An Analysis on Communication between Drivers of Vehicle and Bicycle on Non-signal Intersection

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Abstract: The accident between cars and bicycles still holds a big number which we cannot neglect. By showing summary of the post-accident diary and survey about various reasons on lack of communication between the two, and by reviewing the current study on traffic conflict, human communication and virtual reality technology, it is supposed that lack of communication and traffic accident are strongly related and simulation or models on this problem is rarely paid attention to. In this study, (1) we analysis the reason about traffic accident and points out the current problem about lack of communication; (2) we describe the communication between bicycle and car drivers near the intersection by making a video survey, try to figure out the model of people's decision in traffic conflict and describe the difference which communication brings about. We also compare different communication level on the average speed of whole process; (3) we try to use eye-mark-recorder to record the sight of bicycle drivers and try to summarize the characteristic of bicycle drivers when crossing the intersection. As the survey is still going on, some trial results shows that current daily traffic conflict between the two is short of communication which, however, plays an important role in such process. In order to get close investigation and to solve the problem, this paper also summarizes how to simulate this process on virtual reality, especially the eye contact on multi-user simulator and pick up some measures to improve the current situation.

Key Words : *communication, Vehicle and bicycle, intersection, virtual reality, eye mark recorder*

1. Background

To analyze the communication between drivers of vehicle and bicycle, it is better to seize two clues for background: one is the accident between them, the other one is how communication is being made currently.

(1) The reason of bicycle accident in Japan

Traffic accident has never lost its heat in recent research. **Fig.1** shows the death ratio in all kinds of traffic accident all over the world. We can see that it is only in Japan that the bicycle accident causes an enormous amount of death. That is to say, 16.2% of traffic accident death was caused by bicycle.

When it comes to the proportion, as **Fig.2** shows, divided by age and compared with the original composition ratio of population, we can conclude that the youth and the senior people died more than the original population composition in Japan for bicycle accident, which means it threatens the vulnerable groups. Both the figures show that bicycle accident cannot be ignored in our daily life.

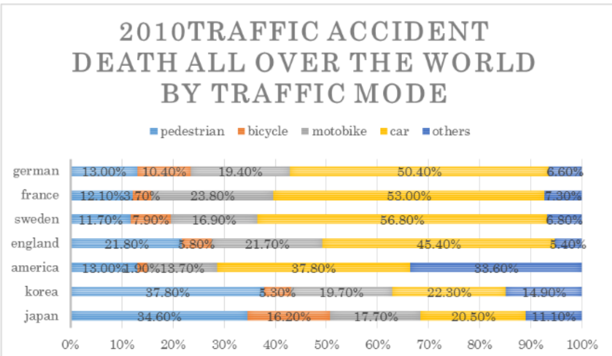

Fig.1 Traffic accident death all over the world by mode.

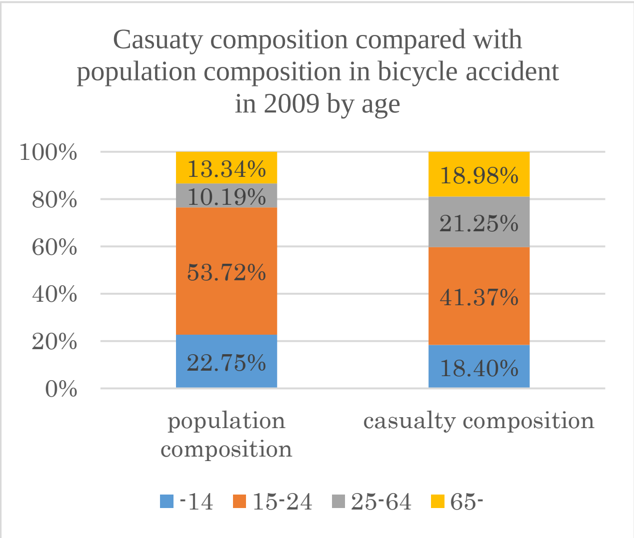

Fig.2 Casualty composition by bicycle accident in 2009

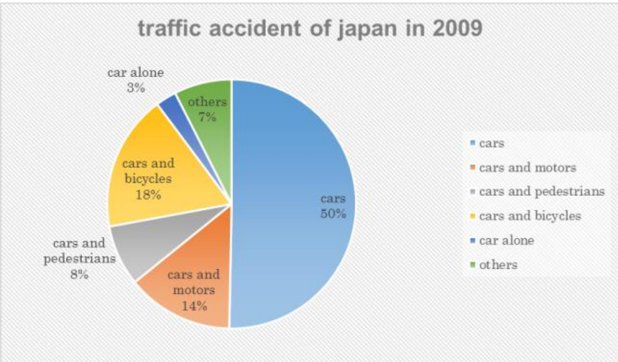

Fig.3 traffic accident in japan in 2009 by mode

Once you study the Japanese traffic accident in 2009, we can see that nearly 17.7% of accident is about bicycle and cars, while 12.4% death comes from bicycle-car accident (refer to **Fig.3**).

Referred to the data from Kyoto Police Agency, without checking is the first cause of a bicycle accident. In the book of statics of accident, the lack of checking takes about 29.4% of responsibility for bicycle accident in non-signal intersection. From these data, lack of attention to front and lack of safety checking is supposed to be main reason of traffic accident. Obviously, it also related to the lack of communication between bicycle and cars.

All of above backgrounds made sense about research on communication between bicycle and cars near a non-signal intersection.

(2) The communication in daily life

The above reports showed that bad communication may relate to the bicycle accident, it makes us unsurprised to see that lots of expert reports warn people the importance of communication between drivers.

A lot of bicycle websites also mentioned the knack to keep bicycle safety is to be visible and using body language can strengthen self-existence.

All the reports seem to say that in daily life people may be neglect to communicate with vehicles. While despite the subjective reasons, some objective condition which may encumber the procession of communication should not be ignored.

Fig.4 objective condition encumbers process to communicate

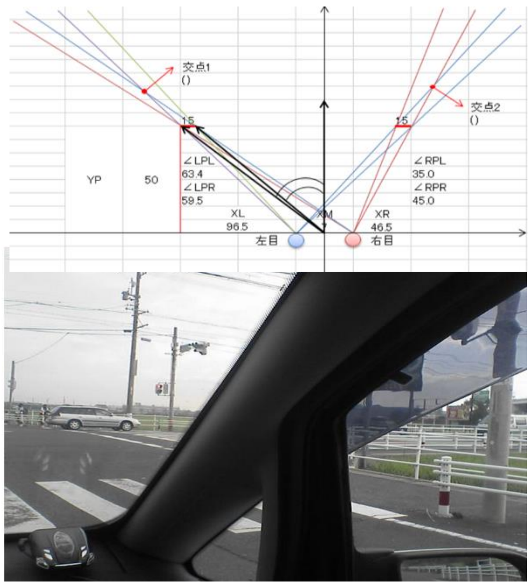

Fig.5 frame of front window encumbers drivers' vision

As the above group of photos in **Fig.4** inferred, that the reflection of light or obstacles on the road may cause the lack of communication directly. However, not only the road environment, but also the car itself may encumber the whole communication between drivers.

Fig.5 is to calculate how the car front window frame hinders our view to get to communication. Due to the frame of window of cars, nearly 15 degrees cannot be seen, that is to say, in the view of the center of eyes, 35.0 to 45.0 degree is invisible for the right pillar, and 59.5 to 63.4 for the left pillar. However, 70 to 75 degree can be seen when the driver is moving, which means nearly 20% dynamic vision cannot be seen due to the frame obstacle.

However, if people want to make communication, the above reasons may not be excuses. From all above, we can make a consumption that the lack of communication may relate to the accident. But why people in daily life don't make communication, so in this paper, we try to figure out the reason. So the following problem is taken into consideration. Is there lack of communication in daily life? Is that related to the traffic danger? If so, what characteristic does it have and how can we study on it and what should we do to solve the problem.

2. Definition and basic characteristic of bicycle riders' communication

Before survey starts, I would like to introduce my structure of research and also some important definitions.

My research structure is mainly composed of 3parts.

Firstly, a video survey is conducted to show a macro results and using eye mark recorder to show a micro phenomenon for the real life communication situation.

Secondly, we consider how we can make the whole process in a virtual reality world or simulation platform to make an analysis.

And finally, the step is to find out what we should do to solve the problem.

(1) definition of communication and communication level

The definition of communication is the activity of conveying information through the exchange of thoughts, messages, or information, as by speech, visuals, signals, writing, or behavior. For this research, the information exchange is about mutual position, speed and decision to move or not. The exchange signal is sent by eye contact or body language.

Table 1 Communication level is divided by different modes

Car and bicycle	Communication level
Neither see the opposite side	0
Only one participant see	1
Both see the other side	2
Eye contact	3
Clearly judged by body gesture	4

Since there are two participants and different communication methods, we'd better define a communication level to take the analysis as the **Table 1.**

(2) An accident result analysis utilizing communication level and psychological reason of bicycle

In this paper, we tried to use this communication level definition to analyze a dairy set from accident victims in Chiba police homepage.

17 reasons that victims wrote distributed as **Table 2** which shows that accident happened only in lower communication level. They also mentioned the psychological reason which accident should be to blame. Bicycle accidents has the characteristics as followings: confidence of control, inconvenient to get off, better feeling to speed up, lack of attention due to chat, confidence to familiar space, space-take up feeling and free route feelings.

Table 2 Bicycle accidents divided by reason they wrote in dairy

Car and bicycle	Communication level	case
Neither see the opposite side	0	6
Only one participant see	1	8
Both see the other side	2	3
Eye contact	3	0
Clearly judged by body gesture	4	0

3. Selection and basic information of survey place

Among thousands of intersections in Tokyo, it is quite difficult to pick up some a place to start surveying for bicycle and cars. In order to watch the communication data, the number of bicycles and cars should not be too small or too big. It is better be a place that conflict could happen between them and we should also clearly figure out what kind of transportation condition may affect our results.

(1) Relation between intersection factors and bicycle accident

According to the Tokyo police HP, we can find the bicycle accident map (as **Fig.6** shows), which described the bicycle accident in 100m*100m unit mash. We cut an area of 900m*900m in Google view of the same area near Gakugeidai station and pick up 161 intersections from 36 100m*100m-units, then made a comparison between intersection factors and bicycle accident.

Fig.6 Bicycle accident map and Google view mash up

$$\gamma = s*num_{signal} + m*num_{mirrorl} + p*num_{pending} + z*num_{zebra} + pa*num_{pavesign} + st*num_{stopsignl} + a*num_{asphalt} + o*num_{oneway} \quad (1a)$$

γ: relative traffic accident rates

num_x; the number of factor-x in the unit

Formula 1a is supposed to describe the relation between relative accident rates and the intersection factors. In order to make a multiple regression analysis, a relative accident rates are appropriate. However, the current traffic flow data is hard to get where we make an approximate calculation that the traffic flow density is inversely proportional to the distance of position and the station as the **Fig.7** shows.

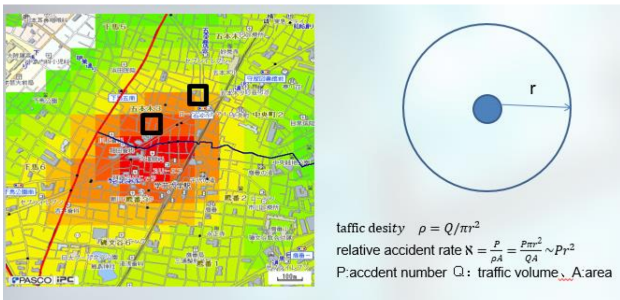

Fig.7 Relative accident rates using an approximate calculation

As **Table 3** shows, referred to t-value, the most effective measure is colorful asphalt, which is quite conspicuous to warn people. The one-way route and the pending mark have effect to anti-accident while other factors show low relative to the accident.

Table 3 Multiple regression analysis of road factors and relative accident rates

coefficient	value	t
s(signal)	-24.1433	-0.8198
m(mirror)	6.849474	0.732621
p(pending sign)	9.042189	1.034925
z(zebra crossing)	8.518684	1.014682
pa(pavement sign)	-4.16116	-0.22629
st(stop sign)	-0.95416	-0.31556
a(asphalt)	-25.0262	-1.84289
o(one-way road)	14.1653	1.59502

However, the result may have two problems, which are, (1) the factors are cut too small, it may be better to cut the intersection into different type; (2) the factor may reflect the whole area's function while the factor may have effect only in a certain type of intersection.

So we divided the intersection into 5 different types (as **Table 4** shows) and do the regression analysis again as the formula 1b tells.

$$\gamma = s*num_{signal} + m*num_{mirrorl} + i**num_{inside} + b*num_{biginside} + e*num_{exit} \quad (1b)$$

γ: relative traffic accident rates

num_x :the number of factor-x in the unit

From the analysis of **Table 5**, we can jump to an implication that the big intersection with road-mirror has a big possibility to cause conflict or accident. After asking the local police, we decide to make the survey at the following place which all is the mirror intersections listed up by **Table 6**.

Also for pedestrian location, we choose intersection near the school and two stations to watch the pedestrian as a control group.

Table 4 Classification of different type of intersection

type	Definition
Signal intersection	Intersection with signal
intersection with mirror	Intersection with road mirror
small intersection insight	Small intersection without zebra line
big intersection insight	Big intersection inside the residential area
exit intersection	Intersection conjunct the inside roads and the main road

Table 5 Multiple regression analysis of intersection type and relative accident rates

Coefficient	value	t
s(signal intersection)	-16.47	-0.74
m(intersection with mirror)	21.731	1.85
i(small intersection inside)	-22.396	-4.66
b(big intersection inside)	-25.712	-0.81
e(exit intersection)	-19.68	-2.08

Table 6 Survey place selection list

place	Abbreviation	Address	Survey time
Gakugeidai station1	G1	Meguro-ku takaban2-13	Apr16th 14:30 -15:30
Gakugeidai station2	G2	Meguro-ku takaban2-18-1	Apr17th 11:15 -12:15
Ebara	E1	Shinagawa-ku Nakanobu2-9-6	Apr18 -Apr26 11:15 -12:15

(2) Survey method and some definition to analysis the result

A precise method can ensure a reasonable survey. After selecting several intersections, the following factors have been done to get the current situation of the bilateral communication.

a) The equipment

Video and voice recorder are used to record the whole survey. In detail, we set up the video camera near the intersection and the observer will stand in the corner where the communication case can be recorded clearly by voice.

b) The definition or standard to judge data into different groups

First, we defined the conflict area as both sides' stop line to the cross point of their route (which I name it as a conflict point).

Then, 10 patterns of different type of bicycle-car passing are noted as abbreviation. The letter order shows bicycle or car passing order and if the same letter comes out twice, the first one means it stops before it passes. They are BC, CB, BCB, BBC, CBC, CCB, BCCB, BCBC, CBCB, and CBBC.

Take the CBC as an example as following

Bicycle passed the conflict point
↓
C B C ← finally ,car passed
↑
Car stopped at first

c) Survey contents and record methods

Communication pattern is judged by both camera and observer who will use the voice recorder to save the situation and use body language to make the video and sound document synchronous.

The speed is also measured. We measured the distance of marked position and cut the video into 10 photos in one second. Then, we calculate the speed before they reach the conflict area.

Swing checking is also recorded as a main index to evaluate people's consciousness of making communication. It is also recorded by video and voice-recorder.

4. Results about survey and analysis

(1) Basic information about results of survey and their purpose

Fig.8 is a set of photos which show the intersection type and basic information. S is for straight direction. T is for turning direction. Red circle is for the position of camera.

The **Table 7** described the basic information about traffic flow during one hour survey of all the intersections.

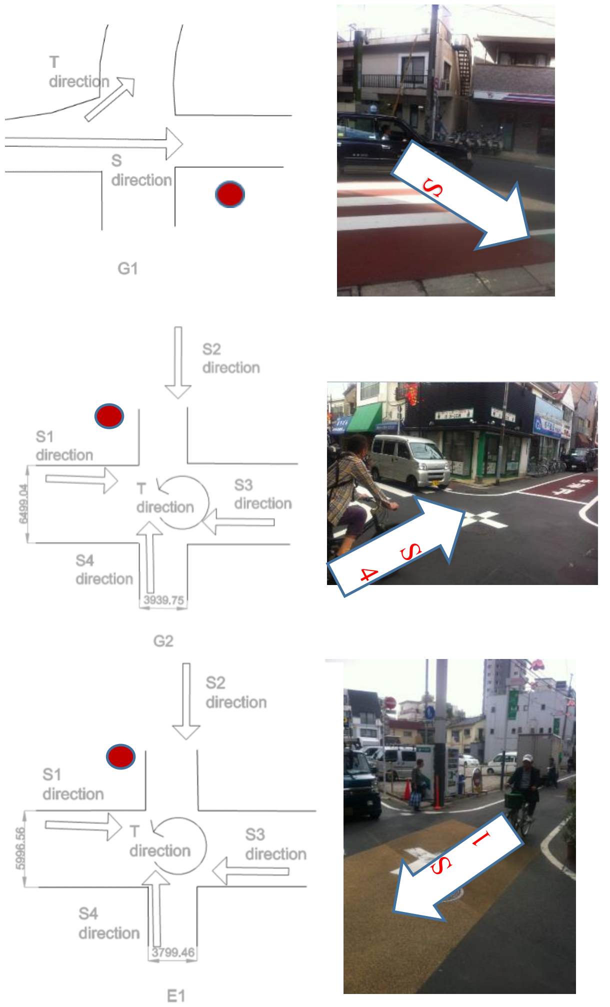

Fig.8 3 Survey places image and the direction contained

Table 7 traffic flow in one hour in 3 survey intersection

code	Bike	Direction	Vehicle	Direction
G1	48	S+T		
G2	185	S+T	13	S4
E1	188	S+T	92	S4

(2) Analysis and discuss

a) Outlook

S direction in G1 intersection (G1S) has quite a bad outlook due to an electrical box near the intersection, while for G2S1+S3 direction, the outlook is better. Let’s compare them; one is 17 bad outlook samplings, while the other is 131 good outlook samplings in **Fig.9**. As the result shows, the frequency for swinging head of bicycle drivers if the outlook is bad is higher than that in a good outlook.

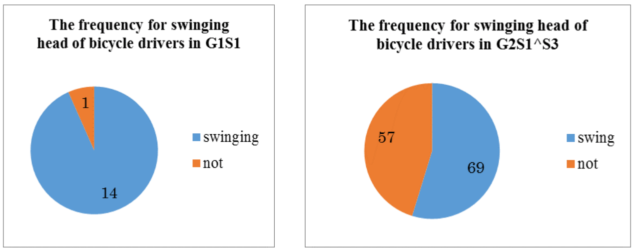

Fig.9 Frequency difference of swinging head divided by the outlook

b) Width of road they passes

G2S2+S4 direction will pass a 6.5m road while both G2S1+S3 direction and E1S1+S3 direction only pass 4.0m and 3.8m wide road. We can see that in **Fig.10** the frequency of swinging head in passing wide road case is more. It maybe because people think the wider road may have a bigger chance for cars passing by. You may wonder that maybe the difference is from the car passing by, however, referred to the table16, G2S4 and E1S4 have different car-passing number while the G2S1+S3 and E1S1+S3 direction have the same low frequency of swinging head. That is because, it is not the car-passing number affect in real case while it is the car number people think there are really matters.

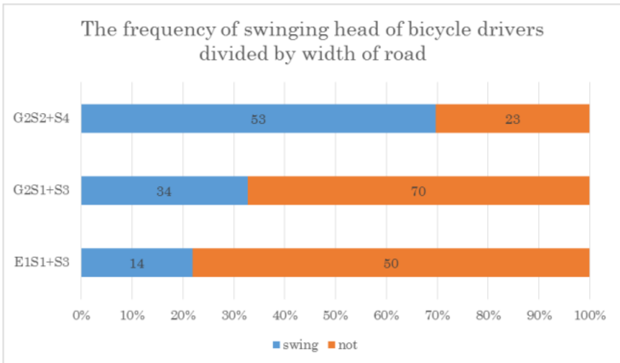

Fig.10 frequency difference divided by the road width

c) Moving direction

The **Fig.11** shows the difference of moving direction. We can see that in all three intersections, swinging head frequency in straight direction is bigger than that if they turn. It maybe because turning of the bicycle doesn't need to change lanes actually which seems easy and safer.

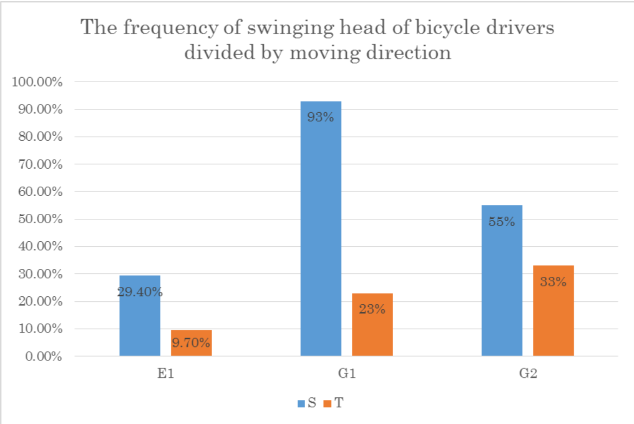

Fig.11 Frequency difference divided by moving direction

d) Speed

Bicycle drivers also acted differently with different speed, as is shown in **Fig.12**. We calculate the E1S3 direction speed of the bicycle and checking their head swinging frequency.

Low speed bicycle drivers show more intention to make communication while the high speed ones just pass by with low frequency of swinging head.

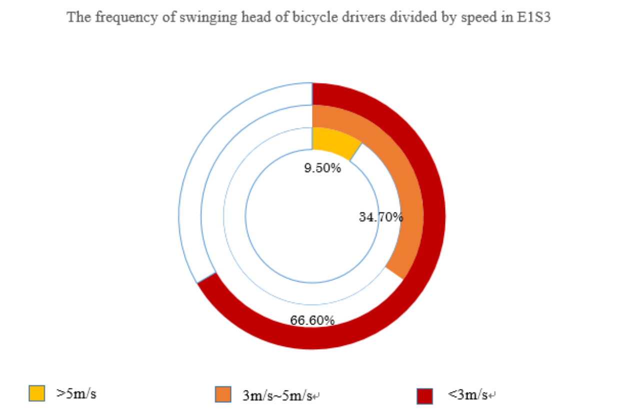

Fig.12 Frequency difference divided by speed

e) With or without cars

Whether there is a car or not in the conflict area at the same time also affects people checking mode. The **Fig.13** shows that a car in the conflict area may stimulate up people's consciousness to check. However, even if there is a car passing-by, there are still nearly half of the people didn't swing their head to check or make communication.

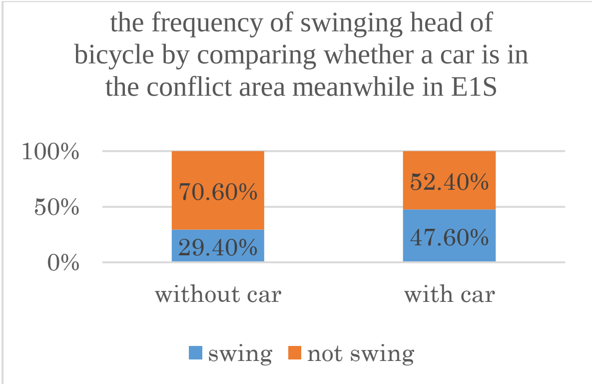

Fig.13 frequency difference divided by speed

f) Familiar VS unfamiliar intersection refer to pedestrian

Bicycle drivers always make their trip near their residential area which they may quite familiar with. In order to check the influence familiarity brings. We made a comparison of pedestrian swinging head mode in Shibuya station (a viewing spot is supposed to be unfamiliar to passing-by pedestrian) and Gakugeidai station (which is supposed to be familiar to pedestrian).

The results in **Fig.14** showed that pedestrian passing unfamiliar intersection may check more than those who are familiar with the area. It can also be a notice for bicycles. Bike-drivers are always passing familiar area which may lead to their careless to check.

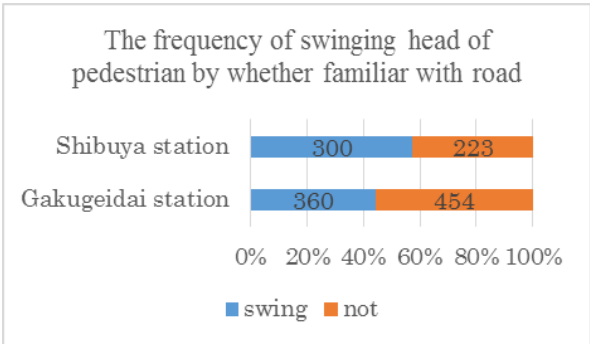

Fig.14 Frequency difference divided by familiarity of pedestrian

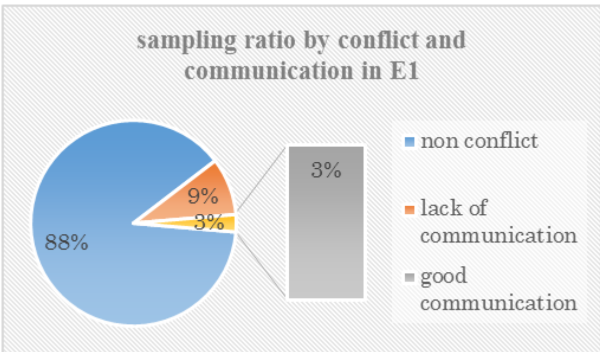

Fig.**15** Pie chart to show the communication proportion

g) Communication case

Since the bicycle and cars pass fast which lead to the conflict between them is low and the case of communication only takes 3% of the whole survey in E1 as is shown in **Fig.15**.

Fig.16 is a stem chart of communication level among all the conflict case by pattern

If we make the level 0 and level1 as low communication and make the level 3 and level 4 as the high communication, than as **Fig.17** shows that if car and bicycle driver had high communication, the bicycle prior to pass happened more frequently which proves that the communication has effect on safety in conflict.

Fig.18 also shows the trend that in low communication case neither of drivers would stop while in high communication case both of the drivers would stop.

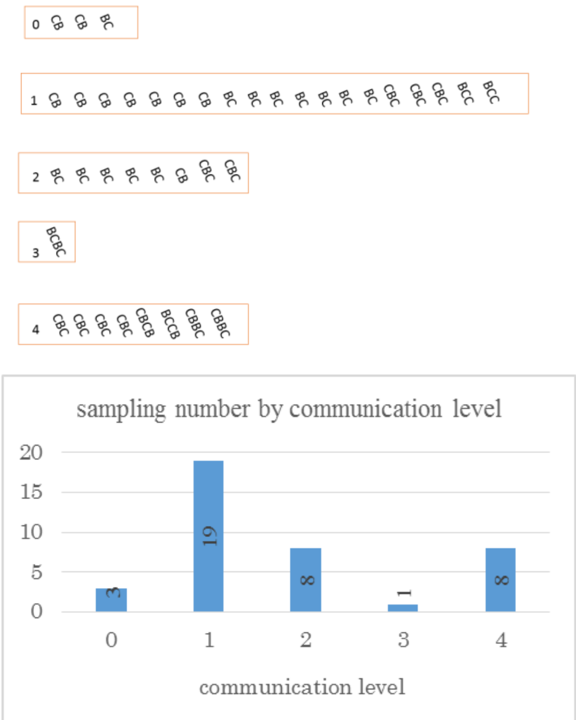

Fig.16 Stem chart to show all the pattern of communication

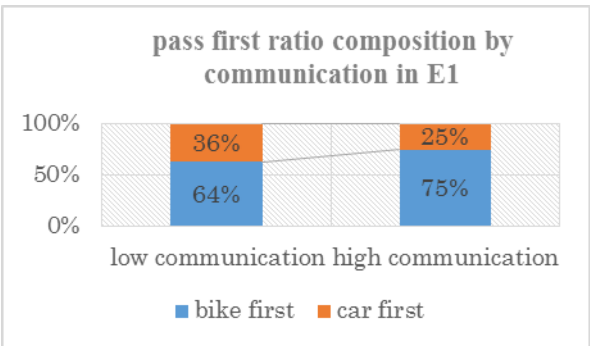

Fig.17 Bike prior case proportion by whether communicate

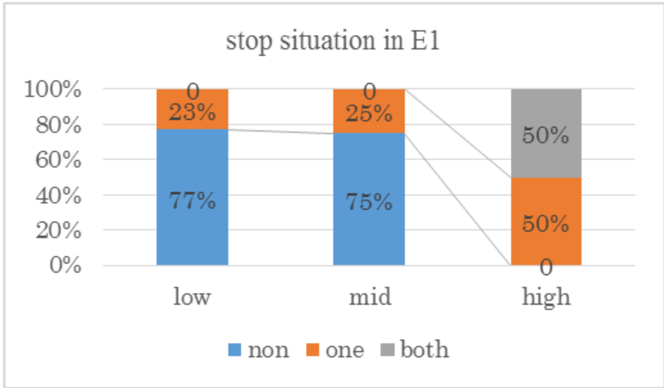

Fig.18 stop situation by different communication level

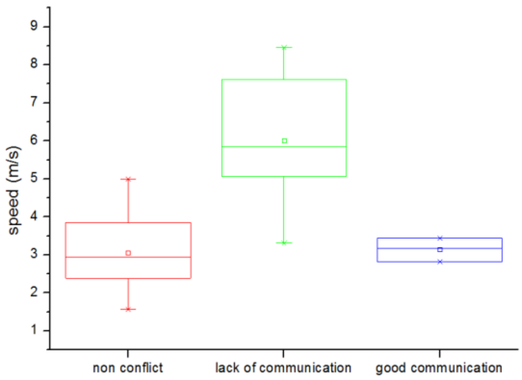

Fig.19 distribution of speed under different mode

Finally, **Fig.19** shows the distribution of speed in non-conflict, lack of communication and good communication case. We can see that in the normal case, bicycle speed is about 2.5m/s to 4m/s while lack of communication case bicycle speed is higher which can be more dangerous and people make good communication seem to be slower.

h) A passing model of pedestrian and cars as reference

Since the case of communication of bicycle drivers is low, which may reduce the effectiveness to make a model.

We use the pedestrian data to build a model as reference, in which we can see how communication have effect on conflict decision process.

In this model we consider pedestrian and car drivers make decision by utility.

U1 is a utility for people prior to car and U2 is for car pass firstly.

$$U1 = ASP1 + \beta_{TD1} * TIME_{diff} + \beta_{CS1} * CAR_{STOP} + \beta_{PS1} * PP_{STOP} + \beta_{C1} * COM + \beta_{S1} * SIGNAL \quad (2a)$$

$$U2 = ASP2 + \beta_{TD2} * TIME_{diff} + \beta_{CS2} * CAR_{STOP} + \beta_{PS2} * PP_{STOP} + \beta_{C2} * COM + \beta_{S2} * SIGNAL \quad (2b)$$

In these equations:

ASP : constant coordinate

$TIME_{diff}$: time difference of bicycle and drivers passing by

CAR_{STOP}: whether stop before get into conflict area

COM : whether made a communication

$SIGNAL$: intersection with or without signal

β_x : factor x's coordinate

273 samples have gathered and the results are listed as following **Table 8**. The coordinate shows that communication really have an effect on making people pass first while it is still lower than the car or people stops. From this, we may conclude that people seems to make their decision by whether the opposite side stop or not rather than make a clear communication. However, as the report we mentioned in the opening pointed out, choosing to pass by just because car stops are quite dangerous.

Table 8 coordinate in the utility function for pedestrian and car conflict

coordinate	Value	Std err	t-test	p-value
ASP_1	0.00	fixed		
ASP_2	0.278	0.305	0.91	0.36
β_{C1}	1.94	0.920	2.12	0.03
β_{C2}	0.00	fixed		
β_{CS1}	3.72	0.643	5.78	0.00
β_{CS2}	0.00	fixed		
β_{PS1}	-3.53	0.655	-5.39	0.00
β_{PS2}	0.00	fixed		
β_{S1}	0.973	0.491	1.98	0.05
β_{S2}	0.00	fixed		
β_{TD1}	-0.736	0.264	-2.78	0.01
β_{TD2}	0.00	fixed		

5. Eye movement characteristic

(1) Bicycle drivers eye movement and simulation

As the professor Uchikawa mentioned it in the book, our eyes cheat our brains. Two characteristics have been pointed out as follows

a) Partial attention

Our eyes have low attention to things we are familiar with. The book takes our nose as example. Although nose must be in our sight, we never see it. This phenomenon also can be the cause of conclusion f. We pay more attention to the intersection which we are not familiar with.

b) Get used to mistake

The second characteristic is more interesting. Our eyes may mistake our sight to the familiar scenario. Just read the following sentences.

"Aoccdrnig to a rscheearch at an Elingsh uinervtisy, it deosn't mttaer in waht oredr the ltteers in a wrod are, the olny iprmoetnt tihng is taht frist and lsat ltteer is at the rghit pclae. The rest can be a toatl mses and you can sitll raed it wioutht porbelm. Tihs is bcuseae we do not raed ervey lteter by itslef but the wrod we get usde to."

Although most of the sentences above have spelling mistakes, it doesn't make trouble for us to get the meaning and read it fluently. This phenomenon may infer that if we get used to a place being safe usually, we may neglect its danger even in emergency.

Since our eyes have those kinds of characteristic, it is not possible to catch all the details in the real life. That is because, if you watch them closely, it may disturb to the natural situation and if you want lots of people to attend the actual experiment, no one could assure the safety for them. So a simulation of bicycle and car drivers is needed.

Nowadays, with the development of virtual reality, more and more institutions make it with the simulation being more realistic, although most of which focus on only one-user simulation. For our theme, a multi-user, especially a bicycle driver and a car driver, both of them taking part in the simulation is needed.

However, it is still a big project to fulfill the multi-user making communication in a virtual reality world. A direct method or an indirect method can be proposed. As the direct method, if we want to simulate user A and B have eye contact, at first, the computer should judge that A is looking at B* and then the screen in front of B may make B feels being seen by player A*. On the other hand, as for the indirect method, if A sees B, A should press some kind of button to make the computer know, then the computer screen will show B he is being looked at by A*. By the research of professor referred to **Fig.20**, with the time passed, the angel of eye balls may related to the head angle positively, we can also let computer calculate the angel of eye balls by measuring the head angle, which is easier to catch.

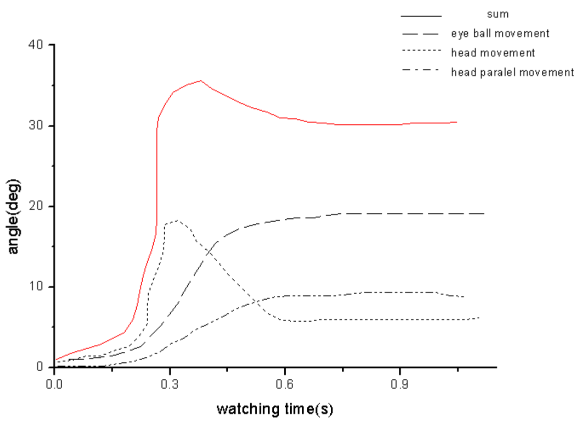

Fig.20 angle of head and eye movement with the change of watching time

6. Conclusion

As the analysis above shows, (1) the current communication between bicycle and cars is little which may relate to traffic accident;(2)bicycle drivers shows low frequency of making communication or safety-checking under some transportation condition.

Of course, since the current research focus on the macro survey, it is better to consider bicycle drivers eye movement characteristic in a micro view. In future, we may use an eye-mark-recorder to record the individual aspect of their eye movement.

Finally, to solve the problem, not only should we emphasize the education for both bicycle and car drivers to strengthen their consciousness for communication, but also we should do our best level up the communication technology. As the data-communication technology develops, a data core equipment set on intersection which can pass the mutual location information to both bicycle and cars before they enter into the conflict area is supposed to be a good choice.

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