a typical acceleration value, and the distance to the path of cross traffic. For the situation of two motor vehicles, it takes the westbound driver so long to get to the cross-traffic path that a collision will typically occur if the cross-traffic northbound driver enters the intersection 4 to 6 seconds or more after their light has turned red, depending on the specific values used in the analysis.

Generally, if a motor vehicle (northbound, for example) enters an intersection on a stale yellow (towards the end of the 3-4 s yellow signal phase) or just after the yellow gives way to red (such as often happens if the driver maintains speed during the yellow phase in an attempt to enter the intersection before the red signal appears), the extended time taken by other (westbound, in this example) drivers – waiting for the all-red period to end, reacting to green onset, and accelerating at a typical rate of 0.15 - 0.25 g – allows those other (westbound) drivers to notice and avoid the northbound vehicle that entered on a stale yellow or early red and is still in the intersection.

A typical cyclist, however, takes much more time to cover the distance from entering the intersection to reach the cross-traffic collision path. Although the all-red period and operator reaction time does not change, the travel speed for bicyclists is typically significantly lower than posted speed limits, especially in urban and suburban environments with light-controlled intersections. The timing analysis (which will be illustrated in greater detail in our presentation) indicates that a cyclist can end up in conflict with a motor vehicle if the cyclist:

- a) enters on a yellow light - because cross traffic will be reaching conflict zones before the cyclist has passed through the intersection, and also because a motorist in cross traffic may enter at speed when his light turns green
- b) enters soon (less than 2 seconds) after the light turns red – for similar reasons as above
- c) enters later (4 or more seconds) after the onset of the red signal - an egregious violation with likely conflict, even for automobiles entering the intersection so long after the light turns red

## 3 DISCUSSION

Running a red light carries risk of a collision. For motor vehicle operators, the risk is mitigated by the tendency of most red-light running to occur very soon after the light turns red, a period when collisions are relatively unlikely because the violating driver is apt to clear the conflict zones before a collision can occur. Injuries in the event of collision can be catastrophic but are at least partially mitigated by the protection offered by the vehicle structure along with air bags and seatbelts. If the vehicle entering on red is a bicycle, however, a timing analysis predicts less favorable conditions, with entry even very soon after the red light leading to potential conflict with cross traffic; in the case of collision, a cyclist has no injury protection (other than a helmet, if worn, which offers far less protection than what is available to an occupant in a car or truck). It also follows that a bicyclist entering on a green signal is at risk of collision with a red-light running motorist, and that the unprotected cyclist generally fares much worse than the motorist from an injury standpoint.

Furthermore, even entering an intersection on a yellow signal can leave a cyclist stranded in an intersection long enough for cross-traffic motorists to enter on green and represent a threat. There is evidence that drivers fail to notice or properly interpret the approach of bicycle as well as motorcycle riders (6).

Unfortunately, red-light violation is far more common by cyclists than by motorists (4,5). A study of cycling-related crashes in the Netherlands found that 11% of crashes were attributed to red-light violations by cyclists (9). This does not necessarily indicate that cyclists are oblivious to their personal safety as road users. A study of cyclist behavior at stop signs found that cyclists as a rule would stop if there was an obvious conflict (although

not otherwise), and that they looked right and left as they approached, traveling at a speed low enough to allow collision avoidance by means of emergency braking if necessary (3). There is some evidence that most cyclists are similarly self-protective at signal controlled intersections, proceeding through red lights primarily in the absence of evident potential conflicts with other road users (7). Nevertheless, considering the timing implications discussed in this paper, and the relative lack of protection for cyclists compared to motorists, it appears that red-light violations should be a focus of cyclist safety research mitigation efforts. One promising direction comes from research on the value of high conspicuity clothing in reducing cyclist crash risk (8); bright colored clothing in the daytime (and lights and reflectors at night) may be especially important when cyclists find themselves at risk in intersections.

#### 4 CONCLUSIONS

The letter of the law is that a bicycle or other vehicle entering an intersection on a yellow light has control of the intersection and thus the right of way. However, bicyclists entering on a yellow at typically lower speeds than automobiles face a considerably higher risk of being in an intersection collision than automobiles travelling at or around the posted speed limit and entering at the same time. Further enhancing the risk of being in an intersection collision is the accepted fact that bicycles are smaller and less conspicuous than most automobiles. Considering the serious injuries that occur to bicyclists from collisions with automobiles, it is small solace to the bicyclist that he or she entered the intersection legally and technically had control of it. It may be useful for bicycle safety education programs to emphasize the risk associated with intersection collisions and explain the ramifications of bicycles entering intersections at different phases of the traffic light cycle in order to emphasize the additional caution required by cyclists to negotiate intersections.

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