ATTACHMENT A

PUBLIC SAFETY COMMITTEE HEARING
OCTOBER 13, 2015
AGENDA

1. The proposed ordinance to require street hazards to be marked during construction
2. Bikes on sidewalks- enforcement and stenciling efforts (Wil will have a map and memo for the meeting to hand out)
3. Cars and delivery trucks in bike lanes- enforcement efforts
4. General Bike enforcement
    a. Lights
    b. Light running
    c. Wrong way
    d. Do we need a special bike ticket to help capture specific enforcement efforts
        i. If so, how do we do that
5. Traffic lights that don't activate for cyclists
    a. Garden and Sherman by firehouse (?)
    b. Other?
        i. Can we fix them
6. Signage to allow bicyclists to
    a. Turn left at Waterhouse and Mass (now only MBTA buses can do that)
    b. Enter streets even when those streets are marked "Do Not Enter" during certain hours
        i. Cogswell
        ii. Whitimore
7. Non-bikes moving in bike lanes
    a. Skateboards?
    b. Electric 'vehicles'
    c. Joggers

ATTACHMENT B

MEMORANDUM

DATE: August 27, 2015

TO: Councilor Craig Kelley

FROM: Wilford O. Durbin

RE: Consistency Lacking in Enforcement of Biking-Prohibited Sidewalks, Use of "No Biking" Stencils

Summary

Over the past several years the city has greatly expanded its network of bicycle infrastructure, from bike lanes, signals, raised paths, and turning lanes, all with the goal of improving the accessibility and safety of Cambridge's streets to cyclists. While trying to make the roads safer for bikers, the city should also concentrate on making the sidewalks safer for pedestrians, especially in the busiest commercial districts where cyclists are currently banned from sidewalks. When bikers enter the sidewalk, their rights and safety conflict with pedestrians', making it dangerous for both parties.

A survey of the business districts in which riding a bicycle on the sidewalk is prohibited revealed a consistent lack of "No Biking" stencils or other markings declaring the extent of the ban. Many of the stencils are faded, or simply were never replaced after a crosswalk ramp was installed. Considering that not all of Cambridge's sidewalks are banned to bicycles; that bikers rely on the stencils to warn when they have entered a prohibited area; and further that the Cambridge Police Department (CPD) is reluctant to enforce the ban where stencils are missing, it is imperative that the city take measures to replace, maintain, and standardize stenciling in order to appropriately address sidewalk bicycling concerns.

While bicycling on sidewalks presents a genuine public safety concern, enforcement of sidewalk bans should occur only as part of a systematic transportation program that also addresses street hazards, jaywalking, illegal parking, and other issues that endanger cyclists who do not ride on the sidewalk.

Background

Since 1997, Cambridge has prohibited the riding of bicycles on sidewalks in commercial districts such as Harvard Square, Central Square, Inman Square, and Porter Square, while allowing bikers to ride at a "walking pace" on unrestricted streets. The ordinance is codified in Section 12.8(b) of the Cambridge Traffic, Parking and Transportation Regulations, which states: "No person shall ride a bicycle on any sidewalk described in schedule 4B attached to and made part of these regulations and which has been posted with appropriate signs." The CPD apparently takes the stipulation that banned areas be "posted with appropriate signs" at face value, and has consistently noted the reluctance of officers to enforce the ban where clear signage is missing. A search for clarification in exactly what "appropriate signs" means, however, yields few details. Because many pole-mounted signs are missing, often due to vandalism, the city relies primarily on stenciling to declare prohibited areas.

Complaints that bikers disregarded the city ordinance prompted the Council to take action in 2004. Then, as now, the stencils were not maintained and many were missing. The Council sent a unanimous policy order on March 15 to then City Manager Robert W. Healy requesting an explanation "regarding the status of maintaining and improving methods for preventing sidewalk bicycling, including when faded stenciled signs will be repainted and whether pole-mounted signs have been removed and not replaced." City Manager Healy responded on April 12 that there were some 250 stencils applied around Cambridge, and that "all faded and missing stencils will be repainted and any missing signs will be replaced…before the end of August."

This issue came up again in 2006, however, when the whole Council referred the problem of bicycles on sidewalks to the Transportation, Traffic and Parking (TTP) Committee. During a June meeting, TTP Committee Chairman Craig Kelley again addressed residents' frustration to the CPD. Commissioner Watson stated that "Vigorous enforcement will be done on bike riding on sidewalks where stenciled," but that enforcement is "slowed" when stencils are missing from sidewalks, noting that "It is hard to do enforcement when people do not know about the ban." Notwithstanding, the CPD issued a reported 1,059 violations for bikes on sidewalks in 2005.

Findings

At the request of Council Kelley, I conducted a survey on the placement and maintenance of "No Biking" stencils in four of the five commercial districts over several days in August, 2015. During the survey, every crosswalk ramp in the prohibited areas was checked, as well as the entranced from Harvard's campus. The findings of the survey are presented in the attachments.

In each of these areas, the stenciling of "No Biking" warnings was consistently lacking. At the intersection of Cambridge and Hampshire streets that make up Inman Square, 26 crosswalk ramps lacked stencils; in Porter Square along Mass Ave, 65 ramps lacked stencils; in Central Square, 66 crosswalk ramps lacked stencils; and in Harvard Square, a staggering 177 stencils were missing from crosswalk ramps. Particularly around Porter and Harvard Square, it could be said that "appropriate signs" declaring the ban are effectively nonexistent given the absence of stencils.

Turning to the definition of "appropriate signs," the survey yielded no further clarification. In addition to revealing a lapse in the maintenance of "No Biking" stencils, the survey also showed a lack of consistency as to where stencils should be placed. In some districts, stencils were placed on the periphery of the prohibited area, and then only intermittently in between, while in others stencils concentrated toward the center of the business district. Sidewalk ramps facing each other on opposite sides of the same street were not be uniformly stenciled, and ramps across larger roads seldom have stencils. At the corners of streets where two crosswalk ramps extend perpendicular to the other, both ramps are stenciled in some locations, while in others only one ramp is stenciled (some have none at all). Whole streets in the prohibited areas display no outward sign that they are regulated differently than those outside commercial districts. In many locations throughout the city where sidewalk cycling is banned, newly installed crosswalk ramps did not have a stencil, even when stripping was laid across the road, suggesting that the replacing of stencils is not included in maintenance protocol. Only in two locations (both in Inman Square) were pole-mounted signs noticed announcing the ban. The city appears to have abandoned it use of pole-mounted signs, relying entirely on the stenciling.

Recommendations

In the absence of "No Biking" stencils, the enforcement of sidewalk bans breaks down entirely. Bikers are not properly warned when they've entered a prohibited area, and become justifiably frustrated when cited for violating the ban when sidewalks are not properly or consistently marked. Police officers, in turn, are reluctant to enforce the ban when stencils are missing. Equally frustrated are pedestrians, especially seniors or people with young children in tow, who fear a collision with an errant cyclists.

Together with the Councils actions in 2004 and 2006, the present survey suggest that maintaining the stencils is a habitual problem. While steps must be taken to ensure that sidewalks remain "posted with appropriate signs," the city should also reconsider how this is to be achieved. The following recommendations propose a remedy to the problems of properly marking prohibited sidewalks and improving maintenance of the signs.

- **Replace pole-mounted signs**: Formerly the subject of frequent vandalism, the pole-mounted signs may not be such a target now that acceptance of the prohibited areas has grown.

- **Change and standardize the placement of stencils:** Currently, where applied the "No Biking" stencils are placed at the entrances to sidewalks, such as on crosswalk ramps and curb cuts. These locations may be susceptible to greater degradation than the actual sidewalks, especially during the winter, and are harder to maintain. This system of placing stencils is also labor intensive, making maintenance more difficult—an intersection may have as many as eight stencils in a relatively small area. At the intersection of Mt. Auburn St. and JFK St. in Harvard Square, the city has avoided this redundancy by placing a single stencil at each corner, but because they are blocked by a pole, these signs are neither visible to cyclists nor in a space regularly used by pedestrians.

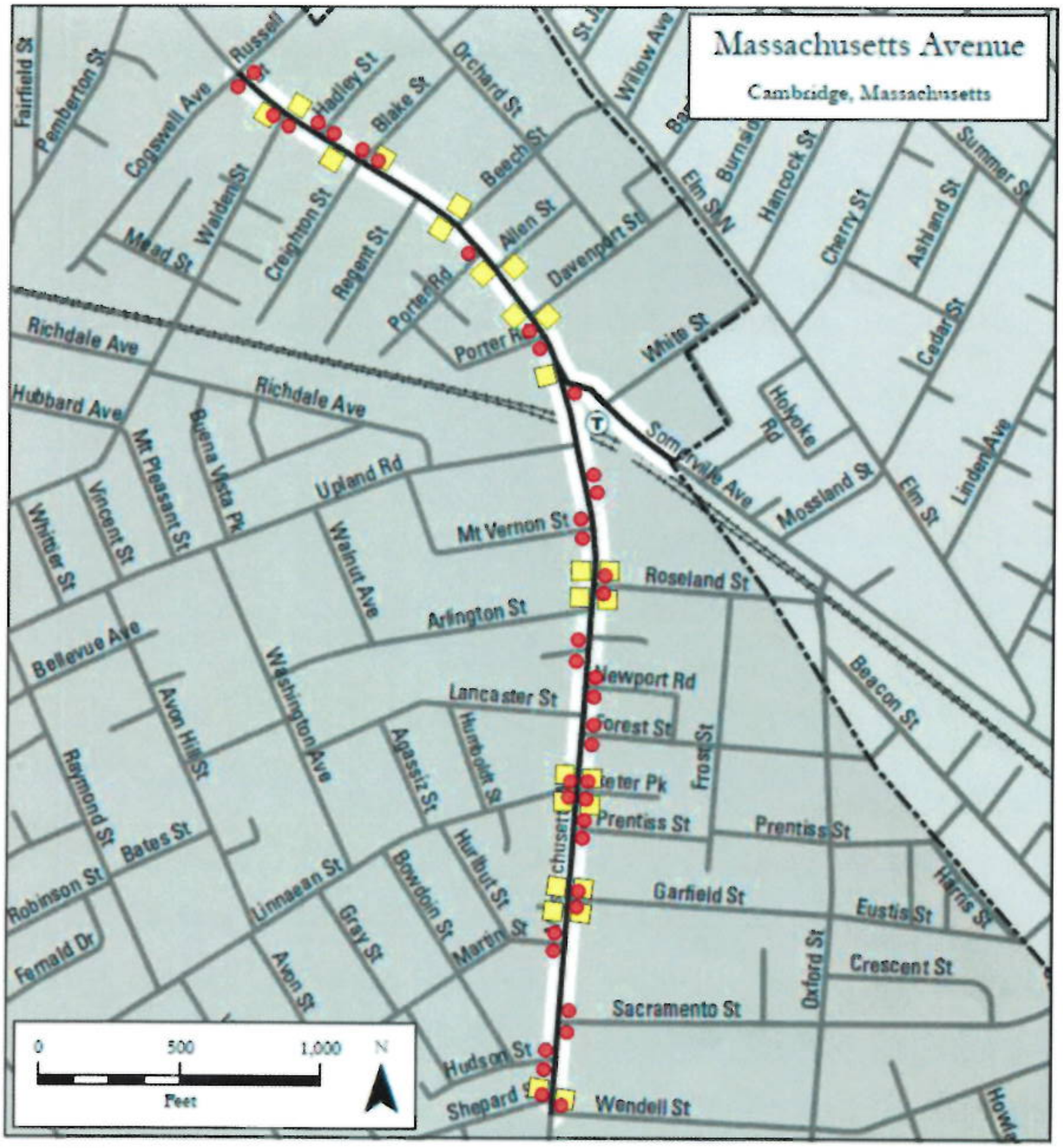
  Rather than placing the stencils on sidewalk entrances, the city should consider placing two stencils in the middle of the sidewalk, laying at one-third and two-thirds of its length, for all sidewalks greater than 100 ft. Sidewalks shorter than 100ft should be marked with one stencil.

  Stencils in the length of sidewalks, rather than at it periphery, also provide officers with a visible metric to gauge whether a cyclist has

- **Incorporate repainting stencils into the protocol and all relevant contracts for replacing crosswalk ramps.**

- **Investigate various stencil and sign designs, and placement.**

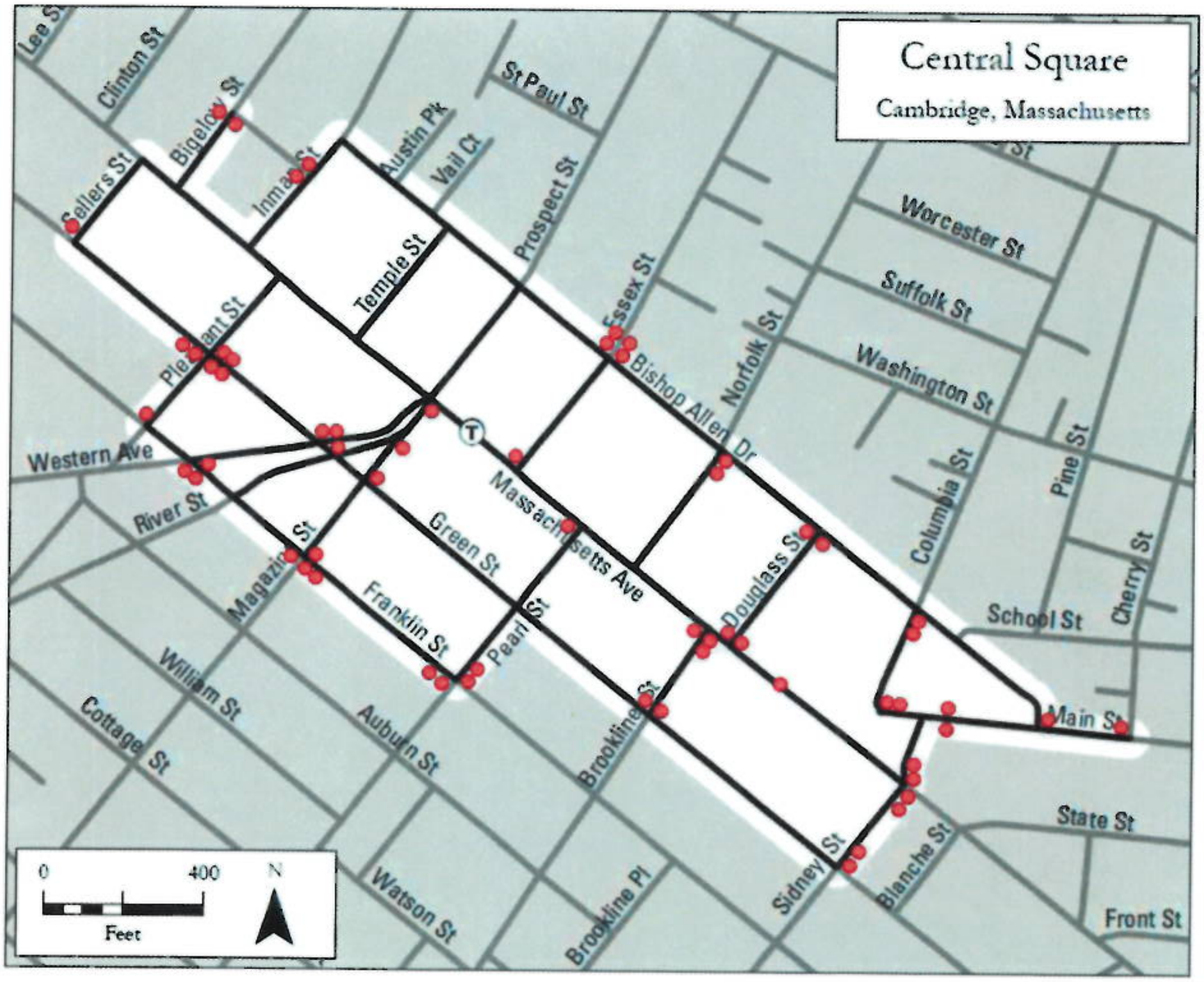
Massachusetts Ave Surrounding Porter



KEY: Denotes missing "No Bike" Stencil on access ramps from Mass Ave.

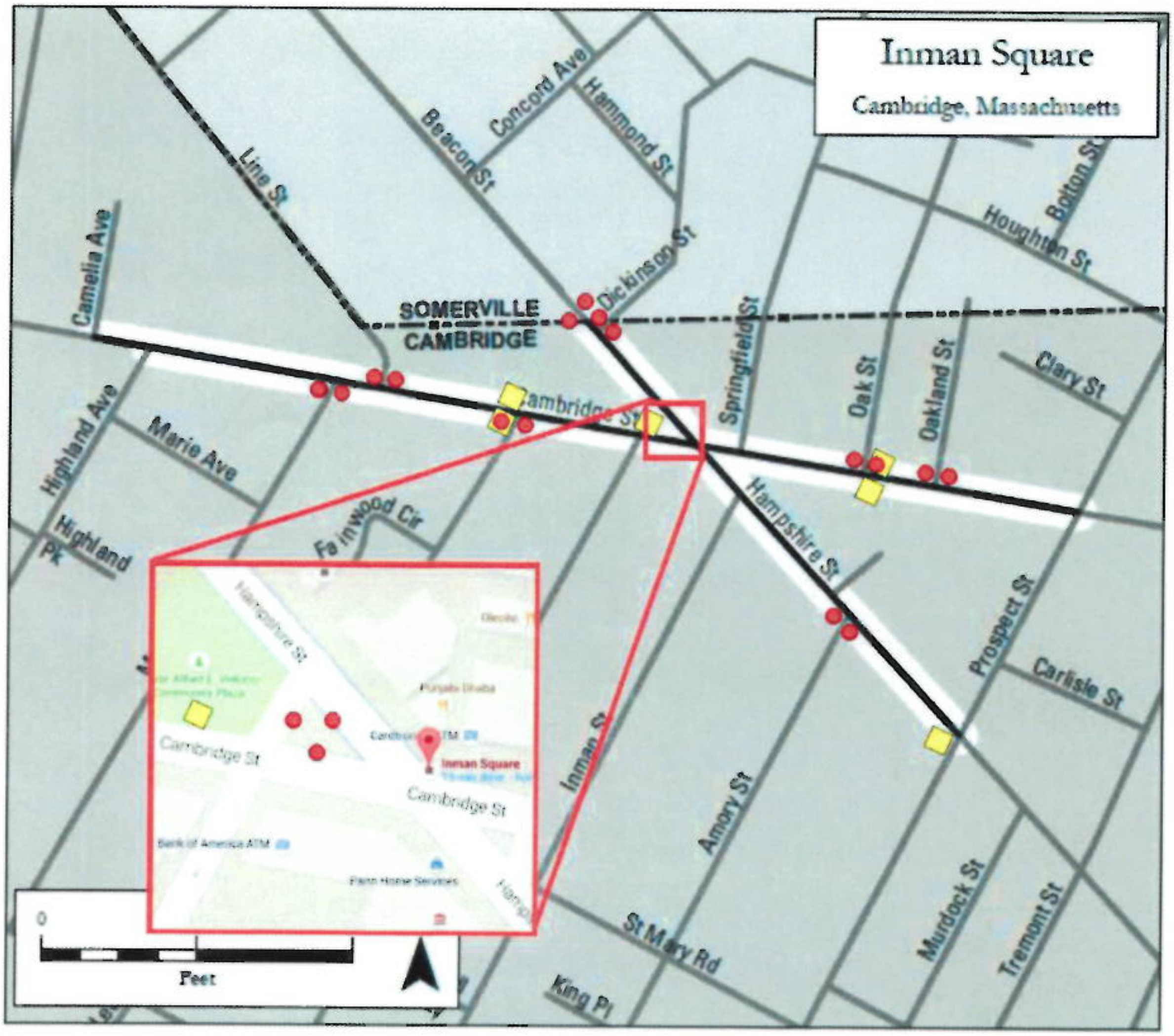
Denotes missing "No Bike" Stencil on cross streets intersecting with Mass Ave.

Central Square Business District



KEY: Denotes missing "No Bike" Stencil

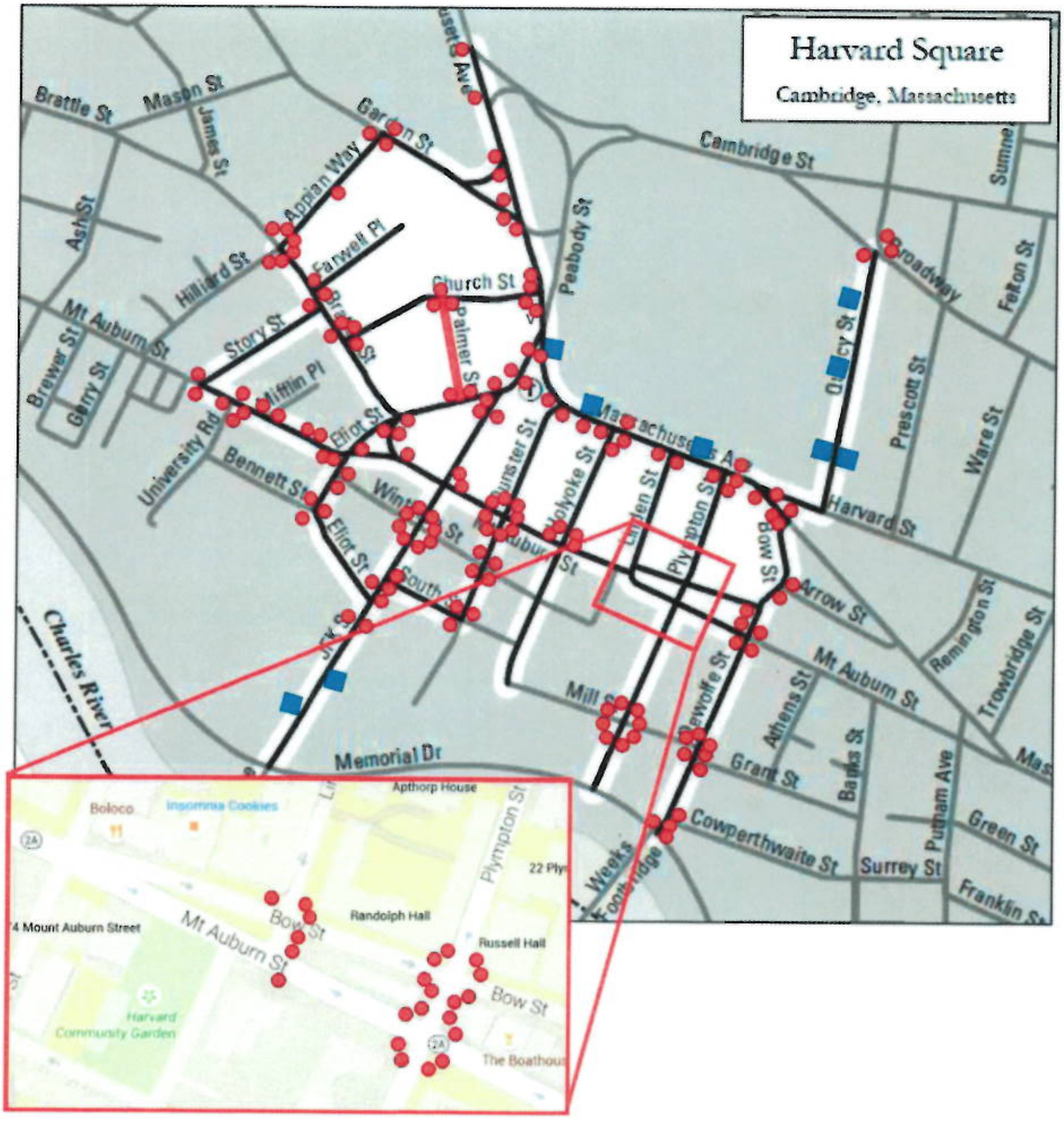
Inman Square Business District



KEY: ● Denotes missing "No Bike" stencil on sidewalks running parallel to Cambridge/Hampshire Streets

■ Missing "No Bike" stencil on pedestrian ramps perpendicular to Cambridge/Hampshire Streets

Harvard Square Business District



KEY: ● Denotes missing "No Bike" stencil

■ Denotes a Harvard gate, no stencils were placed to notify bikers leaving campus.

▬ Palmer St has no markings to warn bikers that it is a banned street. The brick paved street is a heavily used pedestrian crossing and access road to delivery trucks.

Lopez, Donna ATTACHMENT C

From:	David Chase <dr2chase@me.com>
Sent:	Sunday, October 11, 2015 10:46 AM
To:	Kelley, Craig
Cc:	Lopez, Donna
Subject:	Re: Bike Safety Meeting this Tuesday afternoon at 3:30 at City Hall
Attachments:	signature.asc

My opinions (not a Cambridge resident, but I work in Cambridge and ride through 5 days a week):
> 1. The proposed ordinance to require street hazards to be marked during construction
> 2. Bikes on sidewalks- enforcement and stenciling efforts

Stenciling good, enforcement maybe.
Would be nice if there were some discretion around low speed cycling.
If someone is riding at a true walking speed, then they take up less space riding their bike than walking it.

Really strong public education to yield to pedestrians (even when they walk in the "wrong" places) seems like it would be good. Unfortunately, the way I would pitch it (and that I fear might be more effective) might be a little offensive to drivers -- "don't be like those jerks in cars, don't scare people unnecessarily just because you're in a hurry, don't you think the other guy is in a hurry, too?" But just because it's potentially offensive doesn't mean it might not be a good message, since that is exactly what so many drivers do, even if they don't realize it.

> 3. Cars and delivery trucks in bike lanes- enforcement efforts

This would be nice, but what alternative do delivery trucks have?
Do we lack adequate loading zones at the curb?

> 4. General Bike enforcement
> a. Lights

Yes. I think lights are important, studies show lights are important.
Notice the very low rate of serious accidents on rental-bikes?
Notice how they all have lights all the time?
Can we make this a "fix-it" ticket that costs about the same as a decent of lights and rechargeable batteries?

> b. Light running

We need Idaho stop. I see extremely little reckless light running when I commute, though lots of people starting on the leading pedestrian interval -- that ought to be legal even if we don't have Idaho stop. I also see right turns on red where it is banned, and that also ought to be legal as long as we have a strong "yield to pedestrians" message.

> c. Wrong way

I see very very little of this, but enforcement is good.

> d. Do we need a special bike ticket to help capture specific enforcement efforts
> i. If so, how do we do that
> 5. Traffic lights that don't activate for cyclists
> a. Garden and Sherman by firehouse (?)
> b. Other?
> i. Can we fix them

Idaho stop and (in extremity) beg buttons would do a lot to reduce this problem.

> 6. Signage to allow bicyclists to
> a. Turn left at Waterhouse and Mass (now only MBTA buses can do that)
> b. Enter streets even when those streets are marked "Do Not Enter" during certain hours
> i. Cogswell
> ii. Whitimore

Yes, please. We need to make a distinction between controls that exist because cars are dangerous/unpleasant, and those that are there for safety or throughput. Where the control is only to reduce car traffic in a residential neighborhood, there should be an exception for bicycles.

> 7. Non-bikes moving in bike lanes
> a. Skateboards?

I've encountered these and they're not too bad. Wider lanes would help.

> b. Electric 'vehicles'

Again, not entirely sure of the problem, as long as they move at about a bicycle speed.

> Joggers

More of a problem; more often wrong-way, also somewhat less predictable (they're not commuting, they're exercising, sometimes they just *stop*)

You missed two other lane users:

d. roller-bladers -- these can be a problem because (1) need to dodge around road hazards (more than bikes) and (2) some have very wide leg strokes.
Not true of all roller bladers. Good roads and wide lanes would help.

e. 2-STROKE MOPEDS. Anywhere, but especially in bike lanes. These are filthy and noisy. I would cheerfully share the bike lane with sensible-speed electric things if all 2-stroke mopeds were banned from all roads. Each one of these produces as much pollution as dozens, if not hundreds, of modern automobiles.

I don't know if Cambridge can do anything about these, but great if they can.
The state ought to ban their sale outright, and should have done this a couple of years ago. There's electric alternatives now.

Lopez, Donna ATTACHMENT D

From: Leila Haery <leilahaery@gmail.com>
Sent: Tuesday, October 13, 2015 3:07 PM
To: Lopez, Donna; Kelley, Craig
Subject: Comments for today's bike safety meeting

Hello Councillor Kelley and Clerk Lopez,

I would like to submit these comments for today's Bike Safety Meeting (October 13, 2015 at 3:30 pm).

1. Cycling infrastructure in Cambridge needs to be vastly improved in order to (1) allow safer cycling in the city and (2) alleviate the burden on other forms of transportation. Currently, cycling in Cambridge is stressful and dangerous for cyclists, pedestrians, and motorists. There needs to be a massive improvement to prevent these groups from having to share limited resources (i.e., space). The infrastructure should accommodate each form of transit and limit the overlap- e.g., cars and cyclists should not have to share a single lane on the road, and the bike lane should not just be a painted stripe on the road- this causes problems as bikes and motor vehicles are two very different modes of transportation.

2. The current attitude of motorists and pedestrians regarding cyclists is currently very entitled and elitist. Meaning- cyclists are treated as second class citizens and do not have adequate resources.There are constant complaints regarding cyclists breaking the rules, but both motor vehicles and pedestrians also regularly break rules- so there is an unfair emphasis on cyclists behavior. For example, every day there are invariably cars and trucks double parked in the bike lanes on Mass. Ave., taxis/Ubers consistently pull into the bike lane for drop-offs, motorists regularly drive over the speed limit, motorists door cyclists, motorists fail to signal before turning, motorists stand within the cross-walk when stopped at red lights, exit or enter parking spots without waiting for an adequate traffic clearing, and the list goes on. Can those who drive a car honestly say that they have never rolled through a stop sign, and that they stop for the required 3 seconds every single time? I doubt it. So, cyclists are not the only ones that ignore rules. Furthermore, pedestrians regularly jaywalk and even when using a cross-walk, they do not wait for an adequate clearing but rather just walk into the street without looking (and often while staring down at their phones). If there is to be "enforcement," it should be on all offenses and not just on cyclists.

3. I do not support any extra enforcement of the rules on cyclists. Cyclists adherence to the rules is not the problem- but rather- the problem is that cyclists are forced on to the road with some motor vehicles who have no regard for their safety. Almost every single day I have to avoid a dangerous interaction with a motor vehicle, and many drivers either don't care or don't notice. Many motorists even yell at cyclists to get out of the way, with no regard for the laws that entitles cyclists to certain safety measures.

4. There should be major enforcement of moving delivery trucks and double parked cars out of the bike lanes. Especially in Central Square and Harvard Square. I routinely see Cambridge Police pass by these double parked trucks or cars with no regard whatsoever- again, highlighting the fact that infractions against cyclists are ignored, while infractions by cyclists are emphasized.

5. Finally, cycling as a method of commuting is a necessity for the future of Cambridge and the US. Environmentally speaking, it's truly outrageous that individuals continue to actively prevent improving cycling infrastructure. We simply cannot continue to consume fossil fuels and drive cars around at our leisure any longer- cycling is one of the easiest ways to ease the environmental burden of our cities.

Thank you.

Leila Haery, Ph.D.
Cambridge Resident
872 Massachusetts Avenue
Cambridge, MA 02139

ATTACHMENT E.

Public Safety Committee Hearing
Cambridge, MA
October 13, 2015
Testimony from Anne Lusk, Ph.D.

Harvard T. H. Chan School of Public Health
AnneLusk@hsph.harvard.edu 617-432-7076

Instead of ticketing bicyclists who are risking their lives to be fit, not add to traffic congestion, and not pollute, it might be worthwhile t : A. Understand the great risks that bicyclists face; and B. Consider alternatives to ticketing.

A. Driver and bicyclist phenomena:

1) **Car drivers do not see bicyclists**:
   a. Eleven percent of drivers saw the bicyclist before an impact compared with sixty-eight percent of the bicyclists who saw the driver.[1]
   b. Using video cameras to track driver's eyes, drivers turning right scan less frequently than drivers turning left and when turning drivers concentrate on major dangers.[2]
   c. Drivers "looked-but-failed-to-see" bicyclists.[3]

2) **Female bicyclists are more at risk than male bicyclists at intersections because female bicyclists wait dutifully for the light to turn green and are killed by turning trucks.** Male bicyclists can get through the intersection more quickly and also are prone to going through the red light to get away from danger.[4]

B. Solutions instead of ticketing bicyclists:

3) **Sunshields (tents over cycle tracks)** deterred bicyclists from running red lights.[5]
4) **Chinese bicycle countdown traffic signal** with a red and green bicycle and red and green numbers in the middle. This traffic signal is over the intersection so car drivers can also see that the bicyclists have their turn and are legitimate users of the road.
5) The Danes have **railings and foot rests at intersections** upon which bicyclists can balance. Perhaps a test could be conducted in Cambridge to learn if this intervention (which is easier on the narrow roads in Cambridge than a sunshield tent) might discourage red light running by bicyclists.[6]
6) **Chocolates can be given as rewards** for good bicycling behavior instead of punishing bicyclists with tickets. In Copenhagen, bicyclists are given chocolates if they are nice, signal, stay to the right, overtake carefully, and appreciate bells. [7] San Francisco has been rewarding bicyclists with chocolates for politeness.[8] Cambridge could be unique and offer chocolates to bicyclists for carefully proceeding through intersections.

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ATTACHMENTS F-1A

1a

Pergamon

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ATTENTION AND EXPECTATION PROBLEMS IN BICYCLE–CAR COLLISIONS: AN IN-DEPTH STUDY

MIKKO RÄSÄNEN* and HEIKKI SUMMALA

Traffic Research Unit, Department of Psychology, P.O. Box 13, 00014 University of Helsinki, Helsinki, Finland

(Received 19 February 1997; in revised form 21 November 1997)

Abstract—One hundred and eighty-eight bicycle–car accidents in four cities were studied by multidisciplinary in-depth analysis. The sample was representative of the national accident statistics. All the accidents were analyzed in detail to reconstruct the actual movements of those involved and to assess detection of the other party. In 37% of collisions, neither driver nor cyclist realized the danger or had time to yield. In the remaining collisions, the driver (27%), the cyclist (24%) or both (12%) did something to avert the accident. Two common mechanisms underlying the accidents were identified. First, allocation of attention such that others were not detected, and second, unjustified expectations about the behavior of others. These mechanisms were found to be closely related to the system of two-way cycle tracks and to the fact that the general priority rule is applied to the crossings of a cycle track and a roadway. The most frequent accident type among collisions between cyclists and cars at bicycle crossings was a driver turning right and a bicycle coming from the driver's right along a cycle track. The result confirmed an earlier finding (*Accident Analysis and Prevention* **28**, 147–153, 1996) that drivers turning right hit cyclists because they looked left for cars during the critical phase. Only 11% of drivers noticed the cyclist before impact. Cyclists' behavior was in marked contrast to that of drivers. In these cases, 68% of cyclists noticed the driver before the accident, and 92% of those who noticed believed the driver would give way as required by law. Cyclists with a driving license and those who cycled daily through the accident site were involved in different accident types to other cyclists. © 1998 Elsevier Science Ltd. All rights reserved

Keywords—Automobile driver, Bicycle crossing, Cycle track, Cyclists, Traffic rules, Traffic safety

INTRODUCTION

Cyclists' safety risks stem from keeping balance and track and controlling conflicts with other road users. Hospital statistics show that the former category overwhelms the latter in frequency, with 58% of cyclists being taken to the hospital (inpatients) because of non-motor vehicle bicycle injuries (Olkkonen et al., 1990), and a substantial number of accidents with minor consequences remain unreported. However, collisions with other vehicles dominate where more serious consequences are concerned, 90% of cyclists' deaths being caused by collisions with motor vehicles in Finland in 1980 (Olkkonen et al., 1990) and in the U.S.A. (Rodgers, 1995).

Earlier research has revealed certain general factors in bicycle–car accidents. The injury risk is highest for young and older cyclists in relation to exposure (Maring and van Schagen, 1990; Gårder et al., 1994). As Maring and van Schagen (1990) pointed out, age itself is not a causal factor but is related to the cognitive resources available. They further suggested that the lack of knowledge or inability to apply knowledge among high-risk groups may cause dangerous situations. This is in line with the notion in the hospital-based study by Mills (1988) that cyclists over the age 13 were less likely to have caused the accident than younger cyclists. The behavior of children seemed to be more based on the current traffic situation than the formal rules (van Schagen and Brookhuis, 1994). The knowledge of traffic rules probably also affects the type of accident that cyclists get involved in, but this connection has not been assessed. Fatality risks are substantially higher, not only for older cyclists, but also for males and for cyclists who ride in the dark (Rodgers, 1995). This can partly be explained by the fact that male and older cyclists (over 44 years) ride more often in the dark, more often on major roads and/or are more often inebriated in the U.S.A. (Rodgers, 1995). The Finnish and Swedish bicycle fatality data suggests that males continue cycling in old age, resulting in very high fatality rates per head of population in the

*Corresponding author. Tel.: 00358 9191 23468; Fax: 00358 9191 23489; e-mail: mikko.rasanen@helsinki.fi

75+ age group (200 per 1 million in Finland and 60 per 1 million in Sweden), while elderly females rather tend to avoid cycling (Summala, 1996a). Li and Baker (1996) found that the injury risk for males is in fact slightly lower than for women when the number of trips is taken into account. The study by Carlin et al. (1995) showed that the difference in injury risk between boys and girls (4–15 years) was also only a little more favorable for girls, but that children from families in the lowest income category had greater injury risk.

Olkkonen and Honkanen (1990) showed that inebriation (BACs$>1.0\ \mathrm{g\,l^{-1}}$) of cyclists increases the injury risk at least tenfold compared to sober cyclists. Olkkonen and Honkanen (1990) also showed that the fatal injury risk from falling was greater for an inebriated cyclist than the risk of collision. Furthermore, the health disorders which might be harmful in traffic may cause up to seven times greater fatality risk than the corresponding risk for a healthy cyclist (Olkkonen, 1993).

A widely known problem is that cycle tracks are safe on road sections but dangerous at intersections. Most serious bicycle accidents occur at intersections and involve collisions with motor vehicles (Gårder et al., 1994). Many attempts have been made to improve cyclists' safety with different intersection layout (see, for example, Alrutz et al., 1989; Gårder et al., 1994; Räsänen, 1995). Brüde and Larsson (1993) showed that the risk of being involved in an accident (as related to the number of cyclists who pass the intersection) at a junction increases with increasing numbers of motor vehicles but decreases with increasing numbers of pedestrians and cyclists. Much effort has been directed to calculating the various risks for cyclists but not much has been done to investigate the connection between accident type and the participant's task and characteristics in real accident situations.

Vehicle collisions involve, almost by definition, the loss of control by those involved, and this is quite often due to the loss of attention control or a failure to detect the other party (Rumar, 1990; Shinar, 1978; Summala, 1988, 1996b). The lack of detection is, expectedly, the most common feature characterizing situations in night time bicycle–car accidents, when the driver overtakes the cyclist, who is difficult to see (Hogue, 1990). Drivers' learned routines may fail to take account of a cyclist properly and cyclists' expectations may fail if they interpret driver behavior wrongly, for example, slowing down at an intersection before turning. Such a situation was recently shown, which produces bicycle–car accidents. That is, when drivers turning right watch cars from the left and fail to detect a cyclist coming from their right towards the cycle crossing which is located before a road crossing (Summala et al., 1996). Conflict management in traffic is interactive, however, and a strict interpretation of the traffic law ("one should always be able to stop in a road section ahead visible to him/her") suggests that in a collision both parties failed to manage the situation (e.g. the British Highway Code, Para. 57; the Finnish Road Traffic Code Para. 23). It is therefore important to study both cyclists' and drivers' behavior, and to consider both parties' actual tasks in the situation. It is especially important in order to explain why one or both failed in their task.

There are specific problems in research on bicycle–car accidents, however. National accident statistics and hospital records are quite limited in relevant variables (Thom and Clayton, 1993). They typically involve persons killed or injured; accident time (month, day, week, hour); site (province, municipality, type of road and junction); speed limit; circumstances of accident (weather); participants (sex, road user and age group), influence of alcohol, type of driving license and very diagrammatic classification of accident types. It is not even possible to infer the behavior of each party (their paths, directions, turns) from these data bases. However the very basic standpoint of research on causal factors should be a careful task analysis of each party (Summala, 1996b). Since data from hospital records presents a more accurate picture of the variety of bicycle accidents than police records, but do not contain enough information for bicycle accident prevention measures (Stutts et al., 1990), more detailed in-depth accident analysis is needed. This study, based on multidisciplinary in-depth analysis of 188 bicycle–car accidents in four cities, focused on the attention problems of both parties in different collision types. Special emphasis was put on accidents at bicycle crossings.

ACCIDENT INVESTIGATION METHOD

Accident investigation teams have studied all the fatal collisions with at least one motor vehicle occupant deceased across Finland since the late 1960s. This activity is organized by the Traffic Safety Committee of Insurance Companies (Hantula, 1987, 1989, 1992). In 1990, a special project on bicycle accidents was begun. The regional teams studied bicycle accidents in four cities, in Helsinki (population 497,500), Mikkeli (population 32,200), Hämeenlinna (population 43,800) and Ylivieska (population 13,300). The data included all bicycle accidents reported to the police. The Helsinki sample was restricted to those cases which occurred on cycle tracks or at cycle crossings. The total number was 234 of which 46 were non-motor vehicle cases.

Each of the four accident investigation teams consisted of four members: a police officer; a vehicle engineer; a traffic engineer; and a physician. The chairman of the investigation team was informed about an accident by the local police officer. The chairman then called the team to the scene of the accident as soon as possible. Each member had a checklist for his particular investigation sector. These forms were later coded on to files. The police member's duty included collection of the general information regarding the accident and interviewing the parties involved. The variables to be considered included events before the accident, how and why the accident occurred and the background of each party. The vehicle engineer examined the vehicle's technical condition and external damage to the vehicle. The road engineer examined the condition of the road, sight distances and geometric features of the road and reconstructed the pre-crash phase, including a time schedule in seconds. Physicians determined the physical and mental capacities of drivers and cyclists and what affects these factors may have had on the accident. The data obtained by each member was compared at the final meeting. The final report covered the accident itself, the factors contributing to it, injuries sustained and their causes, the effect of safety devices, ways of improving safety and measures carried out or proposed for improving local conditions. If something was based on assumptions or is understood as being probable, this was also mentioned in the final report (Hantula, 1987). The level of reconstruction in these data provides a fairly reliable description of what actually happened.

RESULTS

Representativeness of the sample

The distribution and coverage of the sample is shown in Table 1.

Based on the national statistics provided by Police Statistics and Traffic Insurance Statistics, the sample was representative of collisions between bicycle and motor vehicle by accident type (see Table 2). Road conditions, time of accident, inebriation, age and gender of participants did not differ from national statistics (Räsänen, 1995). The cyclist was inebriated in 10.4% of all accidents and the driver in 4.6%. Over half of cyclists who were inebriated were involved in falling.

Accident type

Routine accident statistics do not give sufficient information on how the accident happened, or even where it happened (e.g. at what kind of crossing). All the study cases were therefore analyzed in detail to reconstruct the accident type with actual movements of those involved, by site. Out of 234 cases, 97 were collisions with a motor vehicle either at marked bicycle crossings (15) or at combined cyclist and pedestrian crossings (82); 30 cases occurred at unmarked crossings; 28 at site accesses; 17 at single combined bicycle and pedestrian crossings and 16 at route sections. There were 13 fatal cases and 21 serious cases (AIS 3–5) where cyclists' behavior was

Table 1. The coverage of the sample for 1992–1993 and the total size of sample in the four cities during years 1990–1994

City	1992			1993			1990–1994
	In-depth study	Police statistics	Traffic insurance	In-depth study	Police statistics	Traffic insurance	Total sample
Helsinki	10	153	118	11	148	133	67
Hämeenlinna	23	18	23	29	17	18	77
Mikkeli	25	21	12	22	11	21	73
Ylivieska	10	7	4	6	6	9	17
Total	68	199	157	68	182	181	234

In-depth studies were first started in the city of Helsinki in 1990, then in the city of Mikkeli in 1991 and finally in the cities of Hämeenlinna and Ylivieska in 1992.

Table 2. The representativeness of the sample by accident type: proportion of the four most frequent accident types

Accident types	In-depth study ($n=234$, %)	Police statistics 1987–1993 ($n=11{,}759$, %)	Traffic insurance statistics 1987–1993 ($n=11{,}701$, %)
Intersecting directions of travel	43	42	49
Opposite directions of travel, turn	15	10	13
Same directions of travel, turn	10	12	10
Intersecting directions of travel, turn	10	9	5

difficult to assess. These cases were distributed equally to all accident types compared to slightly injured or not at all injured cases ($\chi^2 = 4549$, $df = 4$ $p = 0.337$). Forty-six non-motor vehicle cases included 23 single, 16 cyclist–cyclist and seven cyclist–pedestrian accidents. These non-motor vehicle cases were not included in this study. Figure 1 shows bicycle–car collisions at cycle crossings by accident site and

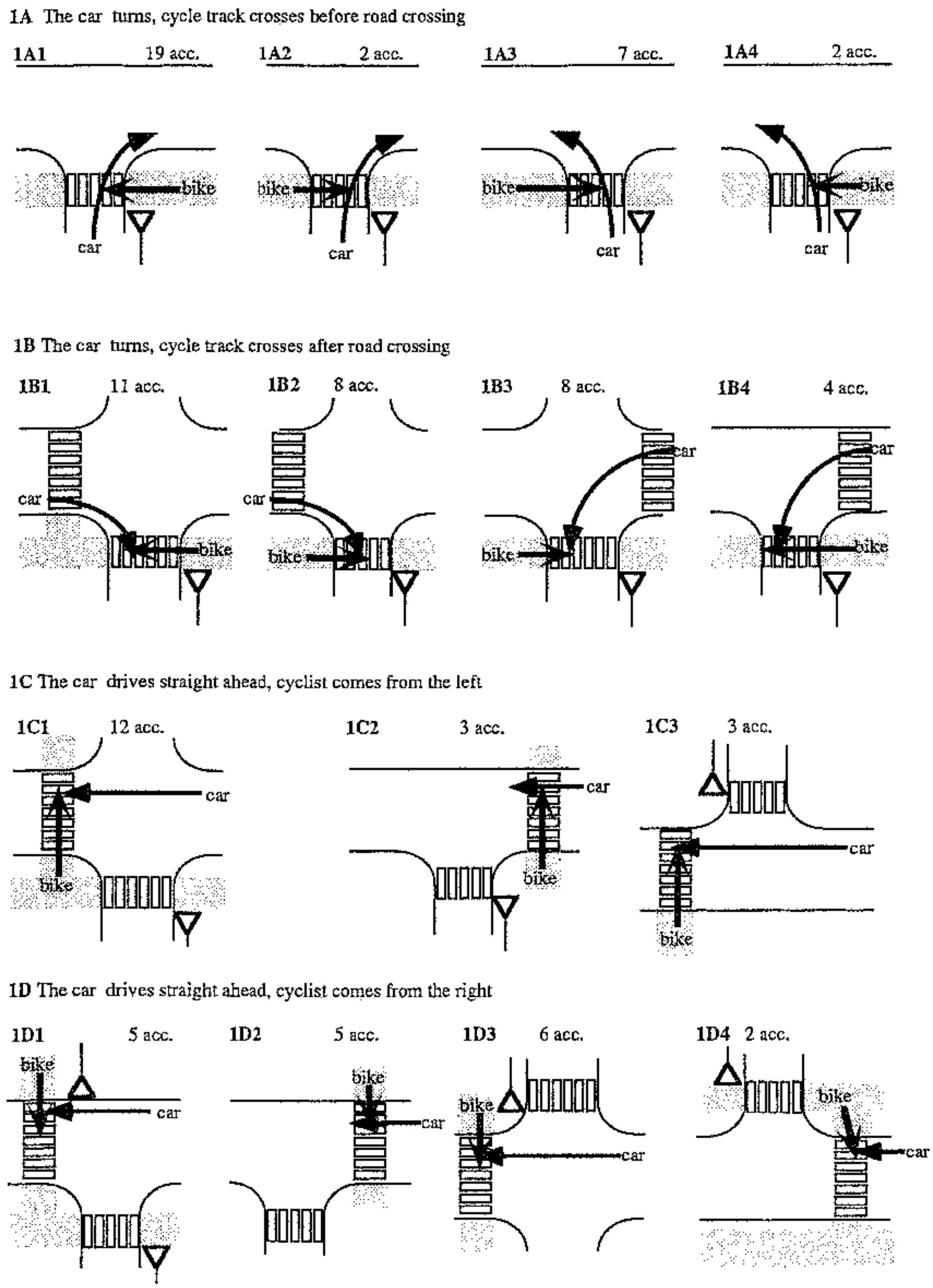

Fig. 1. Bicycle–car collisions at bicycle crossings by type ($n = 97$). Four intersections in 1B1 and 1B2 were signalized; two in 1B3; three in 1C1 and one in 1C2.

movements of those involved. In the three most frequent accident types ($n=42$; 1A1; 1B1 and 1C1), the cyclists approaches to the cycle crossing from the left side of the street.

The distribution of cases within group 1A confirmed the earlier finding that drivers turning right, but not those turning left, hit cyclists coming from the right. As many as 19 cases involved a car turning right (type 1A1), while only two cases involved a car which was turning left (type 1A1 versus type 1A4: $p<0.001$, sign test, considering the change in the driver's task only). The data suggests that a related attention problem may occur when the cyclist is coming from the left. In seven cases the driver was turning left and was presumably watching the right for cars to which he/she should yield (type 1A3). Correspondingly, there were two cases only where the driver was turning right (type 1A2) and the only direction to check for cars was the left (type 1A3 versus type 1A2: $p=0.090$, sign test). There is no reason to expect biases in exposure such as directional differences in vehicle/cycle traffic and sampling biases and, therefore these findings strongly suggest that visual search (and its timing) is largely responsible for car–bicycle accidents at crossings, in line with earlier observational data (Summala et al., 1996). This explanation was next tested against the in-depth analyses.

Attention: avoidance reactions and noticing the other party

The driver's visual search pattern may lead to a situation where a driver does not notice a cyclist. In this study, estimates about parties' behavior were based on structured interviews made by a police officer after the accident. This is not as reliable a method as the earlier observational method since parties are likely to give answers favorable to themselves. However, the parties involved were assured that the interview was only made for traffic safety purposes and it would not effect the legal standing of the parties. Furthermore, it was another police officer, who made the official interview and report. The interview was made at the scene of the accident in most of the serious cases and within few days in other cases. The final meeting of the team also brought up the possible bias and conflicts with the parties' statements when the members of the team compared their data. The taxonomy of accident 'causes' in the tables is the same which the teams used.

The teams' conclusions were that in all bicycle–car collisions, drivers had noticed the cyclist in 51% of cases before the crash and cyclists had noticed motor vehicle in 66% of the cases. Table 3 presents the different combinations of drivers' and cyclists' avoidance reactions, Neither driver nor cyclist realized the danger or had time to yield in 37% of all bicycle–car collisions. In the rest, one (drivers in 27% and cyclists in 24%) or both (in 12%) of those involved did something to avert the accident.

Tables 4 and 5 present cyclists' and drivers' avoidance reactions by group. Table 4 shows that cyclists did something to avert the accident in half the cases at bicycle crossings, when the car turned and the cycle track crossed before the road crossing (group 1A), at site accesses (group 3) and at single, separate bicycle crossings (group 4). Cyclists at bicycle crossings rarely did anything to avert the accident when the car drove straight on and the cyclist came from left or right (group 1C+D) and at unmarked crossings (group 2). Table 5 shows that the driver often did something to avert the accident in collisions at single, separate bicycle crossings (group 4) and at bicycle crossings when the car drove straight on and cyclist came from the left or right (group 1C+D). The drivers rarely did anything to avert the collision in the accidents at bicycle crossings where the car turned and the cycle track crossed before the intersection (group 1 A) and at site accesses (group 3) because drivers usually did not realize the danger at all. In the following, the results from Tables 3–5 and site properties are combined by group.

The car turns, cycle track before the road crossing: group 1A

The behavior of those involved in accident groups 1A and 3 (site accesses) was quite similar (see Tables 4 and 5). Only in these groups did the cyclist

Table 3. The cyclist's and driver's avoidance reactions

	Driver			
Cyclist	Did not realize danger	Did not have time	Did something to avert accident	Total
Did not realize danger	23	5	19	47
Did not have time	17	6	19	42
Did something to avert accident	28	5	17	50
Total	68	16	55	139

Missing data in 49 cases.

Table 4. The cyclists' avoidance reactions by accident group

	Accident group							
	1. Bicycle crossing			2. Unmarked crossing	3. Site access	4. Single bicycle crossing	5. Route section	Total
	A	B	C+D					
Did not realize	8	6	14	10	5	5	8	56
Did not have time	6	9	12	11	9	2	0	49
Did something to avert accident	14	9	3	4	12	8	6	56
Total	28	24	29	25	26	15	14	161

$\chi^2=18.62$, $df=6$, $p=0.005$, did not realize+did not have time versus did something to avert accident (missing data in 27 cases).

Table 5. The drivers' avoidance reactions by accident group

	Accident group							
	1. Bicycle crossing			2. Unmarked crossing	3. Site access	4. Single bicycle crossing	5. Route section	Total
	A	B	C+D					
Did not realize	17	15	5	9	15	4	8	73
Did not have time	4	2	6	7	4	0	1	24
Did something to avert accident	3	11	24	13	6	11	5	73
Total	24	28	35	29	25	15	14	170

$\chi^2=28.27$, $df=6$, $p<0.001$, did not realize+did not have time versus did something to avert accident (missing data in 18 cases).

more often something to avert the accident and drivers realized the danger less frequently than in other groups, perhaps because the accident site was similar in both accident groups. The collision between a driver turning right and a cyclist coming from the right typically occurred at the intersection of a collector road and a residential road with rather low traffic volumes, which is the normal situation at site accesses. In fact, in 10 of the 24 accidents at the site accesses, the direction of motion of the participants was the same as in the largest accident type (1A1).

Many cyclists had noticed the driver before accident in accident group 1A but could not prevent the accident. To clarify this matter the authors analyzed the most frequent accident type (1A1) in more detail. Figure 2 shows that cyclists noticed the motor vehicle in 13 of 19 cases in accident type 1A1. Twelve of these cyclists supposed the driver would give way. Only two drivers out of 19 noticed the cyclist, however.

These results clearly support an earlier finding that the reason why drivers did not notice the cyclist coming from the right proved to be inappropriate scanning behavior. Cyclists on the other hand seem to trust too much that drivers would give way.

The car turns, cycle track crosses after road crossing: group 1B

It can be seen from Fig. 1 that the angular view which drivers needed to notice a cyclist in accident types 1B1 and 1B3 were within 140° of forward visual field and in types 1B2 and 1B4 outside 180° of the visual field before the accident. In the former case, the driver could see the cyclist without head movements but in the latter could not. This naturally applies to cyclists too. The data supported this because in types 1B1 and 1B3 accidents 10 out of 19 drivers did something to avoid the accident, but only in three cases out of 12 among types 1B2 and 1B4 did the driver have time to take evasive action. Cyclists assumed in 52% of accidents that when the driver turned from the opposite direction (types 1B1 and 1B3) that the driver had noticed him or her and would give way.

The car drives straight ahead, cyclist comes from the left (group 1C) or right (group 1D)

Cyclists' and drivers' behavior at bicycle crossings in accident groups 1C+D was completely different to their behavior in group 1A. This is because the drivers' task was quite different. In most of the cases in the groups 1C+D drivers did not have to scan other cars any more because they were leaving the intersection and in this situation the driver usually had more time to take evasive action than in the situation where the driver approached the intersection.

In fact there was also a difference in the traffic situation between groups 1C and 1D. In the accidents of group 1C the driver had more time to react because the cyclist had been on the roadway for some time before reaching the car's path while in group 1D the

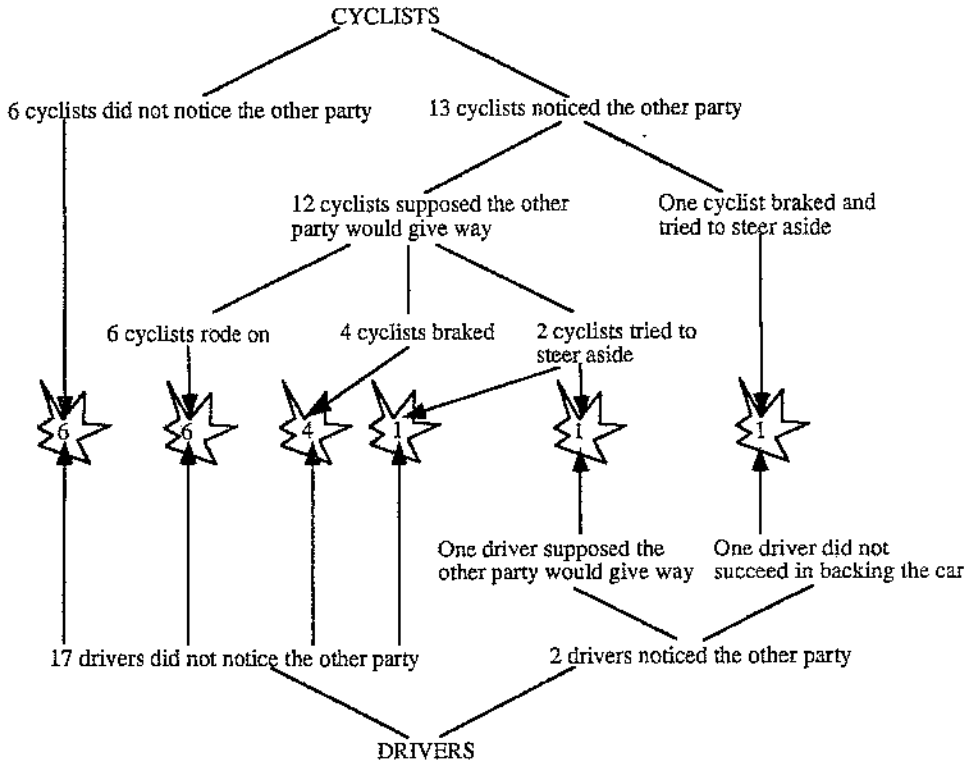

Fig. 2. Cyclists' and drivers' assumptions and behavior before accident in type 1A1 ($n = 19$).

situation was more surprising for a driver, particularly if there was a sight obstacle. The results confirmed this hypothesis: 15 out of 17 drivers had time to take evasive action in cases of group 1C while half the drivers (9/18) either did not realize or have time to do anything in cases of group 1D ($\chi^2 = 5.90$, $df = 1$, $p < 0.05$). Unfortunately the accident data was too small to make a more detailed analysis of the background factors of drivers involved in accident groups 1C and 1D.

Cyclists' driving licence and familiarity with the accident site

Table 6 shows that cyclists with a driving license were more often involved in accidents where they had a clear right of way (groups 1A and 3) than in other accidents. This was even more pronounced in the accident type 1A1 where 15 of 19 cyclists had a driving license.

The accident site was usually very familiar to cyclists in accident groups 1A and 5 (Table 7). Furthermore only one cyclist with a driving licence did not cycle daily at the accident site in the group 1A (Table 8). This implies that cyclists in many cases know perfectly well that they have right of way.

The reports of road investigation teams

According to the accident investigation teams, sight obstacles were the most frequent risk factor in the traffic environment in collisions between motor vehicles and cyclists especially at bicycle crossings. Based on the injuries sustained, it was the opinion of

Table 6. Cyclists with a driving license by accident group; cyclists aged 18 or more only included

	Accident group							
	1. Bicycle crossing							
Driving license	A	B	C+D	2. Unmarked crossing	3. Site access	4. Single bicycle crossing	5. Route section	Total
Yes	16	9	9	7	12	7	8	68
No	8 (6)[a]	9 (8)	12 (9)	15 (5)	3 (9)	2 (7)	6 (2)	55 (46)
Total	24	18	21	22	15	9	14	123

$\chi^2 = 13.24$, $df = 6$, $p = 0.039$ (missing data in 17 cases).
[a]Number of cyclists under 18.

Table 7. Familiarity of the site among cyclists by group

	Accident group							
	1. Bicycle crossing							
Movement frequency	A	B	C+D	2. Unmarked crossing	3. Site access	4. Single bicycle crossing	5. Route section	Total
Daily	23	11	16	17	9	9	13	98
Seldom	4	11	13	9	11	7	3	58
Total	27	22	29	26	20	16	16	156

$\chi^2 = 13.47$, $df = 6$, $p = 0.036$ (missing data in 32 cases).

Table 8. Familiarity of the site among cyclists by group; holders of driving license only

	Accident group							
	1. Bicycle crossing							
Movement frequency	A	B	C+D	2. Unmarked crossing	3. Site access	4. Single bicycle crossing	5. Route section	Total
Daily	13	2	4	6	6	3	5	39
Seldom	1	7	5	1	5	5	3	27
Total	14	9	9	7	11	8	8	66

$\chi^2 = 8.381$, $df = 1$, $p = 0.004$, 1 A versus other groups.

the team that the use of a bicycle helmet would had prevented, for sure or in all probability, the death of eight cyclists out of 13 and injuries would had been prevented or became less severe in 42% of the cyclists ($n = 250$).

DISCUSSION

In the present study the investigation teams concluded that only in 17% of bicycle–car collisions did both participants not notice the other at all before the accident. At least one participant had noticed the other in all the other accidents. Why did the accident happen then? The results suggest two main mechanisms producing bicycle–car collisions which can both be present and linked to each other. The first is the improper allocation of attention which is primarily related to visual search strategies, in which drivers may ignore a cyclist who comes from an unexpected direction (Summala et al., 1996). If a driver is late looking in the relevant direction, he/she simply has no time to stop or yield before hitting the other party. The other mechanism involves misplaced expectations of the behavior of the other party. Cyclists supposed in many cases that the driver would give way as required by the law. Two contributing factors can be seen behind these mechanism.

In Finland, a widely-used solution for cycle traffic is two-way cycle tracks. This often causes unexpected situations for a driver, because a cyclist can appear from a direction inconsistent with normal car traffic flow. In all of the three most frequent accident types, the cyclists approached the cycle crossing from the left side of the street, which can be seen as the most unexpected direction for a driver to encounter a cyclist. Therefore, the accident type where the driver is turning to the right and cyclist is coming from the right (the left side of the street) is the most frequent at non-signalized intersections in Finland. This is also the case in Germany (Kerwien, 1996). Keskinen (1982) already observed the selective attention problem in drivers who enter an intersection where a cycle track crosses in front of it and Schnüll et al. (1992) and Wachtel and Lewiston (1994) demonstrated a greater risk for cyclists riding on the left side of the street. The detailed analysis by Hunter et al. (1995) of bicycle–car crashes of in the U.S.A. indicated that a great proportion of bicycle accidents includes cyclists who come from the 'wrong' (unexpected) side of the road.

The second factor which promotes wrong expectations is the law which gives right of way to a cyclist who comes from the right also at the crossings of a cycle track and roadway. (The law actually changed in June 1997, after completing this study.) Two-way cycle tracks and this law made the cyclists, who come from an unexpected direction from a driver's point of view, have a right of way. From a cyclist's point of view car drivers should yield, according to the law and his/her expectations are seemingly confirmed as drivers usually decelerate when entering an intersection.

This accident type with attention misallocation among drivers and misplaced expectation among cyclists was frequently related to the cyclist's ownership of a driving licence and daily usage of the accident site. Those cyclists who knew the rules were more probable to use their right. The combination of a familiar route and knowledge of having right of way may cause a riding routine in which cyclists do not watch motor vehicles coming from the left carefully enough, especially when drivers have to yield according to law. The accident site also plays a significant role. These accidents typically occur at intersections between a collector road and a residential road. The cyclist has to cross a residential road with low traffic volumes and little expectations of a car coming from it. This was supported by the fact that cyclists in accidents at site accesses, where the cyclists' right of way was similarly very clear, also had a driving license more often than in other collision types.

More complicated traffic situations for cyclists arose, instead, at unmarked crossings (group 2) and at bicycle crossings where the car drove straight ahead and a cyclist came from the left or the right to a major road (group 1C+D). To cross a major road is more demanding than a minor road for a cyclist, especially when the right of way law is indistinct in these traffic situations. Accordingly, cyclists involved in an accident hardly ever did anything to avert it.

Earlier research shows that injury risk is higher for children and elderly cyclists (Maring and van Schagen, 1990; Gårder et al., 1994) and Keskinen (1982) accordingly points out that a special problem of bicycle (and pedestrian) safety stems from the great individual variance in cyclist and pedestrian behavior: children, elderly, and inebriated cyclists behave sufficiently unpredictably to make the driver's task difficult. However, there are specific, rather frequent accident types in which the cyclists involved have a driving licence and are clearly riding according to the traffic rules, but in taking their rights, they may also behave deviantly from the driver's point of view and violate drivers' expectations. It seems now that there is a quite large proportion of bicycle–car accidents in which cyclist's and driver's behavior is both very predictable and results in hazards. Further progress in cyclist safety requires that accident prevention measures be focused on specific kinds of sites and problems.

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ATTACHMENT F-1B

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BICYCLE ACCIDENTS AND DRIVERS' VISUAL SEARCH AT LEFT AND RIGHT TURNS

HEIKKI SUMMALA,[1] EERO PASANEN,[2] MIKKO RÄSÄNEN,[1] AND JUKKA SIEVÄNEN[1]

[1]Department of Psychology, Traffic Research Unit, P.O. Box 11, FIN-00014 University of Helsinki, Helsinki, Finland and [2]City of Helsinki, Traffic Planning Division, Aleksanterinkatu 26, FIN-00170 Helsinki, Finland

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Abstract—The accident data base of the City of Helsinki shows that when drivers cross a cycle path as they enter a non-signalized intersection, the clearly dominant type of car-cycle crashes is that in which a cyclist comes from the right and the driver is turning right, in marked contrast to the cases with drivers turning left (Pasanen 1992; City of Helsinki, Traffic Planning Department, Report L4). This study first tested an explanation that drivers turning right simply focus their attention on the cars coming from the left—those coming from the right posing no threat to them—and fail to see the cyclist from the right early enough. Drivers' scanning behavior was studied at two T-intersections. Two well-hidden video cameras were used, one to measure the head movements of the approaching drivers and the other one to measure speed and distance from the cycle crossroad. The results supported the hypothesis: the drivers turning right scanned the right leg of the T-intersection less frequently and later than those turning left. Thus, it appears that drivers develop a visual scanning strategy which concentrates on detection of more frequent and major dangers but ignores and may even mask visual information on less frequent dangers. The second part of the study evaluated different countermeasures, including speed humps, in terms of drivers' visual search behavior. The results suggested that speed-reducing countermeasures changed drivers' visual search patterns in favor of the cyclists coming from the right, presumably at least in part due to the fact that drivers were simply provided with more time to focus on each direction.

Keywords—Black event, Driver behavior, Intersection, Visual search, Selective attention

INTRODUCTION

An early accident prevention strategy among road and traffic engineers was to put pins for each accident on a map and react with appropriate modifications of black spots where pins accumulated. Quite often even one serious accident triggered this corrective process, and still does so. This method has often been efficient in promoting safer (and more fluid) traffic, but often without proper understanding of accident causes and at the risk of directing resources randomly (e.g. Hauer 1986). Along with this "geographical" black spot method, however, it is essential to continue searching for black spots in the accident mass by splitting it into smaller components by type and participants' behavior, by road and traffic conditions, even by time of week, weather conditions, and participants' characteristics. Well-defined black spots, or peaks in the accident mass are of practical and theoretical significance to accident prevention even without corresponding exposure measures. Thus, by splitting the accidents further by site and each participant's behavior we can ultimately find the elementary road user tasks which also, along with corresponding behavioral studies, make reaching causal explanations possible (Summala 1995). This in turn leads to improvement of general design standards and understanding of road user behavior and accidents, which are not necessarily accessible for a traffic engineer or accident investigator from one single crash or a few at one specific site.

This study applied the generalized black spot, or *black event* schedule to analyze car-cyclist collisions at non-signalized intersections in the Helsinki City area. Based on an earlier work of Pasanen (1992), this paper first reports a marked peak in a certain accident type—a black event—in these collisions. Next it presents field tests for the explanation that drivers develop a visual scanning strategy which favors detecting conflicting motor vehicles but ignores cyclists. Last, preliminary results are presented on the effects of various countermeasures on driver scanning strategies.

BICYCLE-CAR COLLISIONS AT NON-SIGNALIZED STREET CROSSINGS

The City of Helsinki maintains a database consisting of all accidents reported by the police. All the collisions between bicycles and cars, for the years 1987-89, which occurred at non-signalized intersections were identified. These included 39 accidents at 25 intersections altogether. The 19 three-way and 6 four-way (with minor fourth leg) intersections typically consist of a collector road and a residential road with rather low traffic flows (about 200–1000/day). There were both priority and non-priority intersections. However, in the latter case, too, drivers have to yield to cyclists coming from the right according to the general rule in the Finnish traffic code. It should be noted here that the Finnish traffic code allows two-way cycle paths which cyclists use extensively in both directions.

The collisions were split according to the actual direction of motion of the participants into 8 types (Fig. 1). It appeared that a large majority of cases were of one specific type in which a driver was turning right and the cyclist was coming from the right (27 out of 39). This type of collision appears to be a specific safety problem—a black event in the accident mass.

The distribution of 39 collisions into 25 intersections implies that the bias towards one type is not the fault of a few specific intersections, although it is to be noted that the dominant type was more pronounced at 12 sight-obstructed intersections (18 out of 21) than at the other 13 with more adequate sight distances (9 out of 18). It is obvious that exposure to risk expressed as the total number of passes through the intersection cannot explain this extremely skewed type of distribution; although exposure data are not available, there is no reason to suppose such a skewed distribution in the respective flows. We should rather search for the explanation in the behavior of drivers and cyclists. To control for cyclists' behavior, it is further advisable to consider the cases where the driver is about to cross the cycle path before the intersection, and the cyclist is coming from the right. From the total of 30 such collisions, cars turning right hit the cyclist in 27 cases (type A) against 3 of those who were turning left (type C).

The driver's task is different in the two situations considered. While turning left he has to be aware of cars (and other motor vehicles) coming both from left and right but while turning right he has a conflicting path with cars coming from the left only. (It is of special interest to note that drivers turning left manage better with cyclists although their task—considering the need for detecting cars from two directions—is more demanding.) We hypothesized therefore that the explanation lies in the major difference in visual scanning behavior shaped by major threats from motor vehicles, in that while drivers turning right look left for cars and miss cyclists on the right, drivers turning left also have to scan right and incidentally detect cyclists in doing so. This hypothesis was tested using unobtrusive observation techniques in real-life settings.

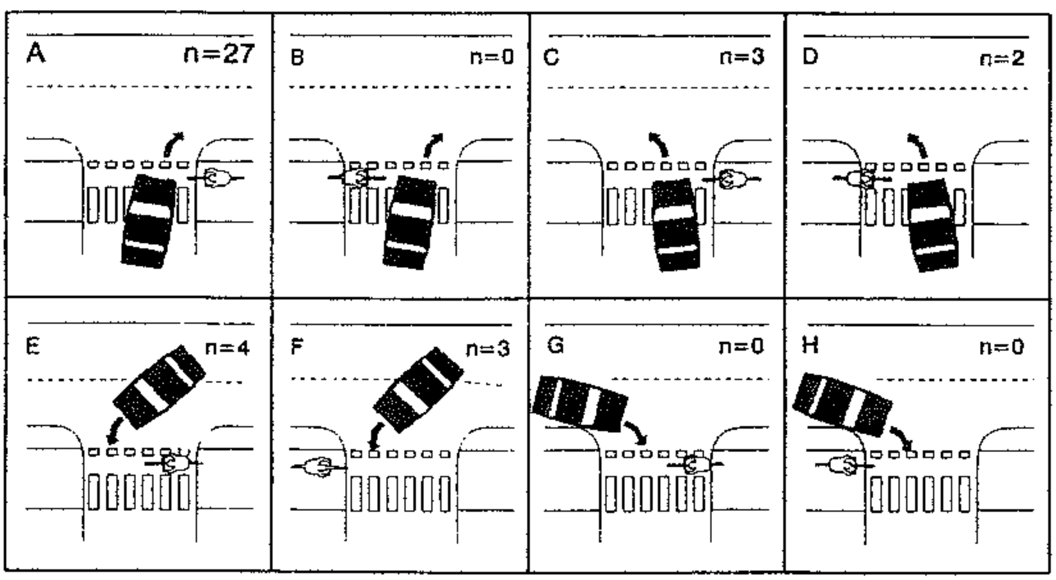


Fig. 1. The bicycle–car collisions by type.

DRIVERS' SCANNING BEHAVIOR WHEN APPROACHING AN INTERSECTION

Method

At two sight-obstructed T-intersections, drivers' head movements were recorded as they approached the intersection. Two videocameras were used for recording (see Fig. 2). One camera (Sony 8 TR55) was positioned at the opposite side of the intersection and showed the windshield and head of the driver. The other one (Panasonic A2) was positioned at the side of the joining leg to show the location of the car at each moment. Both cameras were positioned so that drivers did not notice them. The two tapes were synchronized and later mixed into one screen for the analyses.

Three samples of 3 hours, at both intersections, were collected during non-peak hours in the fall of 1990. Two observers also watched approaching drivers from a car in the line of parked cars at some distance from the intersection. They independently estimated the age (nominal accuracy of 5 years) and gender of the subject drivers. The interrater agreement was rather good for both variables (r_{xy} for age equalled 0.78, and gender matched in 98.5% of cases).Only those car and van drivers who could freely approach and turn into the major street, with no other road users present, were included in the data. The number of acceptable subjects amounted to 51 at Site 1 (33 left and 18 right) and to 60 at Site 2 (44 left and 16 right).

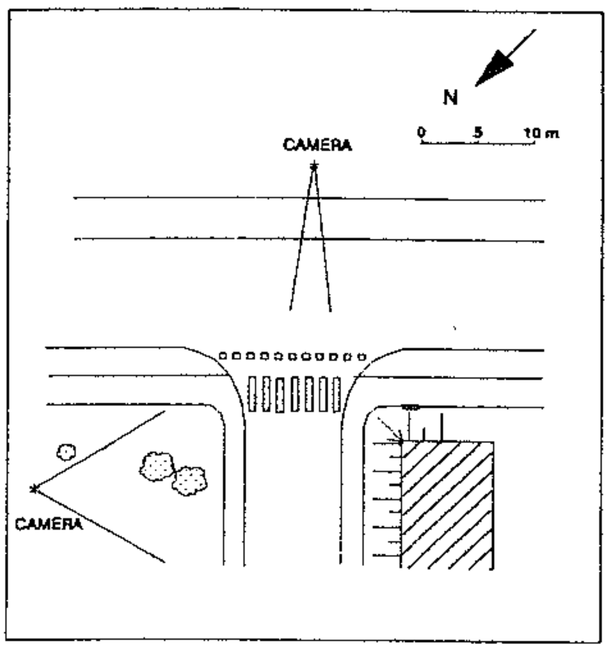


Fig. 2. Measurement Site 1 with its two videocameras. The subject drivers approached the intersection from below and either turned left or right.

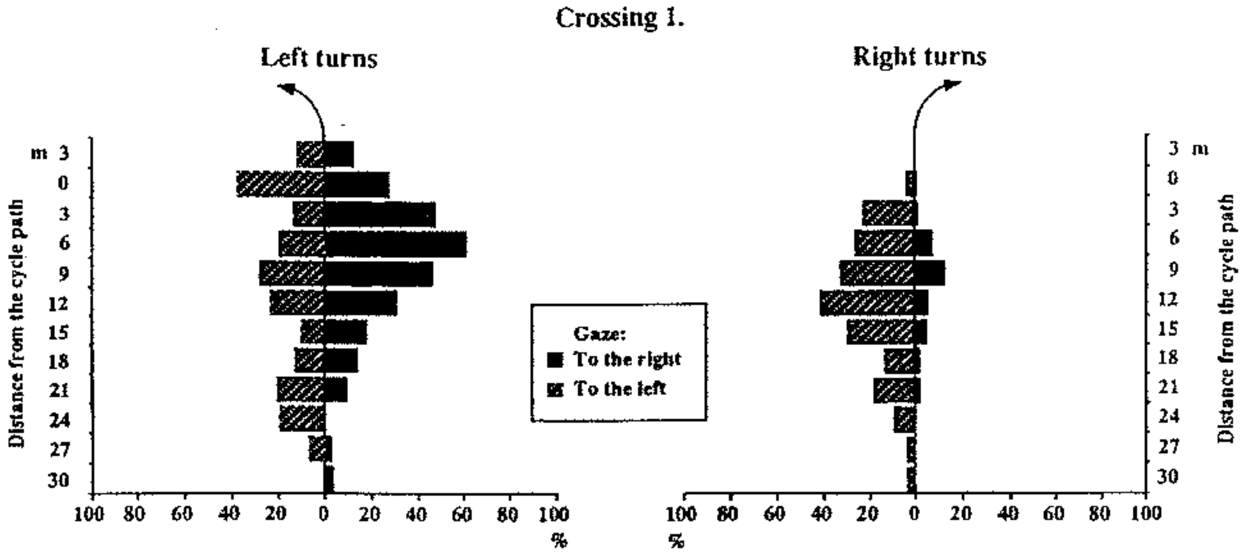
The driver's line of sight was estimated looking at drivers' head movements from the videotapes at intervals of 1 m distance from the cycle track. (The resolution of videotapes did not make estimation of eye-movements possible.) A distinction was first made whether the direction of head of the driver differed from straight ahead or not. If it did, estimates were made using a high nominal accuracy of 5 degrees (as many as 36 steps between straight left and straight right) using order information during successive head-movements. The reliability of the ratings of the two independent observers was very satisfactory ($r_{xy} = 0.73$). In the main analyses, the data were reduced into a three-point scale: looks left, straight ahead, or right. Driving (travel) speed was calculated from the lateral videotape at three distances—at the cycle intersection as well as at two places before it.

Results

Figure 3 shows the proportion of drivers looking left and right averaged over each 3 m stretch as they approached the cycle path, for left and right turns separately.

The results confirmed our hypothesis at both intersections. Most of drivers turning left looked to the right at the location where the view to the right starts to open up a little before the driver passes the corner of sight-obstructing building. The maximum proportions of 60 and 100% were reached 6 and 9 m before the cycle path at each site. In marked contrast, however, drivers turning right rather continued to look left, the respective proportions of right-looking drivers only being 7 and 3% at the same locations. The multivariate analysis of variance with repeated measures for the distance (7 levels) showed a highly significant direction × distance interaction both for Site 1 (Rao's f-appr. with 6 and 44 $df = 4.07$, $p = 0.003$) and for Site 2 (Rao's f-appr. with 6 and 53 $df = 4.06$, $p = 0.002$).

At Site 1, with more variance in approach speeds, scanning behavior was analyzed by speed (computed 8-13 m in front of the cycle path). The average gaze direction is presented in Fig. 4 for three speed groups of equal size. Among drivers turning left, the higher speed expectedly results in more marked—more uniformly timed—looks to the right just at the sight obstacle when the view starts to open up (Rao's f-appr. with 12 and 136 $df = 2.3$, $p = 0.008$). Among drivers turning right, those with lower speed show a somewhat different strategy with two peaks of looking left (16–12 m and 5–3 m before the cycle path) and with some more looks right in between, in contrast



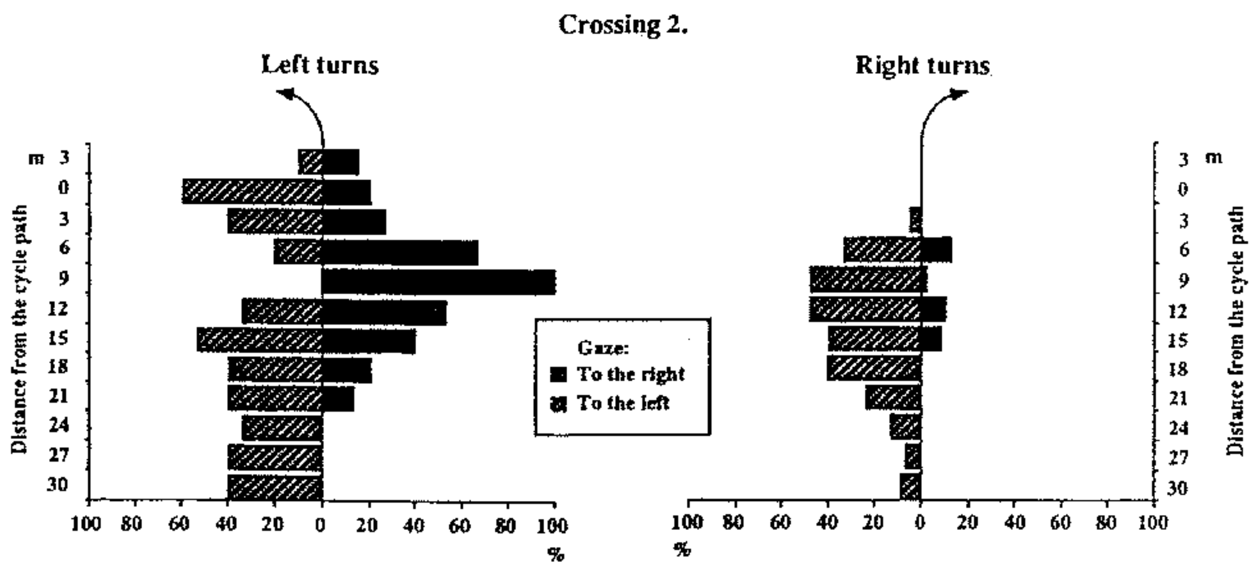


Fig. 3. The proportion of drivers looking left and right when approaching a T-junction, as a function of the distance from the cycle path, separately for left and right turns and for both study intersections. Each point on the *y*-axis refers to the center of each 3 m stretch of distance.

to more even left-looking strategy in faster drivers, but the effect was not statistically significant. It should be noted here that there was no difference in approach speed between the drivers turning left and right and, therefore, speed could not explain our main results of different scanning behavior. Neither estimated driver age nor gender appeared to have significant effects on scanning behavior. (Note however that we could not observe a sufficient number of beginners who are of importance in understanding how drivers learn certain search strategies.)

TRAFFIC TREATMENTS TO MODIFY DRIVERS' SCANNING BEHAVIOR

In the next phase, specific arrangements were introduced by the City of Helsinki to improve the scanning (and speed) behavior of drivers turning right at six intersections with a cycle path and restricted sight.

Treatments

There were three types of measures intended to change drivers' behavior, applied either alone or

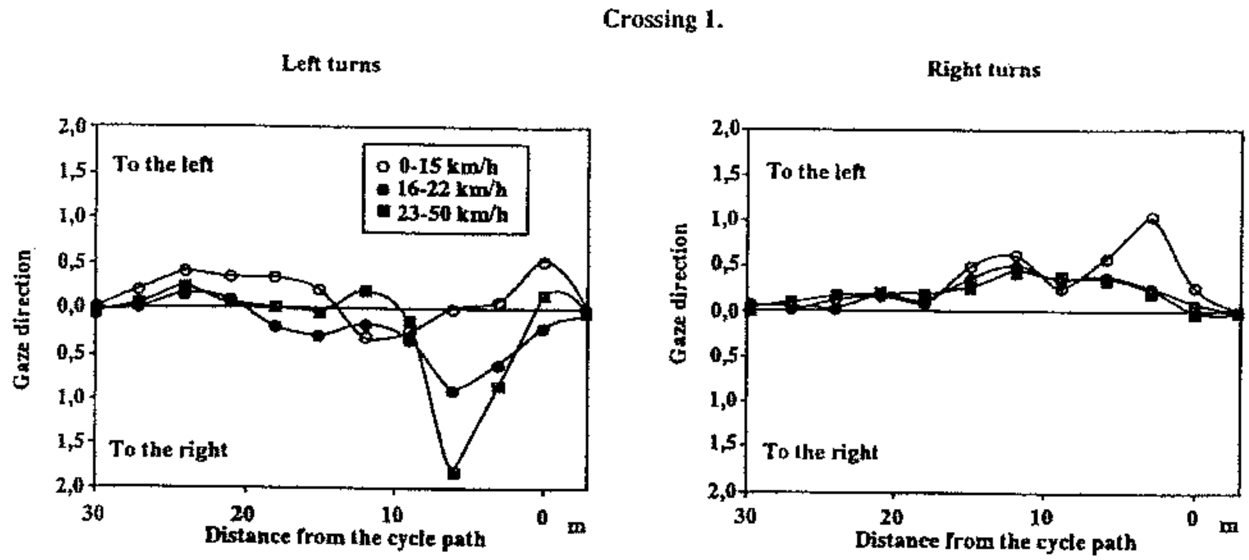


Fig. 4. The average gaze direction (the unit approximately equals 5°) by approach speed, separately for left and right turns.

together with others. (It is to be noted that these treatments were rather preliminary and exploratory in nature.) The first group consisted of warnings painted or installed at the site, aimed at drawing drivers' attention to the cycle path. These warnings included a triangular warning sign painted on the pavement before the intersection and a bicycle sign at the cycle intersection, however not indicating bi-directional cycle traffic. The second group consisted of a hump, an elevated bicycle crossing, and a stop sign prior to the cycle path. This was to provide more time for drivers in conflict situations and to allow or indeed compel drivers to allot time to both directions. Lastly, at one site, a one-page information sheet on the risks at the cycle path was distributed to all of the 70 householders in the residential area near the intersection.

Data collection

At each of the six sites, drivers' head movements were studied before and after these treatments. The method was the same as in earlier measurements. However, only drivers turning right were included, and for each site a critical area was determined within which the driver should look right to be able to detect the oncoming cyclist and give way.

The following method was used to calculate the critical area. The latter boundary (T) of the area simply equalled the (reaction and) stopping distance from the cycle path:

$$T = vt + v^2/(2a),$$

where

v = the speed of the car (m/s)

t = the reaction time of the driver (0.5 s; assuming fairly alert drivers when turning at an intersection, a small value was used in comparison with those measured for unalerted drivers on a plain road; cf. Olson and Sivak 1986; Summala and Koivisto 1990)

a = the deceleration of the car (8 ms^{-2}).

If the driver does not look right until after this boundary and notices a cyclist approaching, he or she can no longer stop before the cycle path. On the other hand, it is of no use to scan to the right too early because of the sight obstruction which prevents the driver from seeing the bicyclist. The front boundary (F) of the critical area was derived from the formula:

$$F = c + v_a/v_b d$$

where

c = distance of the cyclist's path from the corner of the sight-obstructing building

d = distance of the driver's (head) path from the corner of the sight-obstructing building

v_a = the approaching car's speed (actually measured)

v_b = the approaching cyclist's speed (expected top speed, 5.6 m/s was used)

The drivers were then classified into three groups according to whether they kept their head turned left throughout the critical area ("hazardous"); whether they looked right within the critical area ("safe"); and others ("intermediate").

Results

Computed across the sites, a marked increase occurred of those looking right ("safe", from 8% to 31%) and a decrease of those looking left only ("hazardous", from 43% to 25%).

Figure 5 shows the results by site. Due to the small number of observations they only suggest that the proportion of dangerous drivers decreased and safe drivers increased at the four intersections with speed-reducing measures (bump, elevated cycle crossing, stop sign). As expected, the average driving speeds also decreased correspondingly.

DISCUSSION

This study first revealed a peak in a certain accident type in car–cycle collisions at street crossings. In these data, the clearly dominant type was that in which a cyclist comes from the right and the driver is turning right, in marked contrast to the cases with drivers turning left. Unobtrusive field studies confirmed the hypothesis that drivers turning right simply focus their attention on the cars coming from the left—those coming from the right posing no threat to them—and fail to see the cyclist from the right early enough. The preliminary results also suggested

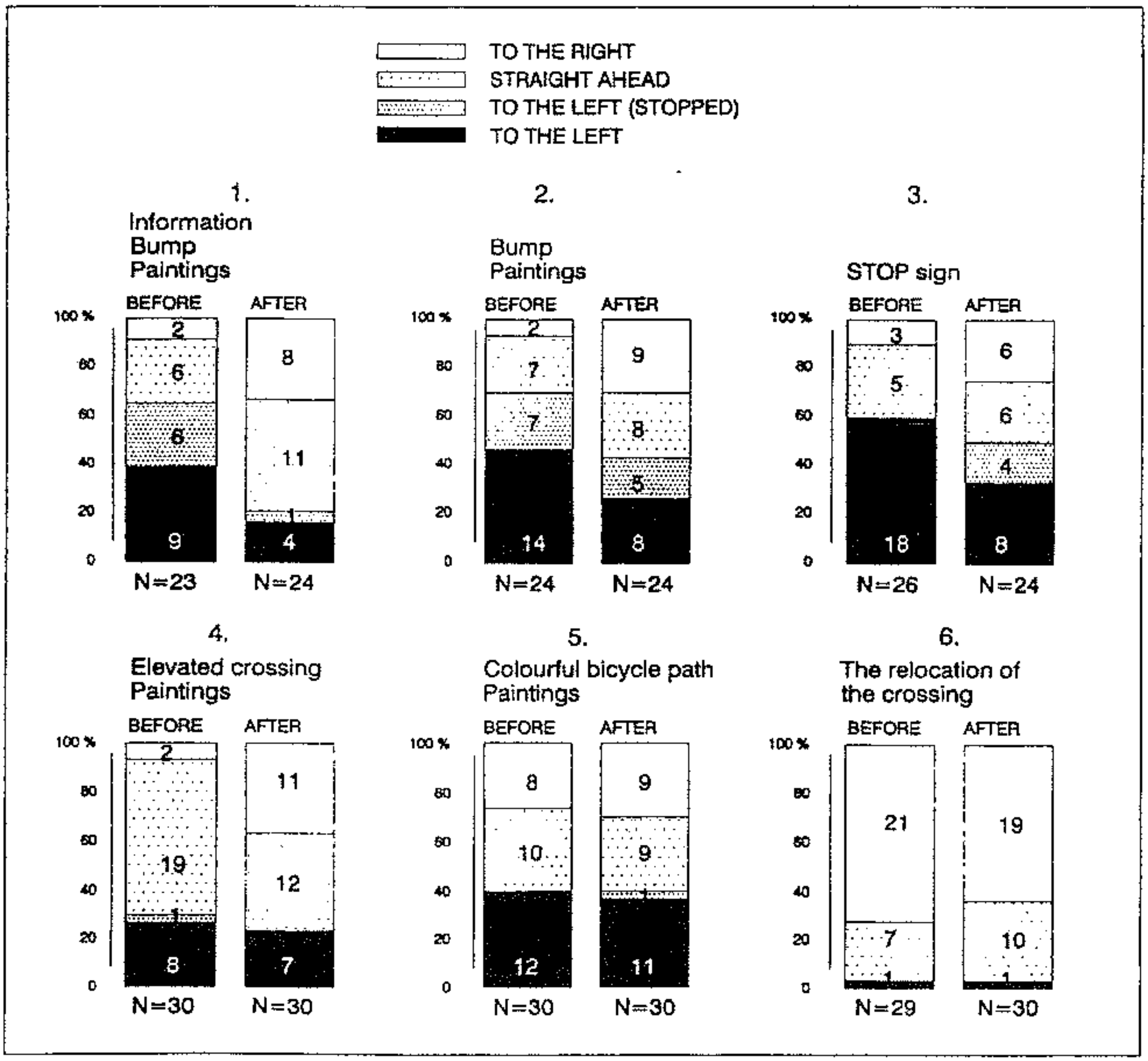


Fig. 5. Six sites with different control measures, and scanning behavior (head movements) of drivers in the critical area before and after the control measures respectively. The drivers who only look to the left and do not stop can be classified as hazardous (black), and those who also look to the right as safe (white).

that speed-reducing countermeasures along with road markings changed drivers' visual search patterns more favorably for the cyclists coming from the right, presumably due to the fact that drivers were simply provided with more time to focus on each direction. The positive effect of these measures was partly confirmed by Beilinson et al. (1992) who performed additional behavior measurements at one of our study sites (Site 1) for a Nordic project (Herslund et al. 1994). Based on on-site estimates of head turns by one observer only, their sample indicated that the number of drivers turning right who looked both left and right before the intersection increased from 21 to 34%. The corresponding figures for drivers turning left showed a decreasing trend (from 72 to 57%), however, presumably implying that a larger share of drivers stop because of the new modifications.

The results of this study show that in a given environment—infrastructure—drivers' visual scanning differentiates according to their specific task and results in "black events", i.e. behavior which does not take into account certain hazards. This differentiation is in line with the general notion that, with experience, drivers learn what is important in the traffic environment and where is it located (Fuller 1984; Näätänen and Summala 1976; Summala 1987, 1994; Theeuwes and Hagenzieker 1993) and, just as in any sufficiently constant environment, develop efficient visual scanning strategies (Moray 1990). Thus drivers learn to scan the relevant directions at intersections to avoid collisions with motor vehicles but, at the same time, they may even develop a scanning strategy which masks visual information about less frequent and less imminent dangers such as a cyclist coming from the right. With a normal visual field of 180°, drivers can detect movement at the far periphery, resulting in orienting reaction and head movement (Sanders 1963) but, as shown by these data, when scanning for cars with the head turned left they may "actively but unintentionally" lose any visual information from the right at the critical phase.

This can be seen as fully rational behavior on the driver's part because it takes the major threats into account, but he or she may not have learnt that there may be cyclists coming from the right in front of the intersection and if there are, our driver has probably learnt that cyclists normally give way. On the other hand, we should note that drivers trade between speed and safety, and they may optimize scanning behavior given a certain speed: to keep "sufficient" speed, they simply have to be selective in attention allocation to the degree that they have to ignore some minor threats. And, when provided with or being forced to take more time by speed reducing countermeasures, our right-turning drivers have no need to allocate too much attention to the cars from the left and they may either scan right or at least straight ahead which makes it possible to detect cyclists with peripheral vision. Another strategy for removing these black events would be to remove cyclists coming from right unexpectedly—to avoid two-way cycle paths.

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ATTACHMENT F-1C

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Looked-but-failed-to-see-errors in traffic

Mai-Britt Herslund*, Niels O. Jørgensen

Centre for Traffic and Transport, Technical University of Denmark, Building 115, DK-2800 Lyngby, Denmark

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Abstract

Danish studies of traffic accidents at priority intersections have shown a particular type of accidents. In these accidents a car driver supposed to give way has collided with a bicycle rider on the priority road. Often the involved car drivers have maintained that they did not see the bicycle until immediately before the collision even though the bicycle must have been clearly visible.

Similar types of accidents have been the subject of studies elsewhere. In literature they are labelled "looked-but-failed-to-see", because it seems clear that in many cases the car drivers have actually been looking in the direction where the other parties were but have not seen (i.e. perceived the presence of) the other road user. This paper describes two studies approaching this problem.

One study is based on 10 self-reported near accidents. It does show that "looked-but-failed-to-see" events do occur, especially for well experienced drivers. The other study based on Gap Acceptance shows that the car driver acceptance of gaps towards cyclists depends on whether or not another car is present. Hypotheses for driver perception and for accident countermeasures are discussed.

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Keywords: Driver perception; Gap Acceptance; Near accident; Car; Bicycle; Looked-but-failed-to-see

1. Introduction

Some Danish studies on traffic accidents at priority intersections have shown a particular type of accidents. In these accidents a car driver supposed to give way has collided with a bicycle rider on the priority road. A special feature with these accidents is that often the involved car drivers have consistently maintained that they did not see the bicycle until immediately before the collision. The police reports leave the impression that the driver statements are quite sincere.

The pattern of these accidents is that the driver approaches the give-way line at a low speed and often stops. The driver then decides to start without having realised that a bicycle is very close. Suddenly the bicycle is either right in front of the car or the bicycle runs onto the car just when the car has started to move. According to the car driver statements to the police they are very surprised and shocked (Herslund, 1993, 2001; Jørgensen and Jørgensen, 1994; Summala et al., 1996; Räsänen and Summala, 1998).

Similar types of accidents have been the subject of studies elsewhere. In literature (Hills, 1980) they are labelled "looked-but-failed-to-see", because it seems clear that in many cases the car drivers have actually been looking in the direction where the other parties were but have not seen (i.e. perceived the presence of) the other road user.

This type of accidents is particularly interesting at roundabouts due to the fact that at roundabouts all traffic has to give way at the approach.

Bicycle accidents are quite numerous at roundabouts in Denmark. In general, car accidents declined significantly, where priority intersections were replaced by roundabouts (Jørgensen and Jørgensen, 1994). But collisions between cars and bicycles remain about the same. They represent 58% of the injured cyclists and 44% of all injuries. So there are good reasons to study this type of accidents.

Two studies have attempted to approach the question: (1) is it possible to show that car drivers actually look in the direction where cyclists are without perceiving them? And if so (2) are there any plausible hypotheses to explain this phenomenon?

If this is so it will probably lead to accidents, to near accidents and to close situations where a car enters the intersection with a very small safety margin—measured in time or distance—to a bicycle.

2. Findings

2.1. Pilot study of near accidents

In 1998 an in depth study of self-reported "looked-but-failed-to-see-errors" in near accidents was carried out.

* Corresponding author. Tel.: +45-4525-1548; fax: +45-4593-6412.
E-mail address: mh@ctt.dtu.dk (M.-B. Herslund).

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One purpose of the in depth studies of near accidents was to show that the numerous car–bicycle conflicts at give-way points are in fact sometimes due to the looked-but-failed-to-see phenomenon. This being done the next purpose was to see if either the involved car drivers had special characteristics or the locations were irregular.

2.1.1. Method of near accident studies

After advertising in different papers and at some working places in the suburbs of Copenhagen 10 persons who had experienced a near accident announced their interest to participate in the study. Eight of these persons were car drivers and two were cyclists. In the cases where the cyclist made the first contact to the researcher the car driver also accepted to participate in the study. Thus all subjects of the study have *actively* chosen to participate, mainly because the near accident was a shocking experience, which the involved parties wanted to discuss with somebody. All self-reported near accidents had the following characteristics.

> The traffic situation was of a kind where a car driver who was supposed to give way almost collided with a bicycle, and the event occurred at a priority intersection or at a roundabout.

All the near accidents between car drivers and cyclists have been analysed by TRK analysis model (TRK, 1978). This method analyses the pre- and post crash situation as well as the accident itself in order to identify the causes of the accident.

2.1.2. Findings of near accident studies

All the near accidents took place in urban areas. Four episodes occurred at a roundabout, four in a T-junction and two in a four-arm priority intersection.

At the roundabouts the car driver was entering a roundabout while a cyclist was approaching on a bicycle path from the left. The incidents happened at larger roundabouts (central island diameter being larger than 20 m, including apron), just as the car had passed a give-way line and a pedestrian crossing and was going into the circulation area of the roundabout. Two of the car drivers were going slowly into the roundabout, as they got aware of the cyclist, who was then right in front of them. In the two other cases, the cyclist was almost hitting the left side of the car, as the car driver (at the interview he/she was not able to explain why) turned the head and spotted the cyclist.

The four near accidents at T-junctions took place in the give-way area just before the car driver entered the priority road, two were turning left and two were turning right. The cyclists were riding on a bicycle path and approaching from the left. In all cases the car driver reported, that he/she looked at both sides, that some cars passed, but that the road was clear and with no bicycles as he/she was about to drive. Then the driver sensed a movement at the left side of the car. This caused him/her to turn the head, and he/she got full vision of a cyclist, who was almost hitting the left side of the car.

Two near accidents at four-arm give-way junctions took place in the give-way area, where a minor road runs into a priority road. The cyclists were riding on the paths of the priority road. In one case, the car driver was entering the priority road from the minor road, he saw no other road users and he drove on, when a cyclist (coming from the left) appeared just in front of him. A collision was avoided because the cyclist took a big turn. In the other case, the car driver had just passed a priority road and was entering a minor road. He, too, saw no other road users and was going on, when he heard a bump and was hit by a cycle-wheel on the right side of the car.

All reported near accidents happened in bright daylight, with good driving conditions and on workdays. In all cases the car driver *knew*, that he was supposed to give way. As a part of the near accident analyses all traffic environments have been examined closely, and it is obvious that in *no* cases there have been external visual obstacles for the driver.

The descriptions of the near accidents of this study are very similar to the descriptions of other analysed accidents involving "looked-but-failed-to-see-errors", and so are the personal data of the involved parties (see also Herslund, 1993; Langham et al., 1998; Larsen, 1998).

Of the involved car drivers, there were five women and five men. Three drivers had their driving license between seven and 10 years and seven of them more than 10 years. No one had an annual driving less than 10,000 km, eight had between 10,000 and 15,000 km per year and two had more than 15,000 km per year.

In this study of near accidents experienced drivers who have been driving cars for more than 7 years commit the perception errors. They all drive more than 10,000 km per year, and they have not earlier been involved in traffic accidents. According to their own reports the car drivers were not tired, stressed or intoxicated prior to the episode, and they were not aware of any distractions, neither in the car nor outside the car. They drove their own cars, the cars were fairly new and with no known faults, and they were driving in well-known areas with the usual traffic load. The car drivers consider themselves as good and careful road users, and they are absolutely positive, that they *had* looked out for bicycles as the near accident happened.

2.1.3. Summary of near accident studies

The analysis of the various near accidents shows, that the conflicts occur because the car driver (in terms of the TRK method) is *missing all information* about the presence of a bicycle. In depth interviews of both car driver and cyclist prove indirectly, that in some give-way situations car drivers look in the direction where cyclists are, without perceiving them. As the descriptions given by the subjects of this study fully match other descriptions of "looked-but-failed-to-see-failures" in traffic, it is plausible to suggest that the "looked-but-failed-to-see-error" does *not* arise due to the physical environment but as a result of the drivers' visual search strategy and/or mental processing.

Therefore, it is well established that looked-but-failed-to-see-errors do exist in the accident category "entering traffic against priority traffic" at give-way intersections including roundabouts.

2.2. Pilot study of Gap Acceptance

One hypothesis in this project is that a car driver in certain cases will apply a visual search strategy, which occasionally may result in an accident because another road user, in this case a cyclist, is not interpreted as a real risk of conflict ("the cyclist is overlooked").

2.2.1. Method of Gap Acceptance studies

A method to examine this hypothesis empirically may be to study the way in which car drivers move into a priority area where they must give way to other road users. This process is known as Gap Acceptance. Methods to study this process are well known and have been applied in numerous studies since the work of Raff (1950) particularly in studies of the capacity of give-way intersections, including roundabouts (e.g. Ashworth, 1966; Harder, 1968). For a review of recent methods, see Aagaard (1995).

Briefly, in the method observations are made of the behaviour of car drivers who reach a give-way line. Measurements are made of the number of seconds which are available to the car driver before the first approaching road user to which the driver must give way arrives at the conflict point (see Fig. 1).

It is recorded how much time elapses from the point in time where entering car reaches the give-way line until the car or the bicycle in the circulation area reaches the measurement section. This is the recorded time gap. Furthermore, it is recorded whether the car enters the roundabout or stays behind the give-way line. This means that a recorded time gap is classified as either *accepted* for entry or *rejected* as too small for entry. It must be noted that the values found for the critical gap are sensitive to the exact position of stop line and measuring lines in relation to the priority traffic. The fact that the priority car is about 5 m further away from the entering car than the priority bicycle means that the critical gap in the car–car events is not directly comparable to the car–bicycle events.

The recordings of the present study, were made at a roundabout in the town of Frederiksvaerk (see Fig. 2). Out of approximately 2 h of continuous video recording at this roundabout approach three categories of give-way situations with selected road user combinations were studied. The entering road user was always a motor vehicle. The categories were:

1. car–car combinations, i.e. only a car and no bicycles in the circulation area;
2. car–bicycle combinations, i.e. only a bicycle and no cars in the circulation area; and
3. car–car/bicycle combinations, i.e. both a car and a bicycle in the circulation area.

Note that "car" here includes other motor vehicles but not a motorcycle. The percentage of trucks was, however, very low.

The idea was to compare these three categories. The comparison may show whether the car–car/bicycle combination seems to reflect the same Gap Acceptance behaviour as the pure car–car or car–bicycle combinations. If this is not the case there is an indication that the presence of two different road users in the circulation area changes the behaviour of the entering driver.

2.2.2. Findings of Gap Acceptance studies

In Gap Acceptance studies a parameter characterising the observations may be calculated. This parameter, called the *critical gap*, measures how large that time gap is, which is accepted by 50% of the road users. A calculation technique for an estimate of this parameter and its variance is given by Aagaard (1995) who applies a technique developed for similar purposes by Kärber (1931).

In these cases three types of events are studied.

1. Car–car combinations: 367 events were observed, in which 175 time gaps were accepted. A critical gap of 4.26 s and a standard deviation of 0.17 s were found. The figure 4.26 s is similar to other results of observations for this type of event at other roundabouts (Troutbeck, 1992; Aagaard, 1995).
2. Car–bicycle combinations: in this case there were 157 events in which 59 time gaps were accepted. A critical gap of 3.33 s and a standard deviation of 0.14 s were found. Only a few other sets of observations of this type exist (Mathiasen, 1989). They showed smaller critical gap figures than observed here, about 2.8 s. However, the geometrical layout was different and there was no distinction between car–bicycle and car–car/bicycle events.
3. Car–car/bicycle combinations: there were observations of 132 events in which 32 time gaps were accepted. The analysis of these observations is more complicated. Two available time gaps are recorded corresponding to the two priority road users:
   - 3.1. the time gap, named $t1$, prior to the arrival of the car at the conflict point and
   - 3.2. the time gap, named $t2$, prior to the arrival of the bicycle at the conflict point.

The observations in car–car/bicycle events are shown graphically in Fig. 3. Each point in the diagram represents a certain situation in traffic with respect to the available time gap for the arrival of the car and the bicycle at the conflict point. The values of $t1$ and $t2$ are recorded at the point in time where the car driver in the approach decides whether he/she wants to accept the time gaps by entering the circulation area or reject the time gaps by staying in the approach behind the give-way line.

One way of analysing the observations in Fig. 3 could be as follows. If only cars and no bicycles were present it should

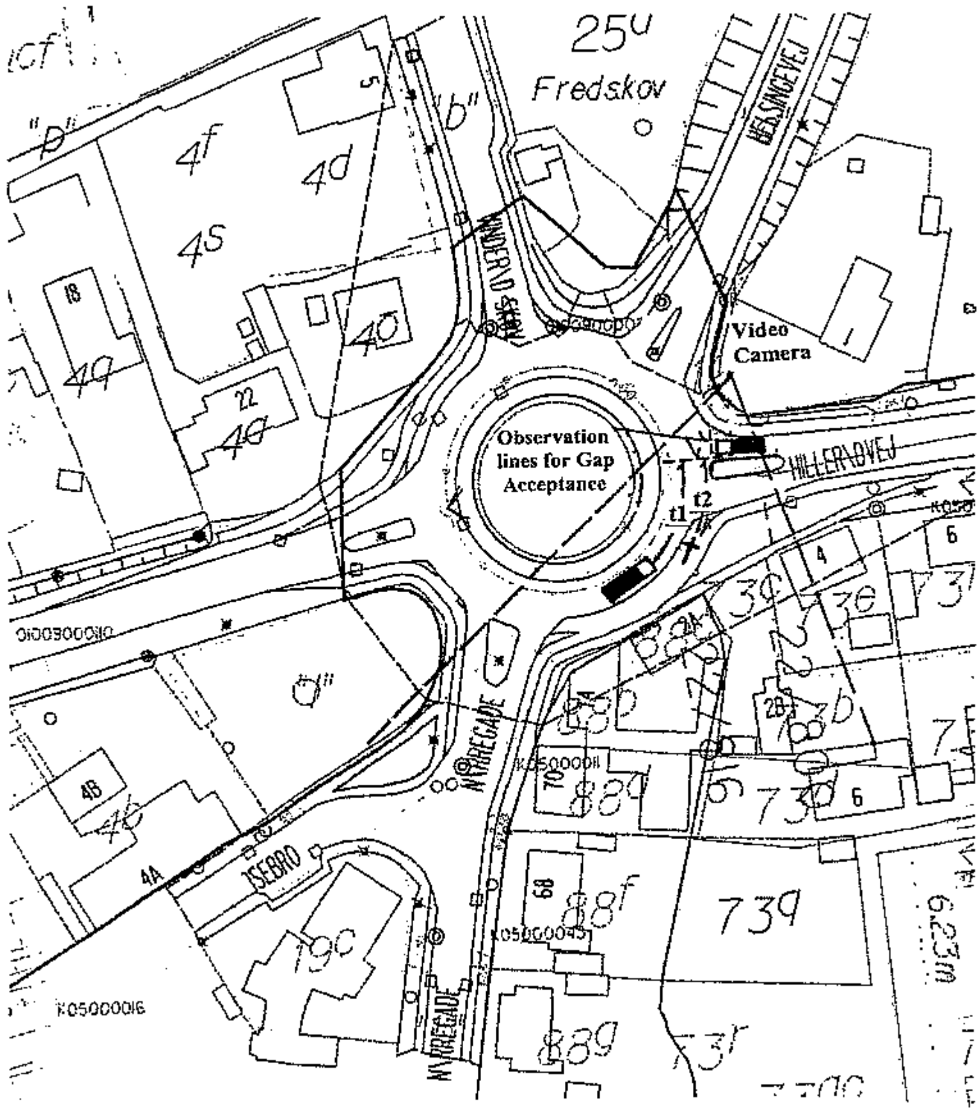

Fig. 1. The layout of the observational study. The location of the video camera and the angle of observation are shown. When the car in the approach reaches the stop line it is recorded if the driver accepts or rejects the available time gaps $t1$ and $t2$ to the first arriving car and/or bicycle in the circulation area. The time gaps $t1$ and $t2$ are recorded from the arrival of the approaching car until the car and/or bicycle arrive at the observational line at the entrance for the approaching car.

be expected that the observations would show the same critical gap as was measured before. So we would expect a critical gap of 4.26 s. If data points in the diagram are analysed without reference to the values of $t2$ we find a critical gap 4.47 s with a standard deviation of 0.24 s. These observations, 4.26 and 4.47 s, are not significantly different when the measured standard deviations are taken into account.

A corresponding analysis made as if only bicycles were present gives a critical gap value of 4.70 s and a standard deviation of 0.21 s. This is significantly different from the earlier result for car–bicycle combinations where the critical gap was 3.33 s with a standard deviation of 0.14 s.

It may be argued that looking at the critical gap for bicycles as if no cars exist in the diagram is wrong because we do not know for any single point why the available time gaps were rejected? Was it because the car or because the bicycle was too close? Could the Gap Acceptance in relation to cyclists be influenced by the value of $t1$?

To answer this question an analysis was performed on a limited part of the data of Fig. 3. Only those points were selected for which $2 \leq t1 \leq 3$, which means that the $t1$ values are fairly uniform. In this way a fairly clean critical gap for entering cars, which must give way to bicycles, is measured although the number of observations is reduced. The critical gap is found to be 4.97 s with a standard deviation of 0.40 s. This does not differ significant from the critical gap value 4.70 s with a standard deviation of 0.21 that is found if all observations are considered. And the value 4.97 with standard deviation 0.40 is still significantly larger than the value of 3.33 s, which was found for the

Fig. 2. Photo from the video recordings showing a car–car/bicycle event where the entering car driver has rejected the time gaps.

car–bicycle events. It appears that Gap Acceptance in relation to cyclists is probably not dependent on the exact value of $t1$. The important point is that a car is present.

This means that the process, in which the entering car driver decides to accept or reject a time gap, is influenced by the fact that there are both a car and a bicycle present at the same time.

One hypothesis may be that the entering car is reacting mainly to the circulating car and more or less overlooking the cyclist when both are present. If this is so, then the critical gap should be shorter measured only on the cyclists when both are present than when only cyclists are present. However, we find the opposite: cars entering the roundabout are apparently reacting more cautiously to cyclist when a car is also present than when the cyclist is alone. We find that the

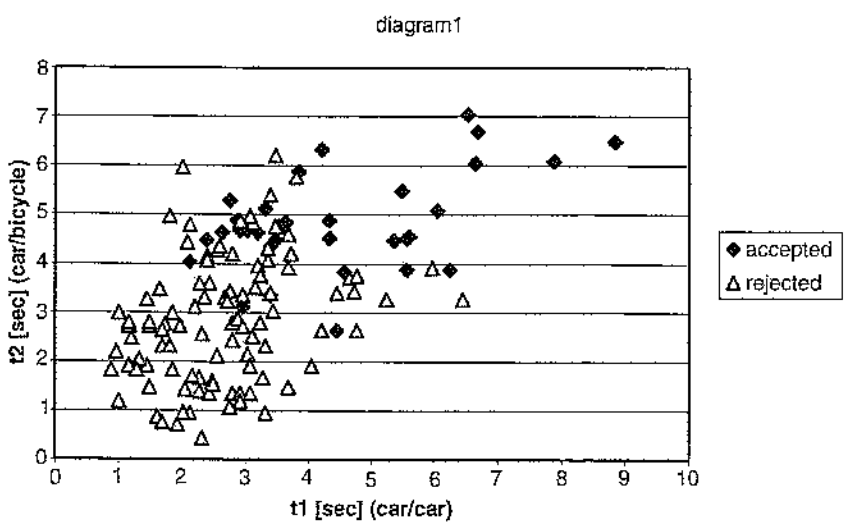

Fig. 3. Time gaps $t1$ and $t2$ observed in car–car/bicycle events.

critical gap in relation to cars is practically not changed. But data show that the car drivers apparently want a larger safety gap to the bicycles when a car is also present than when the bicycle is alone. Results do not indicate that car drivers accept a smaller safety margin in relation to cyclists when cars are also present, hence: "cyclists are not overlooked because of the presence of a car".

3. Discussion

One factor causing "looked-but-failed-to-see-errors" in traffic might be the difference in function of central sight versus peripheral sight. When a driver wants to see and *identify* an object, he or she routinely moves the eyes, so that the object projects onto the *centre* of the retina, as this centre (equal to the fovea) contains a more plentiful supply of receptors than the periphery. For a car driver this means that the visual focus will be located where the relevant objects for identification are found. If the situation gets complex the car driver uses much mental capacity on processing input from the central sight. Consequently relevant information from the peripheral field of vision might not be perceived (e.g. the presence of cyclists).

However, in none of the near accident cases the car driver mentioned the presence of another car as a possible reason for distraction. This corresponds with the accident reports where third parties are not mentioned. And furthermore, the study suggests that car drivers are more cautious towards cyclists (i.e. larger critical gap) when a car is also present.

Another factor causing the perception failure might be the change of visual search strategy, as car drivers get more experienced. Studies have shown that experienced drivers use another search strategy than inexperienced drivers, who typically start their visual search of the traffic scene nearby (Mourant and Rockwell, 1972; Langham and Hole, 1998). As opposed to this, the experienced driver starts the visual scanning (i.e. direct their visual focus) further ahead in the middle of the traffic scene, and therefore the experienced driver needs more time to detect cyclists and pedestrians, who are often nearby. Furthermore, the experienced drivers may develop shorter search times and may extract from the traffic scenes only minimal information based on expectancies about what they are likely to see.

Thus "looked-but-failed-to-see-errors" in traffic may be perceived as a possible negative effect of traffic experience. The experienced driver may develop fixed routines for a search strategy and other information processing leading to high priority of areas and road users, involving the most relevant information for the person concerned. These are other *motorised vehicles* plus the areas they use, and may *not* include cyclists and pedestrians and the areas, *they* use.

It has been suggested that drivers who are supposed to give way frequently make typical mistakes when searching visually the area for potential conflict parties.

One hypothesis might be that the experienced car driver unconsciously concentrates on the locations where other cars usually are. The explanation for this might be that other cars clearly constitute a danger to the driver if he/she makes an incorrect estimation of their proximity. And at the same time a bicycle might not to the same degree be considered as a risk to the driver. This could be a factor in accidents where bicycles are overlooked.

A supplementary hypothesis could be as follows. The relevant case is not when both a car and a bicycle is present in the circulation area but the case when only the bicycle is present. It may be assumed that a car driver will normally concentrate his or her attention on the locations where conflicting cars usually are. When there is no car it is conceivable that car drivers now and then just notes that there is no car and then enters the priority road without noting the presence of a bicycle.

If this is a fairly frequent behaviour by drivers it should be expected that not only accidents and near accidents might be found but even observations of very short accepted time gaps at car–bicycle events could be expected.

We are then left with the question: is it reasonable to maintain that the distribution of the accepted time gaps suggests that it happens every now and then that a car enters the priority area without having seen the bicycle?

Looking at the accepted time gaps in the car–bicycle events we find many short accepted gaps. Out of 58 accepted time gaps there are two less than 2 s and a total of seven less than 2.5 s, corresponding to about 12%. Furthermore, there are 53% under 4 s.

In the observations where both a car and a bicycle were present in the circulation area a total of 32 accepted gaps was found. Looking at $t2$, which is the available time gap to the first bicycle none were below 2.5 s and only five (16%) under 4 s. This percentage distribution of the accepted gaps is significantly different from that of the car–bicycle events.

This means that when only bicycles are present some entering car drivers accept much smaller gaps to the bicycle than when a car is also present. In the cases of the shortest accepted gaps the bicycles were only about 7 m away when the cars entered the circulation area. These cases may well constitute looked-but-failed-to-see-errors, but without the occurrence of accidents or near accidents.

The question is now: if the stated hypothesis is correct how do we then understand that a frequent but erroneous perception happens?

There is no doubt that the cyclist in several of the examined accidents and near accidents and in the very short time gap cases clearly has been in the field of vision of the car driver. Are there known typical perception errors, which could explain these cases?

It has been suggested that for experienced drivers an unconscious sorting out of not sufficiently relevant visual information takes place. The bicycle may be interpreted as not dangerous and therefore less important than a conflicting car. This means that a qualitative sorting of stimuli may happen.

The surprising point is that it may be a missing but expected car that apparently provokes that the bicycle is overlooked.

The hypothesis assumes that the car driver who searches the road area for possible counterparts may focus the attention on the locations where cars usually are. This may lead to lack of reaction to stimuli outside focus even if the stimulus, the cyclist, is in the field of vision. In this case stimuli could be interpreted as spatially distributed and the weighting or sorting of stimuli be based not on their danger potential but rather on their presence in more or less relevant locations.

This last reflection that it is the spatial distribution of the parties that determines the perception may explain certain statistical data. Accident analyses at roundabouts in Denmark suggest that there is no measurable benefit from constructing cycle tracks along the circulation area (Jørgensen and Jørgensen, 1994). The data indicate that a mixing of cars and bicycles in the circulation area may lead to fewer accidents. A similar result has been found in The Netherlands for moderate traffic flows, ADT less than 8000 entering cars (Schoon and van Minnen, 1993). It may be stated in a simplified way. If bicyclists ride in between cars then bicycles are located where approaching car drivers search for counterparts. This may reduce the risk of an error where a car driver overlooks a bicycle.

4. Outlook

These studies give no immediate solutions to the problems associated with "looked-but-failed-to-see-errors" in traffic. But some hypotheses have been suggested.

It appears that experienced drivers may be more likely to make these errors than inexperienced drivers. If this is so, it is doubtful to what extent educational activities may help. Erroneous behaviour learned through experience may be very difficult to treat through educational efforts.

The only engineering suggestion is to mix different road users rather than separate them in order to make cyclists more "visible" in the relevant locations but not all possible effects are known. More data need to be collected before firm conclusions may be reached. However, the hypotheses stated might clarify which data should be collected.

Acknowledgements

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2

ATTACHMENT G

BBC NEWS

Are women cyclists in more danger than men?

By Sarah Bell
BBC News

Women cyclists make up a far higher proportion of deaths involving lorries than men. Why?

Many of the fatalities involving cyclists happen in collisions with a heavy goods vehicle (HGV). This year, seven of the eight people killed by lorries in London have been women.

Considering that women make only 28% of the UK's cycling journeys, this seems extremely high.

There are no national figures but there's little reason to think it is any different. In August, a 27-year-old woman died in Leeds after her bike was in collision with a lorry.

These deaths could be attributed to a tragic anomaly, but some cycling campaigners are concerned whether there is something about how women cycle which puts them at greater risk from lorries.

"It's something we're trying to understand. When you look at HGV accidents there are a lot more women involved than you would expect. We don't know why that is," says Charlie Lloyd, from the London Cycling Campaign.

With this in mind, his group has organised a special women-only bike ride to the Cycle Show in London's Earls Court this weekend, a trip that ends with the chance for participants to sit in a lorry and experience the view drivers have of the road.

The high incidence of women killed by lorries has come to the attention of the authorities before.

In 2007, an internal report for Transport for London concluded women cyclists are far more likely to be killed by lorries because, unlike men, they tend to obey red lights and wait at junctions in the driver's blind spot.

This means that if the lorry turns left, the driver cannot see the cyclist as the vehicle cuts across the bike's path.

The report said that male cyclists are generally quicker getting away from a red light - or, indeed, jump red lights - and so get out of the danger area.

BIKES V LORRIES - THE SAFE WAY

- **1.** Cyclists should never pass a lorry on its left side at a junction, even if there is a wide gap. In addition, they should never stop near the front left corner of such a vehicle as they cannot be seen.
- **2.** Cyclists should always make sure they are far enough in front of the lorry so that the driver can see them - about 15ft (4.6m) for the largest.

But could it be a matter of confidence? Some women don't feel safe on their bikes and nervous cyclists could put themselves in danger, says Wendy Johnston of sustainable transport charity Sustrans.

Safety is the prime factor stopping women from getting on their bikes, she says, so her organisation is leading a campaign called "Bike Belles" to promote women's cycling, including a petition calling for the government to promote safety.

Feeling nervous about cycling can influence the way people ride, she says. Some women tend to cycle too close to the pavement as they want to stay as far away from traffic as possible.

"This can be a problem as vehicles may not regard you as part of the traffic flow and don't give the right amount of space. It means they may be tempted to come closer to you," says Mrs Johnston.

"It can have an impact on how other vehicles treat you. It can also impact on confidence as if they come too close, as it makes you feel you can't come out in the road."

'More aggression'

While many cyclists are calling for more cycle lanes to make their journeys safer, others dislike them because they believe they encourage people to ride down the left-hand-side of large vehicles and towards the kerb.

Marian Louise Noonan, 32, from south London, is a confessed kerb-hugger, and that leaves her feeling quite vulnerable on the roads, unlike her husband.

"He cycles much more aggressively and is aware of all the traffic around him. He cycles as if someone is going to hit him and makes sure he is in a safe position," she says.

"I'm much more nervous of my cycling ability, I'm frightened people might hit me, which means I don't cycle in a positive manner."

SAFE CYCLING

- Be aware of lorries
- Be alert
- Watch your position on the road
- Wait ahead at lights
- Take care in bus lanes
- Be seen and be safe
- Make eye contact
- Ride confidently Source: London Cycling Campaign

The main problem is the attitude of other drivers, she says, as they make her feel like she does not belong on the road.

She also feels reluctant to put herself at the front of the traffic at red lights, which is the safest place for cyclists to be.

"Things like being able to sit in the boxes at the front of traffic lights are safer for someone like me, because it takes a bit more effort to move off and get to the correct speed, but sometimes that annoys other drivers as it looks like you're pushing in."

Ms Noonan's reluctance to assert herself is typical, says Dr Dave Horton from Lancaster University, a sociologist who has written a study on the fear of cycling.

"Being highly visible in public spaces is something women are going to be less comfortable with than men, especially in the road environment in marked areas where people can see you and male drivers can see you.

"There's a discomfort around putting yourself on display. It's the idea that in a car it's much harder to see you."

Nerves

Turning right is also a problem for some women cyclists because they lack the confidence to look over their shoulder and judge when to cross the traffic, says Ian Walker, a professor of traffic and transport psychology at the University of Bath. He drew this conclusion after studying 5,000 cyclists in Oxford and Cambridge.

But he challenges the notion that nervous cyclists are generally more vulnerable because if fear is visible it can help, he says. The more confident you look, the closer the cars get, he says, and a deliberate wobble is sometimes used by cyclists to get more space.

In one experiment, he cycled with a device which measured how much room cars gave as they passed, then repeated it while wearing a long female wig. Drivers gave the "woman" more room.

Setting lorries aside, the bigger picture is that far more men are killed on their bikes. In 2008, 84% of the 115 fatalities were men and 81% of reported injuries were to men.

CYCLING WITH CONFIDENCE

" I try to make as clear signals as possible, I stick my hand right out and when it comes to buses and lorries I'm very aware of blind spots. Confidence in your own ability, spatial awareness, looking and listening to what's going on around you, and making sure you're visible are the most important things. "

Jane Hornsby, who cycles five miles a day

And overall, the number of cyclists killed in Britain has fallen by 27% compared with the mid-1990s. Last year, 115 cyclists were killed on the roads, a 15% fall from 136 deaths in 2007.

Two of the women recently killed were experienced, so it's not just about nerves, says Chief Inspector Graham Horwood of the Met Police Traffic Unit.

"It's often that they are in the wrong place at the wrong time and circumstances get to a certain point where they end up in these positions.

"You can't always blame the cyclists and you can't always blame the lorry drivers, it's a mix of who's responsible."

Confident female cyclists like Jane Hornsby, 49, from Oxford, says it's not just safety that puts some women off getting on two wheels.

Practical issues like changing facilities and bringing a spare outfit also play a part.

Women may also have less time than men, she says, because they tend to have the responsibility of looking after children before and after work, and are often carrying shopping.

Below is a selection of your comments.

This article touches a nerve with me. I am an experienced and confident cyclist, but am uncomfortable about cycling past stationary traffic to get to the front at traffic lights. I've had cars pull out to prevent me getting past. I've also experienced road rage where someone (a female passenger) opened her window and screamed at me for daring to be in the right-hand lane in a one-way system. (I was about to turn right.) I've also had a car go past me so close on a left-hand bend that they've touched my wheel. One-way systems are a menace here for cyclists, as are traffic calming measures that force you on to the opposite side of the road into the path of on-coming traffic. My work does not have showering or changing facilities, which doesn't stop me cycling to work, but makes life more difficult. **Anne Lincoln, Maidstone, UK**

My brother was killed four weeks ago whilst out cycling. He who used to be a semi-professional cyclist and so was very experienced and not nervous. He was wearing all the right clothing etc. The motorist that ran him down did not give him enough room. His life was cut short and it is extremely heartbreaking for all who knew him. **Lynne Daniell, Middlesbrough**

Women are more at risk because they tend to obey the rules of the road - i.e.. stopping at lights and actually riding on the road. I see so many big butch men riding on the pavement like frightened rabbits, it really irritates me. I always ride on the road unless there is a cycle lane, and I always ride well out from the curb, then at least I've got space to fall out of the car's way if it hits me. But mostly, cars just don't give cycles enough room - always trying to squeeze past instead of waiting a few minutes until it's safe to pass. **Elaine Smith, Somerset**

I am a keen cyclist and I do think that it is important to be assertive when cycling in traffic. The key to safety is visibility. The diagram of the lorry and the cyclist at traffic lights is very telling. Also, cycle lanes leading up to traffic lights are best ignored for the reasons stated in the article - visibility. **Nicolas Werner, Hove, UK**

It is not red light jumping which makes men safer at traffic lights, it is the fact that they are more likely to be in a primary position (ie in the middle of the traffic lane) when waiting at the lights. This means that following drivers are far less likely to overtake and turn left. It is this overtaking and turning left by drivers that cause fatalities, not cyclist filtering down the left side of the HGVs. Cycle lanes are not the solution, they are often badly designed and put cyclist in more danger. There should be Advanced Stop Lines at all traffic lights and ALL driver should know and obey Rule 178 of the Highway Code. **Kim, Edinburgh**

Casual observation suggests that women cycle more cautiously and are thus perhaps more likely to wait inside rather than outside at lights, and similarly might be less likely to nip away smartly. A quick inside getaway might put the cyclist back into the drivers's field of view. thereby decreasing the risk of accident. Maybe not? Nice little research project here with potential big safety benefits as outcome. **Peter, Emsworth**

When I did my motorbike training, we were told to not hug the kerb because doing so would encourage drivers to try and squeeze past. If they don't make it, they pull in and, as you are right up against the kerb, you have nowhere to go. Hold your road position and make cars/lorries overtake you properly. If they can't, they'll just have to wait. I also use this philosophy when cycling and I always try & position myself where car/lorry/bus drivers can see me. **Sally, Hullbridge Essex**

Cycling has become more and more dangerous. Motorists, particularly during rush hour, are often distracted or bad tempered and tend to take more risks. Coupled with these modern cars which have very fast acceleration combined with strengthened bodies I am thankful that there hasn't been an increase in cyclist fatalities. In my city there is a severe lack of cycle lanes, and when there is a cycle lane, it is either next to the kerb or actually on the pavement. When there is no cycle lane I feel very exposed even when I am wearing a high-vis vest, helmet and lights. Motorists can be aggressive towards cyclists which forces us further towards the pavement. I have noticed that even when I am able to use a cycle lane the other road users tend to come much closer than I would say is safe. Worse still, people park over cycle lanes and are either not aware of, or don't care about the danger this causes. **Charlotte, Leeds, W Yorks, UK**

One of the worst situations I find as a cyclist is being caught up in the traffic light Grand Prix. As soon as the lights change and it's "GO, GO, GO!...", woe betide any cyclist who's off to a wobbly start. With modern lights often incorporating pedestrian priorities, I would have thought it possible to provide a little extra for "cyclists" in the form of a small green light that comes on for say 5 seconds before all the budding drag racers hit their nitro' buttons when the main lights change. **Richard, Sutton Coldfield**

Today I am suffering from a painfully strained shoulder as a result of a cycling incident. But guess what - it was another cyclist who caused the crash. I was cycling up a hill on the left-hand side of a generously wide residential street when a cyclist wearing all the gear shot out just in front of me between two parked cars - he had clearly been bombing down the pavement on the wrong side - and crashed straight into my front wheel, jarring my bike and me quite severely. Hm.... **Sally, London**

I think it's simply a matter of women failing to appreciate the space needed by HGVs when manoeuvring as well as men. Tests have shown that differences in spatial awareness account for why men are generally better than women at parking, and this could be an extension of the same problem. Men are also more likely to be familiar with HGVs and their characteristics than women. This isn't to say that there aren't some excellent exceptions to the rule! **Jamie, Wendover, UK**

Having seen the way cyclists ride in London, I'm not surprised many are involved in accidents. They ride without lights after dark, ignore traffic lights and ride aggressively as if they own the road. Apparently that is how the LCC want it in parts of London - pedestrians and cyclists only (and I'm sure they would prefer not to have pedestrians in their way as they cycle along the pavement). **Iain, Scotland**

"The main problem is the attitude of other drivers, she says, as they make her feel like she does not belong on the road" I cycle daily and I wholeheartedly agree with this comment. I do not allow my children to cycle to school because of this. Lorry drivers tend to be more polite than car or van drivers, but are more dangerous because of blind spots. **Al, T Wells, UK**

This is a really interesting article. I think men and women generally do cycle differently for all the reasons mentioned. Riding too close to the kerb is a real issue, cars will try to squeeze past if they can even when there is oncoming traffic. By riding slightly further from the kerb (about a foot beyond the grids) you will generally force drives to cross the white line in order to overtake. This puts them in danger of being hit by oncoming traffic which focuses their mind on choosing carefully when they overtake. When my wife and I our out on our tandem we tend to get far more room from drivers; perhaps because the stoker (that's the one on the back) can easily make eye contact with the driver before they overtake? **Mark, Leicester**

In a perfect world it would be safest to overtake the lorry on the right hand side, but my experience of venturing nearer the middle of the road (no-man's land) makes me very wary as you're competing for space with motorcyclists doing the same. Also it puts you in a position where you're closer to the oncoming traffic, equally dangerous. Rock and a hard place really... **Stewart Paling, London**

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The effects of sunshields on red light running behavior of cyclists and electric bike riders

Yiqi Zhang, Changxu Wu*

State University of New York at Buffalo, United States

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Cyclist

ABSTRACT

Bicycles held an important position in transportation of China and other developing countries. As accidents rate involving electronic and regular bicycles is increasing, the severity of the bicycle safety problem should be paid more attention to. The current research explored the effect of sunshields (a kind of affordable traffic facility built on stop line of non-motor vehicle lanes (According to National Standard in China, e-bikes share the non-motor vehicle lane with regular bikes.) which was undertaken to avoid riders suffering from sunlight and high temperature) on diminishing red light running behavior of cyclists and e-bike riders. An observational study of 2477 riders was conducted to record and analyze their crossing behaviors at two sites across the city of Hangzhou, China. Results from logistic regression and analysis of variance indicated a significant effect of sunshield on reducing red light infringement rate both on sunny and cloudy days, while this effect of sunshield was larger on sunny days than on cloudy days based on further analysis. The effect of intersection type in logistic regression showed that riders were 1.376 times more likely to run through a red light upon approaching the intersection without sunshields compared to with sunshields in general. The results of MANCOVA further confirmed that rates of running behaviors against red lights were significantly lower at the intersections with a sunshield than at intersections without sunshields when other factors including traffic flow were statistically controlled. To sum up, it is concluded that sunshields installed at intersections can reduce the likelihood of red light infringement of cyclists and e-bike riders on both sunny and cloudy days. For those areas or countries with a torrid climate, sunshield might be a recommended facility which offers an affordable way to improve the safety of cyclists and e-bike riders at intersections. Limitations of the current sunshield design and current study are also discussed.

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1. Introduction

Bicycling, including electronic bike riding, is beginning to receive renewed attention. This common means of transportation gets support from urban planners because it is non-polluting, energy-efficient, and space-efficient, regarded as a way to reduce roadway congestion (Vandenbulcke et al., 2009). There are programs and policies recommended bicycling as a mean of transportation proposed by department of city planning in United States. For instance, the Congestion Mitigation and Air Quality Improvement program (CMAQ, 2010) suggested by Department of Transportation in Wisconsin encourages efforts to enhance public transit, bicycle facilities, ridesharing programs and facilities, and technologies that improve traffic flow and vehicle emissions. Also the program about bicycles implement by the Department of City Planning in New York City aims to reduce congestion by promoting cycling (BGP, 2012).

1.1. The situation of bike mode share in developed countries

It is known that bicycling is a general mode of transportation in most developing countries, while developed countries have also been experiencing a bicycling boom over the past three decades. Take the development of bicycling in the area of North America and Europe as example.

From 1980 to 1999, the number of bicycle trips in the United States has doubled. Moreover, the number of people choosing to commute to work or school by bicycle in the United States continues to rise in recent years. The 2008 national bicycle commuter mode share of 0.5%, though small, represents 720,000 commuters, an increase of almost 200,000 people in three years (Pucher et al., 1999). US Census Bureau's American Community Survey (ACS) reports twice as many daily bike commuters in 2009 as in 2000 and an increase in bike mode share to 0.6%. At the same time, the data from the Canadian Census reveals a 42% increase in the

* Corresponding author at: Cognitive System Lab at SUNY-Buffalo, 319 Bell Hall, State University of New York at Buffalo, 14260, USA.
E-mail addresses: seanwu@buffalo.edu, changxu.beijing@gmail.com (C. Wu).

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number of daily bike commuters between 1996 and 2006 (Pucher et al., 2011).

In the same period, bicycling has increased significantly in Europe (Pucher et al., 1999), for instance, in Denmark, Germany, Switzerland, and the Netherlands (Dutch Ministry of Transport, 1995; Zegeer, 1994; Tolley, 1997; Pucher, 1997). The number of bicycle trips has grown substantially in these countries and, in many cities, cycling's share of travel has risen as well. In Germany, for example, bicycling modal share for urban trips rose by half between 1972 and 1995, from 8% to 12% (Pucher, 1997). The annual survey reported a tripling rise in bike mode share of work commuters from 3% in 2000 to 8% in 2008 (City of Portland, 2008). Bicycling is also thriving in Scandinavian countries such as Sweden, where older persons commonly use bicycles. The nine million Swedes have more than six million bicycles (Scheiman et al., 2010).

1.2. The situation of bike mode share in developing countries

Compared to these developed countries, developing countries usually regarded bicycling as one of major types of transportation. The participation of bicycling in Bogota, Columbia grew from 5000 in 1974 to over 400,000 in 2005 (Pucher et al., 2010). Bogota has the world's fifth largest intensive bicycle transportation network with 268 km of bicycle paths, and are still building a more intensive and safe bicycle network (Li, 2008). China, taken as another example, has a much higher rate of commuter bicycling. In general, average bicycling modal share for urban trips in China accounts for 38% (Zhang and Lu, 2010). In 2000, ten million people from the age of 15 to 64 in the city of Beijing had 15–20 million bicycles (Zhao and Rong, 2010). Currently, cycling still makes up a large percentage of all modes of travel, such as in Tianjin with a portion of its transportation as large as over 60 percent. Moreover, electric bicycles (e-bike) appeared in south China since 1997 and had become popular in China within a few years (Yao and Wu, 2012), since e-bikes are suitable for urban transportation in south China where there are a lot of cities with around million people. For example, Suzhou city[1] keeps 180,000 pieces of e-bike currently, where 1.5 million e-bikes were sold in 2002 and 3.6 million or more were sold in 2003 (Zhen et al., 2006). Sales of e-bikes reached 15 million in 2005, which made electric bicycles now become a real industry and business (Zhang, 2006). According to the statistics published by the government of Hangzhou city,[2] its ownership of e-bikes has exceeded 50 million units till the end of 2006, where four of every ten families use e-bikes (Wang, 2007). This illustrates how electric bicycles have become one of the vital means of transportation of Hangzhou.

1.3. Cycling accident and the major reason: red light running behavior

Although bicycle commuting is believed to be beneficial to the health of both the individual and the community, the potential for fatalities and injuries also exists (Hoffman et al., 2010). In 2004, the number of regular bicycle riders killed in accidents was 13,655 which account for 12.8% of all traffic fatalities (CRTASR, 2004). Accordingly, the number of e-bikers being killed rose from 589 to 2469 in three years since 2004 (CRTASR, 2004, 2007). According to statistics published by the Hong Kong government in 2006, bicycle related events accounted for 7.4% of all traffic incidents and 6.3% of all traffic-related fatalities (Yeung et al., 2009).

Currently, increasing rates of misconduct of cyclists and e-bike riders, especially electric bicycles (E-bike), have led to an increase in transportation accidents aroused public concern nationwide.[3] Data of traffic accidents collected in Zhejiang Province, for example, further illustrates the safety condition of electric bikes: 430 e-bike riders were killed and 3957 accidents referred e-bikes, representing 5% of all traffic fatalities and 10.8% of all accidents that occurred in 2006. The corresponding figures increased to 798 (14.0%) and 5434 (23.2%) after three years in 2009. As the capital city of Zhejiang Province, Hangzhou's overall accident rate has declined year by year since 2008, but the rate of accidents caused by electric bicycles has increased (Chen, 2010). Looking more closely at the data collected in the year of 2008 (Ding, 2009), the number of traffic fatalities involving e-bikes in Hangzhou rose from 108 to 152, up by 40.74% compared to the previous year, which accounts for 17.63% of total traffic fatalities and 48.41% of traffic fatalities involving bicycles (including e-bikes). In the year of 2010, Hangzhou had 178 fatalities due to e-bikes, representing 23.4% of the total traffic fatalities and 1012 traffic accidents caused directly by electronic bicycles, which grew by 16.19% over the same period of last year. Therefore, the studies about regular bicycle and e-bikes safety are necessary in China to improve the overall traffic safety condition.

Among the reasons, cyclists' and e-bike riders' violation of road traffic law (red light running behaviors or called red light infringement) is the major factor contributing to such vehicle related accidents (Spence et al., 1993). Based on the statistics published by the traffic police department in Hangzhou,[4] red light running behaviors of e-bike riders contributes to 15% of accidents (Hua, 2010). Red light infringement was ranked as the top four reasons resulting in traffic accident referring cyclists and e-bike riders (Everyday Economic News, 2011). Another report shows that red light running is responsible for around 80% of accidents involving e-bike riders in Shaoxing (Another city in Zhejiang province) (Pei, 2011). Cyclists' non-compliance is also viewed as the typical and most annoyed by vehicle drivers (Basford et al., 2002; O'Brien et al., 2002). However, there are only a few studies focused on the red light running behavior of cyclists and e-bike riders. Johnson et al. (2011) observed non-compliance behavior of 4225 cyclists and concluded that travel directions, the presence of other road users, and the volume of cross traffic are three main predictive indexes for the infringement behavior. Wu et al. (2012) observed 451 two-wheeled riders and explored the rate, related factors, and characteristics of two-wheel riders' infringement behavior in China. Accordingly, studies about reducing rate of running behavior on red light of cyclists and e-bike riders might help to improve safety at urban road intersections.

1.4. Improve cycling safety: the facility of sunshield

Recently researchers start to focus on how to improve cycling safety. A few studies about interventions improving safety cyclists come from North-Western Europe, mainly from countries such as the Netherlands, Denmark, and Germany (Wegman et al., 2012). Two subjects related to cyclist safety that have been discussed thoroughly in peer-reviewed literature are bicycle helmets and roundabouts. Aultman-Hall and Kaltenecker (1999) compared differences between collision, fall and injury rates for bicycle commuting on-road, off-road and on sidewalks in Toronto and indicated that moving cyclists away from automobile traffic onto pathways is not, on its own, the solution to the bicycle safety problem. They

[1] Located between Shanghai and Nanjing, with population of half million in the down town area.

[2] Hangzhou is the first city install sun-shield facility for riders in bicycle track.

[3] E-bike belongs to non-motor vehicle according to National Standard in China.

[4] There is no national official data published by China Statistical Yearbook Database. Therefore, we use data from traffic police department of Hangzhou to describe the effect of red light running behavior on traffic accidents.

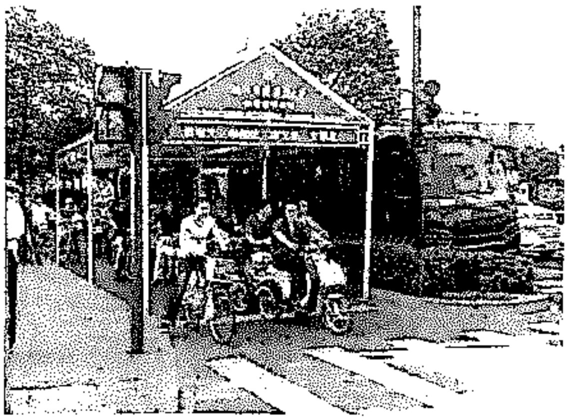


Fig. 1. A sunshield on a bicycle track in Hangzhou city.

suggested that many paths are possibly not built for the volume of non-motorized traffic they carry and off-road facilities might be improved in the future. Teschke et al. (2012) compared cycling injury risks of 14 route types and concluded that quiet streets and busy streets along with bike-specific infrastructure support the route-design approach used in many northern European countries. Also, in some cities of China, traffic police worked in the intersections to supervise crossing behaviors of cyclists and e-bike riders, costing manpower and material resources.

In the present study, we explore another traffic facility—sunshields, set-up on the non-motor vehicle lanes and test its effect on diminishing the rate of red light running behavior. Promoting bicycling as an environmentally friendly mode of transportation, sunshields first appeared at waiting lines of main intersections in Hangzhou (see Fig. 1). This special transportation facility was used only in summer and was designed to help protect riders from sunlight and high temperature. Take the index of temperature in the main district of Hangzhou in 2010, for example, which had 40 days with temperatures over 35 °C and a full week with temperatures above 39 °C. Current statistics suggest that time limit of waiting at red lights is usually 70–90 s in Hangzhou (Liu et al., 2008); however, people are likely to lose patience when exposed to scorching sunlight, consequently leading to an increased rate of red light running behavior more than usual in summer (Larsen and Sunde, 2008).

Although sunshields were design for humanity friendly consideration previously, it was reported to affect the red light running behaviors in practical use. This facility emerged only in recent years and has never been studied before. Hangzhou is the first city where the sunshield was experimented on non-motor vehicles lanes in 2007 with four sunshields set-up at the Zhonghe–Tiyuchang intersection (Shi, 2007). In 2009, 450 easily assembled sunshields were chosen as the final type and were installed in 127 main roads of Hangzhou. Hangzhou, being the city where sunshields first appeared and developed (while scarce in other cities in China or in other countries), was chosen as the test city.

The purpose of this study was to examine the effects of sunshield facility on decreasing the rate of red light running behavior of cyclists and e-bike riders in Hangzhou. In the present study, we will explore its influence on riders' behavior both on sunny and cloudy days. Since sunshields have worked as a facility to eliminate sunlight for riders waiting at the stop line, as we mentioned above, we assumed that it would be more effective on sunny days. As these kinds of facilities are installed only in summer every year, we collected data only in summer from July to September. If this function of sunshields was proved to be effective, it could be a better choice to reduce the rate of red light running behaviors at intersections. The unit price of a sunshield is $400–500 approximately. It indicates that this facility is an easy and low-cost option for countries which have bike paths like China, Australia, Germany, and the Netherlands. The findings of this research might provide new information on improving the safety of cyclists and e-bike riders.

2. Methods

2.1. Test sites

Among 112 intersections being observed in 5 main districts in the city of Hangzhou, there are 11 intersections without sunshields and 10 intersections partially with sunshields while the other intersections are fully equipped with sunshields in four directions. As the purpose of the research is to compare the running behavior under the situation with or without sunshields, two criteria were used for selecting the observational sites. First, the sites selected should fit the requirement of experiment design, namely, having a junction with sunshield and another junction without sunshield. Second, there had to be a considerably high number of bicycle traffic (including both electric bikes and regular bicycles) during the observation period. Before the final intersection was chosen, four intersections were observed and tested.

Two typical four-armed signalized regular intersections on Huanchengbei Road were finally chosen as the observation site after the pilot. The east-west orientated Huanchengbei Road and the north-south orientated Jianguo Road and Huanchengdong Road are all main thoroughfares in Hangzhou (see Fig. 2). The observation was conducted from the end of July to the end of September at Huanchengbei–Jianguo Intersection and Huanchengbei–Huanchengdong Intersection in 2011. The data collection was conducted from approximately 11:30 AM to 12:30 PM. As these observations were conducted during peak hours it could be assumed that cyclists and e-bike riders were commuters.

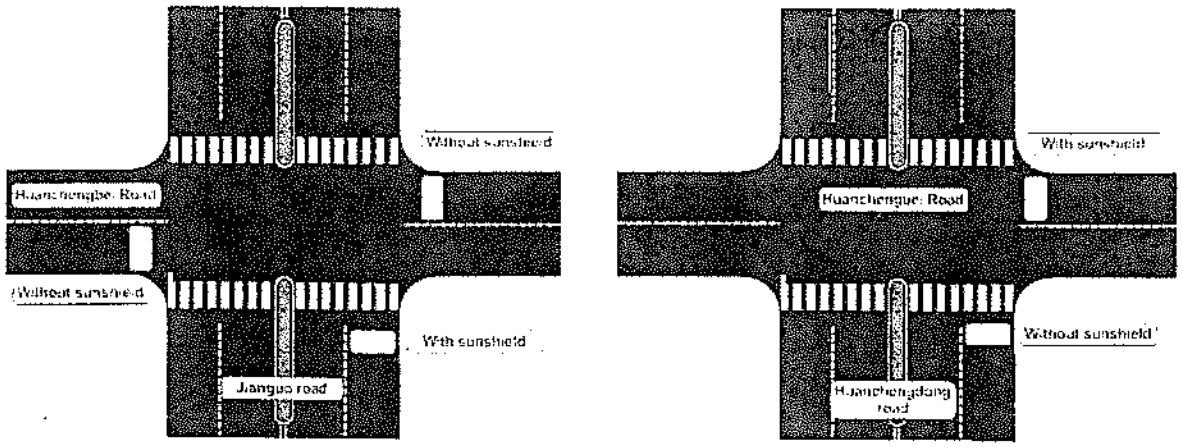
2.2. Video data collection

Two synchronized video cameras (Sony HDR-X100E, Sony Corporation) were used to collect data of riders' crossing behavior. One was positioned on a tripod next to the roadway where the entire crossing process could be viewed. The other footage was taken on the intersecting road just after the right turn to observe the detailed rider's behavior at the stop line. The install of cameras was hid behind the intersection stop line so that the awareness of the camera would be decrease in that case. Since the study aims to investigate the effects of sunshield use on red light running behavior, we collected the data both on sunny and cloudy days.

2.3. Videotape coding

The variables were coded based on the videotape for riders who arrived at the intersections during the red light and flashing light phases (see Table 1).

Riders (both e-bike riders and cyclists) making left-turns were excluded because of the limitation of camera field view, while those making right-turns were excluded because they are not subjected to the red light control according to the traffic rules in China. In order to avoid potential bias in coding, 1-h video recordings (including 72 valid observations) were coded by two independent research assistants. Cohen's kappa (for categorical variables) and one-way intraclass correlations (for continuous variables) were calculated as the coding reliability estimates. All the coefficients ranged from 0.87 to 0.99, indicating that the coding process was reliable.



A. Huanchengbei-Jianguo Intersection

B. Huanchengbei-Huanchengdong Intersection

Fig. 2. Picture of Huanchengbei–Jianguo intersection and Huanchengbei–Huanchengdong intersection.

Table 1
Definition of variables coded.

Variables	Descriptions
Independent variables	
Intersection type	With sunshield: 1; without sunshield: 0
Weather	General description: sunny: 1, cloudy: 0; temperature; UVI (ultraviolet rays index): low, moderate, high
Dependent variables	
Crossing behavior	Red light laws obey: 0; red light running: 1
Safety margin	Gap between the time a bicycle crosses before a vehicle and the time it arrives at the crossing point (recorded only for red light running behavior) (Zhuang and Wu, 2011)
Other factors	
Gender	Male: 0, female: 1
Age group	Estimated age group: young (<30): 0, middle-aged (30–50): 1, elderly (>50): 2 (Yao and Wu, 2012)
Rider type	Electric bike riders:0, regular bicycle riders: 1; e-tricycle riders: 2; tricyclists: 3
Time	Arrival time at the stop line, departure time from the stop line
Traffic light status	Red light status; flashing light status[a]
Cross traffic flow	It is the number of motor vehicles passing the intersection from either direction during the red light status of one cycle, and is measured every 3 s
Group size	Data coding only those who move straight in intersections. Left-turners were excluded because they were in a different roadway, while riders making right turns were also ignored because they were not subject to the traffic signal control according to the road rules in China.

[a] This is a special red light status in China indicating that the light will change from red to green status with a count down in the last 10 s of the red light.

3. Results

3.1. Descriptive statistics

Demographics data were coded for those arrived on red light phases including both red and flashing light statuses. A total of 2477 valid observations were recorded and presented in Table 2. Observations took at intersections with and without sunshield are presented separately. Within each condition the descriptive statistics for two weather conditions were divided as well. It shows a majority of riders were e-bike riders (71.6% at intersections with a sunshield and 80.8% of that without a sunshield) among the rider type group and males (71.5% and 78.2% on two different types of intersections) within the gender group. Since the number of e-bike riders and cyclists accounted for more than 95% of all riders, we defined these two as major rider types in our following discussions. Young and middle aged riders accounted for more than 90% of the total riders on both types of intersections. The numbers of riders collected on intersections with and without a sunshield are not significantly different (1266 vs. 1211, $p > .05$, chi-square test), while within each intersection category, the number of riders recorded on sunny and cloudy days are significantly different (757 vs. 509 and 673 vs. 538, $p < .05$). We paid more attention to sunny days than to cloudy days since sunshields will become more effective during sunny weather, as we hypothesized.

Table 3 lists the statistical summary of the running behaviors against traffic lights including both sunny and cloudy conditions. In this summarization, we concerned the proportion of running behaviors happened from the whole crossing behaviors in different intersection and weather conditions. A chi square analysis was used to analyze categorical variables (such as rider type, gender, and estimated age groups) for the different intersections under both weather conditions. In general, the overall proportion of e-bike riders' running behaviors is significantly larger than cyclists' in both kinds of intersections, with and without sunshields. Nevertheless, male riders are more likely to go against red lights than female riders (42.8% vs. 33.8%) a significant difference only at intersections with sunshields. The rates of running behaviors of different age group are also significantly different only at intersections with sunshields.

3.2. Logistic regression analysis

According to the format of the dependent variable defined in Table 1, crossing behavior was coded as a dichotomous variable (red light laws obey: 0 and red light running: 1) as well as the variable of weather condition (cloudy: 0 and sunny: 1) and the variable of intersection type (without sunshield: 0 and with sunshield: 1). In this case, the dependent variable we want to predict is the crossing behavior (whether violate or obey the red light laws), which is a categorical variable. Therefore, a logistic regression was conducted to predict the probability that red light running behaviors occur. It is a generalized linear model used for binomial regression in which intersection types and weather condition so as other

Table 2
Frequency of the observations in each descriptive category.

Intersection type	With sunshield			No sunshield		
Weather	Sunny	Cloudy	Total	Sunny	Cloudy	Total
Rider type						
E-bike riders	535(70.7%)	371(72.9%)	906(71.6%)	532(79.0%)	446(82.9%)	978(80.8%)
Cyclists	209(27.6%)	120(23.6%)	329(26.0%)	108(16.0%)	75(13.9%)	183(15.1%)
E-tricycle riders	5(0.7%)	3(0.6%)	8(0.6%)	9(1.3%)	1(0.2%)	10(0.8%)
Tricyclists	8(1.1%)	15(2.9%)	23(1.8%)	24(3.6%)	16(3.0%)	40(3.3%)
Gender						
Male	536(71.0%)	368(72.3%)	904(71.5%)	532(79.0%)	415(77.1%)	947(78.2%)
Female	217(28.7%)	138(27.1%)	355(28.1%)	136(20.2%)	121(22.5%)	257(21.2%)
Age group						
Young	294(38.9%)	233(45.8%)	527(41.7%)	227(33.7%)	256(47.6%)	483(39.9%)
Middle-aged	382(50.5%)	227(44.6%)	609(48.1%)	375(55.7%)	237(44.1%)	612(50.5%)
Elderly	78(10.3%)	46(9.0%)	124(9.8%)	66(9.8%)	43(8.0%)	109(9.0%)
Overall	757	509	1266	673	538	1211

Table 3
Proportion of red light running behaviors in each descriptive category.

Intersection type	With sunshield			Without sunshield		
Weather	Sunny	Cloudy	Total	Sunny	Cloudy	Total
Rider type						
E-bike riders	194(36.5%)	189(50.5%)	383(42.2%)	216(39.9%)	254(57.0%)	468(47.2%)
Cyclists	60(27.6%)	64(47.4%)	124(35.2%)	47(35.6%)	42(46.2%)	89(39.9%)
X^2	5.384^{**}	0.388	5.183^{*}	0.823	3.478	4.296^{*}
Gender						
Male	199(37.1%)	188(51.1%)	387(42.8%)	210(39.5%)	231(55.7%)	441(46.6%)
Female	55(25.3%)	65(47.1%)	120(33.8%)	52(38.2%)	64(52.9%)	116(45.1%)
X^2	9.591^{**}	0.638	8.597^{**}	0.070	0.291	0.683
Age group						
Young	109(37.1%)	125(53.6%)	234(44.4%)	91(40.1%)	148(57.8%)	239(49.5%)
Middle-aged	116(30.4%)	104(45.8%)	220(36.1%)	141(37.6%)	125(52.7%)	266(43.5%)
Elderly	29(37.2%)	24(52.2%)	53(42.7%)	30(45.5%)	22(51.2%)	52(47.7%)
X^2	3.822	2.918	8.408^{*}	1.561	1.562	4.034
Total	254(33.5%)	253(49.7%)	510(40.3%)	262(38.9%)	295(55.0%)	557(45.9%)

** $p<.01$.
* $p<.05$.
Otherwise $p \geq .05$.

category variables were used as predictor variables. Crossing behaviors were analyzed in total conditions including red light and flashing light statuses in Table 4.[5]

The results indicate that both intersection type and weather condition were significant variables for predicting traffic light running behavior in total red light status (including both red light and flashing light statuses). The effect of intersection type showed that riders were 1.376 times more likely to run through a red light upon approaching the intersection without sunshields compared to with sunshields in general. On sunny days, the riders were 1.756 times more likely to run through a red light without sunshields compared to those with sunshields. On cloudy days, the riders were 1.223 times more likely run through a red light without sunshields compared to those with sunshields. For the variable of weather type, the results indicated that riders are 1.739 times more likely to run through a red light upon cloudy weather compared to sunny conditions.

In addition, rider type, gender and levels of cross traffic flow were identified as significant predictor variables on red light running behavior. E-bike riders were 1.834 times more likely to run against red light than cyclists, while male riders were 1.265 times more likely to have red light infringement behavior than female riders. Under low and median levels of traffic flow, riders were 1.406 and 1.556 times more likely to run against a red light compare to high level of traffic flow. However, age group could not serve as a significant variable for predicting red light running behaviors on either light condition.

3.3. Analysis of variance

The study aimed to explore the influence of sunshield on running behaviors of cyclists and e-bike riders. The rates of red light running behaviors in each group was defined as the proportion of riders going against red lights among the total riders over each red light waiting period in which the traffic light turned from red to green. As it shows in Fig. 3, cyclists and e-bike vehicle riders have a lower rate of running behaviors on the intersection with a sunshield than without one, especially in sunny weather.

The analysis of variance (ANOVA) was used to further analyze the influence of sunshields on red light running behaviors. ANOVA was conducted with intersection type and weather condition as independent variables and the rates of red light running behaviors as the dependent variable. Main effects of both

[5] The logistic regression is not applied to analyze safety margin, since it is a continuous variable rather than a categorical variable. We will present the analysis of safety margin in the result of multivariate analysis of covariance (MANCOVA) later.

Table 4
Logistic regression results for traffic light running behaviors.

Light status		Adjusted OR	Adjusted 95% CI	Wald χ^2
Total (including both red light and flashing light statuses)	**Intersection type**			
	Without vs. with sunshield	1.376	1.124–1.168	9.562**
	Weather type			
	Cloudy vs. sunny	1.739	1.456–2.077	37.295***
	Rider type			
	E-bike rider vs. cyclist	1.834	1.030–3.264	4.250*
	Gender			
	Male vs. female	1.265	1.028–1.558	4.926*
	Age group			
	Young vs. elderly	0.883	0.642–1.215	0.582
	Middle aged vs. elderly	0.749	0.544–1.033	3.113#
	Crossing traffic flow			
	Low vs. high	1.406	1.071–1.847	6.020*
	Median vs. high	1.556	1.216–1.992	12.312***
	Hosmer and Lemeshow test	14.680		

* $p<.05$.
** $p<.01$.
*** $p<.001$.
\# $.05<p<.10$.
Otherwise $p \geq .10$.

intersection type ($F(1, 2473)=23.128$, $p<.001$) and weather condition ($F(1, 2473)=226.096$, $p<.001$) were significant. This indicated that intersections with sunshields had a significantly lower rate of red light running behavior compared to that of intersections without sunshields. At the same time, the red light running behavior rate is lower in sunny weather than is on cloudy days. No significant interaction effect of intersection type × weather condition was revealed for rate of red light running behavior. In other words, the significant difference of red light running behavior rates caused by different intersection types (with and without sunshield) is not depended on weather types (sunny and cloudy weather).

Simple effect results indicated that the rates of running a red light were significantly lower at intersections with a sunshield than at intersections without one on both sunny days ($F(1, 1428)=13.191$, $p<.001$) and cloudy days ($F(1, 1045)=11.535$, $p<.01$). On sunny weather condition, the mean value of running behavior rates at intersections with sunshields is 5.5% less than that at intersections without sunshields. The same difference of red light running behavior rates between two types of intersections is 4.8% on cloudy weather condition.

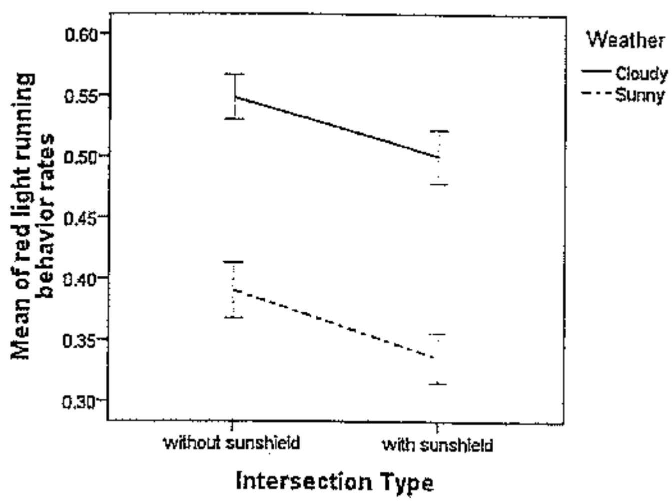


Fig. 3. Rates of running behaviors at two types of intersections (with vs. without a sunshield, error bar: ±2SE).

The effects of intersection type and weather condition on safety margin were analyzed as well. The safety margin in this observation was defined as the time from which a rider crossed the intersection to the time the next vehicle arrived at the crossing point. This dependent variable could be measured to evaluate the relative safety of running behaviors against red lights. Significant effects of two independent variables were revealed on safety margin, including intersection type ($F(1, 855)=65.034$, $p<.001$) and weather condition ($F(1, 855)=10.725$, $p<.01$). Result showed significant interaction effects of intersection type and weather condition on safety margin ($F(1, 855)=8.014$, $p<.01$). Simple effect results indicated that the safety margin were significantly larger at intersections with a sunshield than at intersections without one on both sunny days ($F(1, 374)=36.850$, $p<.001$) and cloudy days ($F(1, 481)=23.610$, $p<.001$). In addition, significantly larger safety margin is indicated on sunny days than on cloudy days only at the intersections with a sunshield ($F(1, 405)=10.181$, $p<.01$). These results revealed that potential danger of running behavior, which is indicated by the variable of safety margin, is smaller on intersections with a sunshields than that on intersections without one.

3.4. Multivariate analysis of covariance

Traffic flow was supposed to be a preliminary predictor of red light running behaviors. During the observation, it is found that red light running behavior happened more frequently when there is relative low cross traffic at the intersection. Result from logistic regression also suggested that traffic flow is a significant predictor of red light running behavior. Therefore, in this section, multivariate analysis of covariance (MANCOVA) was conducted with intersection type (with sunshield vs. without sunshield) and weather condition (sunny weather vs. cloudy weather) as between-subjects factors and the rates of red light running behaviors and safety margin being analyzed as dependent variables with traffic flow being considered as a covariant.

Both effects of two independent variable on rates of red light running behavior were significant, including intersection type ($F(1, 853)=4.293$, $p<.05$) and weather condition ($F(1, 853)=85.294$, $p<.001$). No significant interaction effect of intersection type and weather condition was revealed for rate of red light running behavior ($F(1, 853)=0.255$, $p>.05$). Simple effect results indicated that the rates of running a red light were significantly lower on intersection with sunshield than on intersections without sunshield on both sunny days and cloudy days. The lower rates were also indicated on sunny days than on cloudy days. Significant effects of two independent variables were revealed on safety margin, including intersection type ($F(1, 853) = 60.768$, $p < .001$) and weather condition ($F(1, 853) = 9.052$, $p < .01$). Result showed significant interaction effects of intersection type and weather condition on safety margin ($F(1, 853) = 7.307$, $p < .01$). Simple effect results indicated that the safety margin were significantly larger on intersection with sunshield than that on intersections. The larger safety margin on sunny days than on cloudy days was only indicated at the intersection with sunshields.

There was one significant effects of covariant indicated by this step of analysis, namely, traffic flow ($F(1, 853) = 9.149$, $p < .01$) on rates of running behaviors, whereas the effect of traffic flow on safety margin is not significant ($F(1, 853) = 0.453$, $p > .05$). Simple effect results indicated that intersection with median traffic flow had highest red-light running rates compare to intersection with low or high traffic flow.

Furthermore, the MANCOVA was conducted with rider type, gender, and estimate age group input as covariates as well to avoid the any potential confounding effects from these factors. The results of these covariates showed no significant effect on either of the two dependent variables. The effects of rider type ($F(1, 851) = 1.901$, $p > .05$), gender ($F(1, 851) = 1.041$, $p > .05$), and estimate age group ($F(1, 851) = 0.249$, $p > .05$) on red light running rate are not significant, respectively; while the effects of these covariates on safety margin, including rider type ($F(1, 851) = 0.221$, $p > .05$), gender ($F(1, 851) = 0.953$, $p > .05$), and estimate age group ($F(1, 851) = 0.034$, $p > .05$) are neither significant. In addition, the significant results of effects of independent variables on both red light running rate and safety margin are not affected with all these covariates (including traffic flow, rider type, gender, and age) input into the model. The main effects of two independent variables on red light running rates were significant, including intersection type ($F(1, 851) = 4.373$, $p < .05$) and weather condition ($F(1, 851) = 85.872$, $p < .001$). No significant interaction effect of intersection type and weather condition was revealed for rate of red light running behavior ($F(1, 851) = 0.358$, $p > .05$). Significant effects of two independent variables were also revealed on safety margin, including intersection type ($F(1, 851) = 60.791$, $p < .001$) and weather condition ($F(1, 851) = 8.938$, $p < .01$). Result showed significant interaction effects of intersection type and weather condition on safety margin ($F(1, 851) = 7.518$, $p < .01$).

3.5. *Results summary from the three analyses above*

Results from logistic regression and analysis of variance reached almost the same conclusion: Riders are significantly less likely to run through a red light at intersection with a sunshield compared to that without one both on sunny and cloudy days. And this effect of sunshield on reducing red light running rates was larger on sunny days than on cloudy days. Furthermore, after other factors (e.g., traffic flow, ride type, etc.) were statistically controlled, this effect of sunshield in reducing red light infringement rates was confirmed on both sunny and cloudy days according to the result of MANCOVA. All in all, we can conclude that sunshields installed at intersections are able to reduce the likelihood of red light infringement of cyclists and e-bike riders on both sunny and cloudy days.

Results from ANOVA and MANCOVA regard to safety margin are also similar. The safety margin is significantly larger at intersections with a sunshield than at intersections without one on both sunny days and cloudy. Also, significantly larger safety margin on sunny days than on cloudy days is only indicated at the intersections with a sunshield. These results revealed that potential danger of running behavior, which is indicated by the variable of safety margin, is smaller on intersections with a sunshields than that on intersections without one.

4. Discussion

Bicycling actually held an important position in transportation in China and is involved in a great many accidents, as we mentioned above. In light of these conditions, more and more researchers focus on ways to decrease the rate of accidents caused by bicycling. The present study examined the efficacy of sunshields, a traffic facility installed at intersections, on diminishing the rates of red light running behavior under both sunny and cloudy weather conditions by observing a total of 2477 bicycles (including regular bikes and e-bikes). Overall results highlighted that the main effect of intersection type (with vs. without sunshield) was significant on the bicycles' propensity to ride through intersections against a red light especially in sunny weather, meaning that sunshields do help to decrease the rates of red light running behaviors.

Demographic results in Table 2 provide a basic description of bicycles (including regular bikes and e-bikes) crossing intersections during our observations. There was no significance between the number of riders crossing intersections with or without sunshields. Under both types of intersections, the size of the male group passing by was larger than the female one, as was the size of middle-aged group and e-bike riders group compared to other groups under the same subcategory.

By controlling other variables (including cross traffic flow), the logistic regression analysis was conducted to explore estimated parameters in predicting red light running behaviors. Both intersection type and weather were found to be significant variables to predict red light running behaviors. Results of intersection types suggested that riders are 1.376 times more likely to run against traffic light upon intersection without sunshields than with shields, which prove a valid function of sunshields in reducing rates of red light running behaviors. Moreover, the riders were 1.756 times more likely to run through a red light without sunshields compared to those with sunshields on sunny days. Findings on cloudy days were similar, and the only difference was that odds of infringement on intersection without sunshield decreased to 1.223 times more likely compare with those on intersections with sunshields on cloudy day. A conclusion was revealed accordingly that effect of sunshield was larger on sunny days than on cloudy days.

In the further analysis of red light statuses, a conflicting result for the independent variable of intersection type was found: that the rates of running behaviors happened at intersections with sunshields are less than those without sunshields upon flashing light conditions. This was the opposite upon the red light condition. The reason for this contradiction may be due to the significant difference between running behavior rates on flashing light status and on red light status ($t = 2.980$, $p < .05$). In other words, riders were more likely to run against traffic lights on flashing light status than on red light status. In short, the general effect of sunshields on diminishing running behaviors against traffic light is effective, especially on flashing light status.

Moreover, the main effect of intersection type (with sunshield vs. without sunshield) and its interaction effect with weather condition (sunny weather vs. cloudy weather) were shown in Fig. 3. Cyclists and e-bike riders had a significantly lower rate of running behaviors at intersections with a sunshield than without in both sunny and cloudy weather ($F(1, 2473) = 23.128$, $p < .001$). The interaction effect of intersection type and weather condition was not significant and results from simple effect indicated that the rates of running a red light were significantly lower at intersections with a sunshield than at intersections without one on both sunny days ($F(1, 1428) = 13.191$, $p < .001$) and cloudy days ($F(1, 1045) = 11.535$,

$p < .01$). Consequently, the effectiveness of sunshields on reducing the rate of red light infringement was supported by this result. Finally, considering riders' crossing behaviors were related to the factor of traffic flow and the variable of safety margin was used to evaluate the relative safety of running behaviors against red light, the multivariate analysis of covariance (MANCOVA) was conducted to further analyze the effect of intersection type with other factors statistically controlled. The main effect of sunshields on reducing running behavior rates which we focused on is significant ($F(1, 853) = 4.293$, $p < .05$) and significant effects of weather condition ($F(1, 853) = 85.294$, $p < .001$) and traffic flow were indicated ($F(1, 853) = 9.149$, $p < .01$). The rates of running a red light were significantly lower on sunny days than on cloudy days, while intersection with median traffic flow had highest red-light running rates compare to intersection with low or high traffic flow. Therefore the results of the effect of sunshields on diminishing the likelihood of red light running were consistent with ANOVA results when other factors (including traffic flow, rider type, gender and age) were being controlled.

The results of safety margin indicated that red light running behaviors at intersections with a sunshield have larger safety margin compare those at intersections without a sunshield. As the indicator of potential danger of running behavior, the results showed that the red light running behaviors were less danger at intersections with a sunshield compare to those at intersections without one. These results further indicated that intersections with a sunshield installed had less dangerous red light running behaviors and therefore provided supplementary evidence that sunshields can used to improve the safety of cyclists and e-bike riders.

As a consequence, the effective influence of sunshields on reducing the rate of red light running behaviors of e-bike riders and cyclists was confirmed completely in this study combining the results from logistic regression, ANOVA and MANCOVA. When bicycle riders were exposed to higher temperatures and more sunlight, they prefer waiting under the shade of sunshields which lead to the decrease rate of running behavior. This conclusion supports our previous viewpoint that the facility of a sunshield will improve the safety of intersections for bicycling on both sunny and cloudy days. Consistent results that sunshields were shown as being more effective on sunny days than cloudy days were obtained from logistic regression and analysis of variance.

The result also indicated that there were more red-light running events on cloudy days as compared to sunny days considering the effect of weather condition on red light running behavior. There might be possible reasons for this result and further studies are needed. As we inferred, it is possible that riders do not need sunshield to avoid sunlight on cloudy days comparing to sunny days, which explained the higher traffic violation percentage on cloudy days than that on sunny days at intersections with sunshield. As for that higher violation percentage at intersection without sunshield, we found riders are easy to get tired due to the higher temperature and strong sunlight. Sunny weather in the summer in Hangzhou city usually has a higher temperature than cloudy days, and high temperature was reported to have a negative effect on human performance (Pilcher et al., 2002). Therefore, we infer that the velocity of riding may be higher on cloudy days (better riding performance), which may increase their difficulty to stop bikes near an intersection when traffic light is changing from green to red. Meanwhile, upon flashing light status, riders may estimate that they can cross the road quicker without hitting by vehicles on cloudy days due to higher riding velocity in cloudy and cooler weather situations, creating higher rate of red-light running behavior. Both of these reasons may increase possibility to run against red light on cloudy days compare to that on sunny days at intersections without sunshield. While there may be numerous reasons for this finding of the weather effect, the effectiveness of sunshield, which is the focus of current study, is verified in both sunny and cloudy weather conditions.

In addition, the effects of other factors including rider type, gender, age and traffic flow were also summarized. Table 3 tallied frequency and proportion of red light running behaviors in each category. In particular, e-bike riders were more likely running against red lights than cyclists in both types of intersections (with and without sunshields), which was consistent with the result of Wu et al. (2012). As regard other factors, the rates of running behaviors of different gender and age group were only significant on intersection with sunshields. It is revealed that male riders were more likely run against red light than female riders. As concerns the effect of age, middle-aged riders were less likely run against red light compare to young and elderly riders. From the MANCOVA result, the effect of rider type, gender, age on red light running rate are not significantly different at two sites (with vs. without sunshields) or under two weathers (sunny vs. cloudy) with other variables statistically controlled.

By controlling other variables statistically (including cross traffic flow), results of logistic regression (see in Table 4) revealed that factors such as rider types (e-bike riders vs. cyclists), gender (male vs. female), and traffic flow (low, median, and high) were all significantly associated with red light running, while age (young, middle-age, and elderly) was not a significant predictor in red light running behavior. The predicable effect of rider types revealed that e-bike riders are more likely to go against red light than cyclists, which was discordant with previous study (Wu et al., 2012). This inconsistency may due to the relatively larger number of observations in the current study compared to previous studies, which were also mentioned as one reason that rider type was failure in prediction in their paper. Results of significant differences were concluded on gender that males are more likely running against red light. A consistent result of traffic flow indicated that riders showed more likelihood of red light infringement under low and median levels of traffic flow than under high level of traffic flow (Wu et al., 2012). Moreover, there was potential for some errors in the subjective classification of rider age which may contribute to the failure of age in prediction of red light running behavior.

Although the current study validated the effectiveness of sunshields on reducing the frequency of red light running behavior of riders, there are still several problems of the current design of the sunshields and limitations of the current work. In our observations, we found that a few riders stopped across the stop line of intersections which might disturb the vision of crossing motor vehicles from other directions upon a green light. If there was a small distance between the position of sunshield installed and the stop line, riders might more likely stop *before* stop lines. This standpoint could be a direction for improvement this facility in further studies. We were also concerned that sunshields on the non-motor vehicle lanes may interrupt the view of drivers who turned right on red light, which might need further exploration. In addition, our observations did not include data taken on rainy days since the facility is designed to protect riders on hot, sunny days, such as in the summer from June to early October (after the rainy season of Hangzhou). During our observations, sunshields were dismantled temporarily because of the heavy rainfall brought by No. 9 Typhon of the year of 2011. Future studies could provide observation data on rainy days to evaluate the effects of the facility more comprehensively.

All in all, the present work proves that, in practice, the use of a sunshield installed on non-motor vehicle lanes reduces cyclists' and e-bike riders' red light running behavior rates in both sunny and cloudy weather condition. Compare to traffic police supervising the red light running behaviors in the intersection, sunshields is an affordable facility without employing manpower. This type of facility could be applied to non-motor vehicle lanes at the intersection for those areas and countries with hot climate for both safety and humanity friendly consideration.

5. Conclusion

The present study proved the effective influence of sunshield on reducing the rate of red light running behaviors of e-bike riders and cyclists at least on sunny days in a field study by which intersection type (with sunshield vs. without sunshield) and weather condition (sunny vs. cloudy) were examined as independent variables. The result also indicated that there were more red-light running events on cloudy days as compared to sunny days considering the effect of weather condition on red light running behavior. Main results of ANOVA indicated that intersections with sunshield had a significantly lower rate of red light running behavior, compared to that of intersections without sunshields. Moreover, intersection type was proved to be a significant predictor in logistic regression analysis for red light running behavior rates, which were lower at intersections with sunshields than intersections without one. The results of MANCOVA further confirmed that rates of running behaviors against red lights were significantly lower at the intersections with a sunshield than at intersections without sunshields by taking traffic flow into consideration. Based on these result, it is concluded synthetically from the present study that sunshield showed significant effectiveness in reducing the frequency of red light running behavior on both sunny and cloudy days. These findings demonstrated that sunshields installed for cyclists and e-bike riders, besides acting as a traffic facility for humanity friendly consideration, helps to diminish the likelihood of red light infringement.

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ATTACHMENT H


新亚大包

5

G+1 7 More Next Blog» ATTACHMENT I

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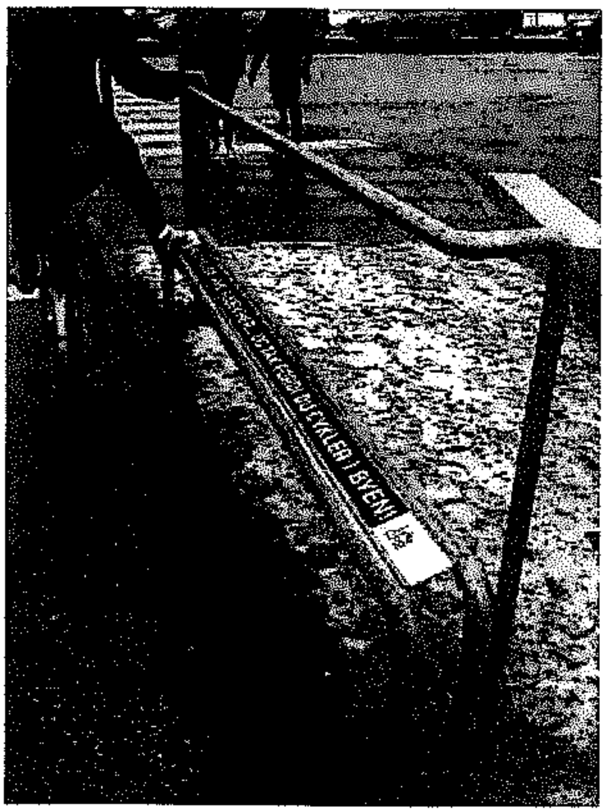
Bicycle Urbanism for Modern Cities. Since 2007.

13 JANUARY 2010

Holding On to Cyclists in Copenhagen



Pling. All of sudden this little bicycle-friendly detail showed up on the urban landscape in Copenhagen one day. I'm quite sure that very few people have noticed it, except for the people who roll up next to it. Which is the point, really.

I'm talking about the railings that the man is holding onto and resting his foot on. It's located on a little traffic island on which cyclists who are heading straight on wait. The City of Copenhagen has implemented this double railing simply as a convenience for the cyclists who stop here. A high railing to grasp with your hand and a foot railing for putting your foot up, if that's what you fancy doing. Either way you can also use the railing to push off when the light changes.

The foot rest reads: "*Hi, cyclist! Rest your foot here... and thank you for cycling in the city.*"

Another example of the city using the 'Hi, cyclist!' behavourial campaign/communications template that I developed for them.

It's a tiny detail. No bells and whistles, just a simple idea to make a tiny fraction of the day a little bit easier for a small percentage of the cycling citizens of the city.

Which is precisely why it's brilliant.

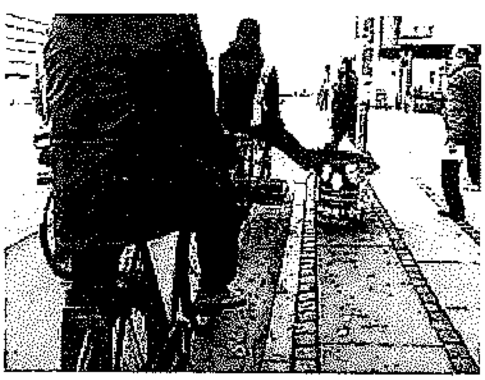
This may not be a direct example of a 'Desire Line', but it certainly is a fine example of the City understanding human behaviour and basic anthropology.

Because people are always going to lean:




And people will always put a foot up if they can:






When riding about in schools of Copenhagen cyclists and rolling up to a red light, the cyclists along the curb will all wait with a foot on the curb. If there is a traffic light post close enough to the sidewalk there will, as a rule, be a hand resting on it and holding the person in question up.

Why not spoil a few cyclists with a fantastically cheap and practical idea? A couple of metal railings. Slap 'em up. Make a few hundred cyclists a day feel loved.

Fair enough, it's not a solution that can be implemented at every intersection. Nobody wants metal railings all over town. But find a place where they work and just do it. At some other intersection, perhaps another idea will fit perfectly.

Bicycle Culture Buddhas

Actually, if you cycle about in Copenhagen take a look at the light posts next to where cyclists wait for lights to change, you'll see a tiny anthropological detail. I called it Bicycle Culture Buddhas.

The metal is rubbed smooth on precisely one side of the post from all the cyclists' hands that lean up against it. Just like the tummies of so many Buddhas.

Human traces. Urban spaces.

Like 725 people like this. Be the first of your friends.

G+1 7

Put here by Mikael Colville-Andersen at 19:59

tags: "bike facilities", "bike infrastructure", anthropology, bike facilities, hej cyklist, how to market cycling, promoting cycling

33 comments:

Clever said...

This comment has been removed by the author.

21:55

Clever said...

my first thought is that this is meaningful mainly for a population whose coaster-braked bikes make starting and stopping in the saddle comparatively awkward. a hand-hold lets them push away when the pedals are stuck in a dead spot, and since even a few seconds of track-stand are difficult, the pole prevents needing to get off!

21:57

Kiwehtin said...

Track-standing is really not practical when you have to wait for an extended period at a light or at a stop sign while waiting for a gap in cross-traffic on a main street. And even for shorter waits, track-standing is really a bit of a (usually young 'n' athletic male) subcultural subsegment of the larger biking community. It's not for everyone, hence the usefulness of the arm and footrests.

22:17

Klaus Mohn said...

This rules SO HARD.
Paris streets are full of poles, barriers, etc that have the sole puropse of preventing drivers from driving or parking antisocially. It's sad, the streets are so littered visually compared to, say, pictures from the fifties. And i'm not even talking about advertising.And then you see this simple, helpful, plain HAPPY thing or cyclists... wish we could have it everywhere.

23:05

Melbourne Cyclist said...

This post made me smile - thank you!

23:35

Chris Hutt said...

This is a clever idea. Based on observations of real life human behaviour, simple, durable, low tech and low cost. There's little to say against it except that it might be visually intrusive in some locations, but the idea can be modified, say with just the footrest or just the handrail, to make it less so.

00:19

Nick said...

Certainly a lovely idea if the intention is an innocent as claimed.

The cynic in me can't help but wonder, however, if this is not also a backhanded way of forcing pedestrians to cross only at the crosswalk. These look like the famous railings in London and so many other cities that are thought to make things safer for pedestrians but only further alienates them and makes them feel like cattle. I don't know how often pedestrians in Copenhagen 'J-walk', but in other cities these devices are used to reign in the scofflaws who arrogantly think they have a right to walk around the city unhindered.

Kensington High St. famously decreased accidents after they removed the railings.

05:59

Mikael said...

Nick: there is no sidewalk next to this railing. there is a crosswalk in front of where the bikes wait, but pedestrians dont' walk next to the railing.

it's a unique solution tailor-made for a unique location.

denmark is one of the most pedestrianized countries in europe so we don't often restrict pedestrian movement.

so take off your cynic hat and go back to your happy place for a nice cup of cocoa... :-)

07:57

blighty rider said...

Superbly simple! The foot rail is a double rail to stop the foot from sliding off.
Well done Copenhagen.

10:26

townmouse said...

Um, look. This is getting ridiculous. Do you think you and the Dutch could just stop with the bicycle infrastructure for a bit so the rest of us could catch up? And maybe if you guys have the equivalent of VSO or the Peace Corps or something you could send some traffic enginers to the developing (cycle) nations like the UK?

12:45

Anonymous said...

Sweet. Love having the ability to "stay in the saddle" at long stops and some times a high curb can be used. Maybe these have another purpose beyond cycling fun, sidewalk love handles? Quickies at red lights?
Jack

14:41

BicyclesOnly said...

Would love to see these in NYC. It is not only a convenience for cyclists but also teaches cyclists not to "shoal" (spread out horizontally jockying for position to enter the intersection first instead of waiting in line).

On the other hand, in a traffic environment like ours in NYC where cyclists' presence often is not anticipated or respected, positioning oneself at the extreme right instead of in front of the motor vehicles may reduce safety. Perhaps we could introduce them on the few European-style cycle tracks that have been installed.

17:23

lagatta à montréal said...

This is wonderful. Cyclists seek out the places such amenities exist by accident.

I'm in my 50s and have arthritis that sometimes flares up. It is fine now, but a few years back, the "launch" was very difficult - after I got started I could cycle as well as anyone. We want people to be able to keep cycling at all ages.

I had never heard the term "track-stand". I am able to balance on my bicycle long enough to respect a stop sign and look both ways, but not for the period a traffic light is red. The technique as shown in wikipedia has absolutely nothing to do with workaday cycling.

It is not like those horrible intersection railings I've seen in Rome - and sometimes pedestrians actually had to take underground tunnels!

04:47

neil said...

Too cool!

Sometimes the best ideas are the simplest!

18:13

W. K. Lis said...

It may also help in control jaywalkers. Pedestrians would tend to be funneled to the crosswalk, instead of starting their walk early.

03:48

Mikael said...

controlling jaywalkers? what about controlling the cars?

anyway, these barriers are NOT meant to be implemented where they may impede pedestrians, nor will they be implemented in places where they may do so.

08:06

stanspangenberg said...

Nice idea, but this will never work in Holland. A structure like this will certainly be used by other cyclists to lock there bike on to it from both sides. And then it becomes useless.

11:02

Shaw said...

nice, and you don't have to put your foot into a cold puddle either. Too bad here in sunny Florida, where there is bicycle weather year round, no one can ride their bikes because American drivers are on the warpath against them.

17:39

nurytche said...

nice place for biker's

07:42

Clarence Eckerson Jr. said...

I gotta say, this is super clever. And when you see facilities like this, it just makes you feel respected by your city. Nice!

18:18

wvcycling said...

This is a really neat, inside view of the little things that make cycling in such a prefecture so accepting. Or is it the amount of cycling that demands these things that makes them accepting? Chicken or the egg??

14:07

GoodPeace said...

This is cool, and I can't wait to get on my bike tomorrow and look for it - especially during wet wintertimes, I try to avoid putting my feet in the snow, and rather rest it on the curb or something else.

With regards to the pedestrians in the crosswalk, I could actually hope this thing will incline cyclist to stay put behind the line in front of the crosswalk - rather than being a dipshit riding into the crosswalk.
The down side of so many cyclists here in Copenhagen is the terrible selfish behaviour by so many of them. Of course, if it's even more comfortable to stay outside the intersection while you wait for your turn, cyclists may actually do it....

23:16

Anonymous said...

First, this is a brilliant, and thoughtful, idea. I can't see any downside to it at all in an urban setting.

Second, I concur that you need to start an international bicycle outreach corps to help underdeveloped and developing nations (like the United States). We're struggling to develop a commuter bicycle culture here in Los Angeles and need aid from developed nations like yours! ;)

18:16

Larcery Díaz Barrantes said...

Que interesante idea..Felicitaciones

22:30

Kyralessa said...

For those who are wondering, "Why don't the cyclists just put their feet down?"...

Bicyclists often use types of pedals that allow you to clip your foot into the pedal. When you stop, you have to unclip (and when you go again, you have to reclip), which is a bit of a hassle.

But if you can lean on one of these, you don't have to unclip/reclip. Not a huge issue, but certainly something that makes cycling a teeny bit more pleasant.

19:48

Frits B said...

Found this via Anna in Vienna:
http://derstandard.at/1262208799183/Radkasten-Der-schwungvolle-Rotlichthenkel

16:42

Mikael said...

Kyralessa: nobody uses those kinds of pedals here. 500,000 people on bicycles every day and maybe a fraction use them.

21:03

Charlie O said...

I noticed this the other week too, it came out of nowhere! Have used it several times and appreciated the friendly messaged from Københavns Kommune.

Just a shame it's next to such a busy road. I started cycling on the other side of the lakes now to avoid all the exhaust fumes from the traffic on my way to work in the morning.

12:56

stefano said...

I'm Italian from Milan, where riding your bike is a life threatening adventure....when i saw the rest bars i couldn't undertstand what that thing was for...then i read it and i could not believe it!!:-)
Happy i moved here, also for this little but very smart details.
Stefano

08:23

Footrests said...

This is a really neat, inside view of the little things that make cycling in such a prefecture so accepting. Or is it the amount of cycling that demands these things that makes them accepting?

Footrests

15:19

South San Francisco Gym said...

Hey...
Its too cool as well as interesting.. i really like it...
thanks for you to share it with us..
carry on..

13:27

z rest footrest said...

Superbly simple! The foot rail is a double rail to stop the foot from sliding off.
Well done Copenhagen.
Thanks for post..

16:32

Miguel Barroso said...

A Swedish designer, took the idea and designed a differente iteration: http://www.designboom.com/design/bikers-rest-by-marcus-abrahamsson-for-nola/

11:00

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Bike Coalition Rewards Polite Cyclists With Chocolate Bars and a Vacation

Posted By Erin Sherbert on Wed, Mar 6, 2013 at 3:15 PM

Jim Herd

The blind optimist

With all the animosity between cyclists and drivers and cyclists and pedestrians (and pedestrians and drivers for that matter), the Bike Coalition thought now might be a good time to try to **sweet talk our two-wheeled friends** into being a little, well, sweeter on the road.

And what's sweeter than sugar and cash?

The group will be kind-heartedly watching cyclists pedal through San Francisco to observe how well-behaved they are. In other words, are they blowing stop signs and traffic lights? Are they speeding? Are they flipping off the driver next to them?

During this spot check, any cyclist busted being "polite," will get: 1. chocolate bars, and 2. the chance to win a get-away vacation at the Bear Valley Inn.

And if you aren't riding like Mr. Rogers, then what do you get?

Not a chocolate coma, but probably not a traffic ticket either.

So here's **why** the Bike Coalition is trying to sugar coat the city's transportation tensions:

> We know that the majority of people biking in San Francisco are biking politely, and giving pedestrians the right of way. So we at the San Francisco Bicycle Coalition wanted to say thank you! Thank you for following the law, being a great bicycle ambassador and leading the way in safe, civil streets. Stopping behind the crosswalk and giving pedestrians the right of way keeps people who are on foot safe and goes a long way to making our streets safer and more comfortable for everyone.
>
> The San Francisco Bicycle Coalition will be giving out delicious treats for those we catch biking polite. If you "got caught" by us, enter your information and ticket number below and you'll be entered for a chance to win a great getaway at the Bear Valley Inn. Thanks to Alter Eco for donating the delicious chocolate rewards!

Anyway, if you are commuting cordial enough to score one of those chocolate bars, don't forget to enter your name in the **Bike Coalition's vacation raffle.**

Nice!

The Snitch

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