Statistical analysis of traversal behavior under different types of traffic lights

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Abstract. According to the video observation, it is found that the traffic signal type signal has a significant effect on the illegal crossing behavior of pedestrians at the intersection. Through the method of statistical analysis and variance analysis, the difference between the violation rate and the waiting position of pedestrians at different intersecting lights is compared, and the influence of traffic signal type on pedestrian crossing behavior is evaluated. The results show that the violation rate of the intersection of the static pedestrian lights is significantly higher than that of the countdown signal lights. There are significant differences in the waiting position of the intersection of different signal lights.

1. Introduction

In order to divide pedestrians and motor vehicles on time and space, the city road junctions usually install lights to reduce the conflict between pedestrians and motor vehicles. According to the video observation, it is found that the traffic signal type has a significant effect on the illegal crossing behavior of pedestrians at the intersection. So the influence of the traffic light type on pedestrian crossing traversal behavior is analyzed in depth in this article.

At present, there are three kinds of pedestrian lights used in China: static pedestrian lights, dynamic pedestrian lights and countdown pedestrian lights[1]. Static pedestrian light is use of the earliest and most popular pedestrian lights in China. This signal is relatively simple and energy-saving[2]. Dynamic humanoid lights in the green light mirror is a dynamic human form, while transmitting the information about the right of passage, it can also transmit the fuzzy time information which is about to gain or lose the right of passage[3]. This kind of signal light has better information identification than static signal, and it can improve the efficiency of pedestrian crossing[4]. Countdown pedestrian light has a stopwatch, this kind of signal light time information is clear, the psychological comfort is high, can help the pedestrian to regulate the street behavior and the speed, but the cost is relatively high[5].

In summary, the green light is mainly static type, dynamic type and countdown type, and the red light is mainly static and countdown type. This paper mainly studies the behavior of pedestrians crossing the street during the red light, so the signal type includes static and countdown.

2. Method

This study mainly uses the method of field investigation, data acquisition and analysis are carried out by video shooting. This method is widely used in the study of pedestrian characteristics at urban signalized intersection.

2.1. Observation location
On the basis of many field surveys, in order to compare the differences of pedestrian behavior at different intersecting lights, the survey sites in this study are Jinbao Street - Dongdan North Street and Zengguang Road - Capital Gymnasium South Road intersection. The first intersection is equipped with countdown signal light, the latter one is equipped with dynamic signal light.

2.2. Observation and coding

Before the implementation of the investigation, it is necessary to determine the camera shooting range and angle in advance. In addition, the video shooting takes place during the peak hours (9:00-11:00am, 2:00-4:00pm) of the day when the weather is good. In order to ensure the comparability of the data, the two intersections have chosen the same time for simultaneous shooting.

The camera records all pedestrians passing through the intersection, but this article focuses on pedestrian data arriving at the intersection during the red light, so the sample arriving during the green light is not counted as a valid sample.

Pedestrian violation of the street includes red light violation as time violation and without walking cross the crosswalk as space violation. Time violation refers to the cross-street traffic facilities (pedestrian signal light) are not in accordance with the instructions and fail to obey the corresponding phase crossing the street. In other words, pedestrians cross the street illegally during the signal red light. Space violation refers to pedestrians who have not used traffic facilities (crosswalk, overpass, underground passage, etc.) to pass through the intersection.

The pedestrian character variables considered during the observation process are gender and age; About the age, Young is 18~35 years old, Middle-age is 35~50 years old, Elderly is elder than 50 years old. The environmental variables considered during the observation process are Signal type, Length of red light, Traffic flow and Number of lanes.

The pedestrian behavior variables considered during the observation process are Arrival time, Waiting time, Waiting position, Number of pedestrians for waiting and Number of conformity. When the sample reaches the signal intersection, the waiting situation can be divided into four types: cross directly instead of waiting, waiting in a reasonable area, waiting in the middle area, waiting in the dangerous area. The middle area refers to the non-motorized road around the reasonable area, the dangerous area refers to the area outside the reasonable area and the middle area.

3. Result

This study mainly uses the method of field investigation, data acquisition and analysis are carried out by video shooting. This method is widely used in the study of pedestrian characteristics at urban signalized intersection.

3.1. Statistical analysis of traversal behavior under different types of traffic lights

3.1.1. Comparison of Sample Data Distribution and Violation Traversing Behavior. A total of 1152 valid samples were obtained during the previous sample selection process. It can be seen from the data in the Table 1 that the overall sample violation rate is 48.3%, there are some differences between the different types of sample violation rate, the specific analysis is as follows:

(1) There are significant differences in the sample violation rate between different signal types ($\chi^2 (1) = 13.928, \ p<0.001$), and the violation rate of the intersection of the static pedestrian lights is higher than that of the countdown pedestrian lights (56.3% and 40.3%, respectively). It can also be seen that the violation rate of the intersection of the countdown pedestrian lights is lower than Static signal lights intersection, indicating that the countdown signal can effectively reduce the signal at the intersection of illegal behavior.

(2) There were no significant differences between the different gender samples ($\chi^2 (1) =2.533, \ p=0.112$). Moreover, there is no significant difference between the different sexes in the static pedestrian signal ($\chi^2 (1) =1.503, \ p=0.220$) and the countdown line signal ($\chi^2(1) =1.094, \ p=0.296$).
There were significant differences in the rate of violation of different age samples ($\chi^2(2) = 101.712, p<0.001$), the highest rate of violation of the elderly pedestrian (59.7%), and the lowest rate of youth samples (39.3%). There were significant differences in the violation rate of different age samples under static pedestrian lights, and the violation rate of the elderly was as high as 69%, the middle age sample was the second (58.3%), and the young sample was the lowest (51.5%). There was also significant difference in signal intersection between different age samples ($\chi^2(2) = 56.718, p<0.001$), the distribution of the violation rate and the static intersection of the same, but the age of the violation rate is lower than the static signal intersection. The relationship between the violation rate of different age samples is determined by its main groups, the majority of young students, the law-abiding awareness is relatively strong.

There were significant differences in the violation rate of samples in different arrival periods ($\chi^2(2) = 40.321, p<0.001$), and the violation rate of the front part of red light (63.6%) was the highest, and the violation rate of latter part of red light (38.3%) was the lowest. For the sample arriving in front part of red light, the pedestrian violation rate of the countdown signal is higher than that of the static pedestrian signal, which is accurate with the countdown signal to the pedestrian phase of the remaining time; For the sample arriving in middle part and latter part of red light, the pedestrian violation rate of the countdown signal intersection is lower than that of the static pedestrian signal intersection.

| Table 1. The distribution of violation rate of samples under different classification |
|---------------------------------|-----------------|-----------------|-----------------|
| **Signal light type**            | **Static pedestrian lights** | **Countdown pedestrian lights** | **Total** |
| **Gender**                       | Male            | 172(58.9%)      | 109(34.4%)      | 281(46.1%)   |
|                                 | Female          | 150(53.6%)      | 125(47.5%)      | 275(50.6%)   |
| **χ²**                          |                 | 1.503           | 1.094           | 2.533        |
| **Age**                         | Young           | 134(51.5%)      | 56(25.0%)       | 190(39.3%)   |
|                                 | Middle-age      | 148(58.3%)      | 132(48.9%)      | 280(53.4%)   |
|                                 | Elderly         | 40(69.0%)       | 46(53.5%)       | 86(59.7%)    |
| **χ²**                          |                 | 64.273***       | 56.718**        | 101.712**    |
| **Arrival time**                | Front part of red light | 135(60.5%) | 103(68.2%) | 238(63.6%) |
|                                 | Middle part of red light | 78(47.3%) | 80(41.0%) | 158(43.9%) |
|                                 | Latter part of red light | 109(59.2%) | 51(21.8%) | 160(38.3%) |
| **χ²**                          |                 | 10.016**        | 40.321**        | 20.717**     |
| **Total**                       |                 | 322(56.3%)      | 234(40.3%)      | 556(48.3%)   |

*p < 0.01, * * p < 0.05, other p > 0.05

### 3.1.2. Sample waiting position distribution

Because of the time information which the pedestrians have obtained at the different types of signal intersections is different, the waiting position will be different when pedestrians arrive at the intersection. Table 2 shows the location of pedestrians for different types of signal intersections. The specific analysis is as follows:

(1) The sample as a whole, there are significant differences between the waiting positions of different types of intersections ($\chi^2(3) = 73.184, p<0.001$). The proportion, which pedestrians don’t wait to cross the intersection, of static signal intersections(40.1%) is much higher than that of countdown signal intersection(18.4%); The proportion of pedestrians waiting in the dangerous area or intermediate area is that the countdown signal intersection is higher than the static signal intersection(24.0% vs. 11.6%,33.0% vs. 24.6%); The proportion of samples waiting in a reasonable area under two types of signals change a little(33.0% vs. 24.6%); This is due to the time information is more clear at the countdown signal intersection, some pedestrians will be based on the remaining time to move their position.

(2) There was no significant difference in the proportion of male and female samples waiting in the reasonable area under different signal types. However, the differences were significant in different age samples, the proportion of middle-aged samples waiting in a reasonable area under two signal types was 20.6% and 61.3%, respectively; The proportion of elderly pedestrians waiting in reasonable areas was...
31% and 16.7% respectively; There were also significant differences in the waiting position of the samples in different arrival periods, among which the proportion of waiting in reasonable areas in the latter part of red light was 17.4% and 7.7%, respectively.

### Table 2. Distribution of sample waiting position under different classification

| Signal type                  | Waiting position | Reasonable area | Intermediate area | Hazardous area | No waiting |
|------------------------------|------------------|-----------------|-------------------|----------------|------------|
| Static pedestrian lights     | Gender           |                 |                   |                |            |
| Male                         | 68(23.4%)        | 77(26.5%)       | 22(7.6%)          | 124(42.6%)     |            |
| Female                       | 67(24.1%)        | 63(22.7%)       | 44(15.8%)         | 104(37.4%)     |            |
| Age                          |                  |                 |                   |                |            |
| Young                        | 65(25.1%)        | 68(26.3%)       | 26(10.0%)         | 100(38.6%)     |            |
| Middle-age                   | 52(20.6%)        | 56(22.2%)       | 36(14.3%)         | 108(42.9%)     |            |
| Elderly                      | 18(31.0%)        | 16(27.6%)       | 4(6.9%)           | 20(34.5%)      |            |
| Arrival time of red light    |                  |                 |                   |                |            |
| Front part                   | 59(26.8%)        | 49(22.3%)       | 25(11.4%)         | 87(39.5%)      |            |
| Middle part                  | 44(26.7%)        | 49(35.8%)       | 11(6.7%)          | 61(40.0%)      |            |
| Latter part                  | 32(17.4%)        | 42(17.4%)       | 30(16.3%)         | 80(43.5%)      |            |
| Total                        | 135(23.7%)       | 140(24.6%)      | 66(11.6%)         | 228(40.1%)     |            |
| Countdown pedestrian lights  | Gender           |                 |                   |                |            |
| Male                         | 80(28.3%)        | 90(31.8%)       | 82(29.0%)         | 31(11.0%)      |            |
| Female                       | 46(20.1%)        | 79(34.5%)       | 41(17.9%)         | 63(27.5%)      |            |
| Age                          |                  |                 |                   |                |            |
| Young                        | 59(30.9%)        | 62(32.5%)       | 54(28.3%)         | 16(8.4%)       |            |
| Middle-age                   | 55(61.3%)        | 84(33.7%)       | 58(23.3%)         | 52(20.9%)      |            |
| Elderly                      | 12(16.7%)        | 23(31.9%)       | 11(15.3%)         | 26(36.1%)      |            |
| Arrival time                 |                  |                 |                   |                |            |
| Front part of red light      | 47(31.1%)        | 55(36.4%)       | 18(11.9%)         | 31(20.5%)      |            |
| Middle part                  | 61(33.0%)        | 60(32.4%)       | 47(25.4%)         | 17(9.2%)       |            |
| Latter part of red light     | 18(7.7%)         | 54(23.1%)       | 58(24.8%)         | 46(19.7%)      |            |
| Total                        | 126(24.6%)       | 169(33.0%)      | 123(24.0%)        | 94(18.4%)      |            |

### 3.1.3. Comparison of the passing time of the violation samples

The behavior of pedestrians crossing the street is influenced by many factors. Through the observation and comparison of the two types of intersections, it is found that the pedestrian crossing rates varied at different red light periods. Fig. 1 gives a comparison of pedestrians’ illegal crossing times at two signal intersections. As can be seen from the figure, at the static pedestrian signal intersection, the violation rate of the pedestrian crossing during front part of red light is relatively large, which is 58%; while the violation rate of the pedestrian crossing during latter part of red light at the countdown signal intersection is relatively large, up to 62%.

This is because the pedestrian at the static pedestrian light intersection do not know remaining time of the current signal phase, and mostly choose to follow the front pedestrians across the street at the start of the red light, so lead to a higher proportion of illegal crossing during front part of red light; Pedestrians crossing the road during front part of red light have chosen to cross the street illegally, so the proportion of pedestrians who cross the street illegally during middle part of red light is lower; The pedestrians arriving at the latter part have lower proportion of illegal pedestrians due to the shorter waiting time and uncertain remaining time.

Pedestrians can obtain the current phase remaining time at the countdown signal intersection. When the latter part of red light, pedestrians know that the red light is about to end, so cross the street illegally ahead of time; In the middle of the red light, pedestrians have been waiting for some time, and know that there is still a period of time before the red light is over, so there is a certain percentage of pedestrians crossing the street illegally.
Figure 1. Finite element calculation model of arch dam and bedrock

3.2. Comparison of pedestrian crossing behavior based on variance analysis
This section uses the variance analysis method to further analyze the impact of traffic signal type on pedestrian crossing behavior. According to the analysis results of the previous section, it can be seen that the age and arrival time have a significant effect on pedestrian violation rate and waiting position. Based on this, the classification variable like signal type, age and arrival time are selected as independent variables.

3.2.1. Analysis on the Differences of Violation Crossing Behavior Based on Variance Analysis. Take whether pedestrian crossing illegally as dependent variable, and then carry out the variance analysis. Table 3 presents the results of variance analysis of pedestrian crossing violation at signalized intersections.

It can be seen from the table: the type of light($F(1,1143)=36.676$, $p<0.001$), age($F(2,1143)=25.559$, $p<0.001$), arrival time($F(2,1143)=41.803$, $p<0.001$) are on the red light violations have a significant impact. This indicates that there are significant differences in the rate of violation between pedestrians of different traffic lights, pedestrians of different ages and pedestrians at different arrivals.

| Variance source       | sum of square | Degrees of freedom | Mean square | $F$     | Sig.  |
|-----------------------|---------------|--------------------|-------------|---------|-------|
| Signal light type     | 13.553        | 1                  | 3.553       | 36.676  | 0.000 |
| Age                   | 10.891        | 2                  | 5.445       | 25.559  | 0.000 |
| Arrival time          | 17.812        | 2                  | 8.906       | 41.803  | 0.000 |
| Signal light type * Age | 5.403        | 2                  | 2.702       | 12.681  | 0.000 |
| Signal light type * Arrival time | 0.974    | 2                  | 0.487       | 2.285   | 0.102 |
| Age * Arrival time   | 9.021         | 4                  | 2.255       | 10.585  | 0.000 |
| Signal light type * Age * Arrival time | 4.270        | 4                  | 1.067       | 5.010   | 0.001 |
| Error                 | 457.423       | 1143               | 0.213       |         |       |
| Total                 | 954.000       | 1152               |             |         |       |

In addition, there are also interactions between the three variables. The interaction($F(2,1143)=12.681$, $p<0.001$) between the type of light and the age indicates that there are significant differences in pedestrian violation rates for pedestrians of different age groups under different signal types. The interaction($F(4,1143)=10.585$, $p<0.001$) between age and arrival time indicates that there are significant differences in pedestrian violation rates for pedestrians of different ages during different periods of arrival. That is, for different age pedestrians, the impact of the type of light is different.

3.2.2. Analysis of Waiting Positions Based on Variance Analysis. The purpose of the signal light setting is to allow pedestrians to wait in prescribed time and position until the light turns green, and then pass
through the intersection. In the next analysis, continue to use the method of variance analysis, take whether pedestrian waiting for the specified position as dependent variable. The analysis results in Table 4.

| Variance source                  | sum of square | Degrees of freedom | Mean square | F     | Sig. |
|----------------------------------|---------------|--------------------|-------------|-------|------|
| Signal light type                | 22.569        | 1                  | 22.569      | 19.314| 0.000|
| Age                              | 17.210        | 2                  | 15.555      | 16.480| 0.000|
| Arrival time                     | 15.385        | 2                  | 7.692       | 9.992 | 0.000|
| Signal light type * Age          | 3.668         | 2                  | 2.784       | 6.304 | 0.032|
| Signal light type * Arrival time | 2.476         | 2                  | 1.238       | 11.608| 0.000|
| Age * Arrival time               | 8.630         | 4                  | 3.407       | 8.585 | 0.371|
| Signal light type * Age * Arrival time | 2.401       | 4                  | 1.067       | 5.010 | 0.416|
| Error                            | 2269.000      | 753                | 0.770       |       |      |
| Total                            | 1303.000      | 759                |             |       |      |

The results show that the signal type (F(1,753)=22.569, p<0.001), age(F(2,753)=15.555, p<0.001) and arrival time(F(2,753)=9.992, p<0.001) have significant influence on pedestrians waiting in reasonable place. In addition, there are interactions between the factors. The interaction between the type of light and the age indicates that there are significant differences among the proportion of pedestrians waiting in reasonable areas under different age and signal types. The interaction between the signal type and the arrival time also indicates that the type of signal light has a significant effect on the waiting position of pedestrians for different arrivals.

4. Conclusion
Firstly, the statistical analysis method is used to analyze the distribution of samples and the rate of violation under different signal types and the difference of waiting position and crossing time of the sample.

Secondly, pedestrian illegal crossing probability and the proportion of waiting in reasonable area are compared and analyzed by means of variance analysis in two types of signalized intersections.

The results show that the violation rate of the intersection of the static pedestrian lights is significantly higher than that of the countdown signal lights. There are significant differences in the waiting position of the intersection of different signal lights. The signal light type has significant influence on the pedestrian violation rate and the proportion of waiting in the reasonable area. For pedestrians of different ages, the signal light type has a significant effect on the rate of violation of young and middle-aged pedestrians and the proportion of waiting in a reasonable area. For pedestrians of different arrivals, the signal light type has a significant effect on the behavior of the samples arriving in the middle part of red light and latter part of red light.

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