EXPLORING THE IMPACTS OF AUTONOMOUS VEHICLE ON PEDESTRIAN BEHAVIOR USING CAMERA DATA

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These days most of the research related to Autonomous Vehicle (AV) technology focuses on AV itself and lesser on the environment around the AV. To fill in the research gap, we investigated possible conflicts among many categories of objects including pedestrians, conventional car (MVs), and AVs. By studying pedestrians' readiness to cross, crossing speed, and looking behavior when crossing, this study provides new perception into their behavior. This study proposed the pedestrian-vehicle conflicts into the pedestrian behavior model. The AV's modest speed approximately at 15 m/s and its ability to halt when it senses an object nearby gives a pedestrian a sense of security. However for MV, it is difficult to anticipate the driver's behavior since the driver might choose to stop in front of the pedestrian. Overall, the results indicate that sooner or later an individual will feel safe and trust AV.

Key Words : *Autonomous Vehicle, pedestrian behavior, speed, trust, collision avoidance*

1. INTRODUCTION

Autonomous Vehicle (AV) can play an important role in addressing the issue of driver's workload and the number of accidents caused by human error. The Ministry of Land, Infrastructure and Transportation Japan [1)] reported that human factors caused 75% of accidents. Considering that many traffic accidents are caused by human errors and AV may contribute to the improvement in traffic safety, it is necessary to develop an environment for the development and dissemination of AV.

There are five levels of AV, which differ based on the distribution responsibilities between the driver and the system. Generally, AV may be classified into two groups:

i. Require the human driver to monitor the driving environment all the time (level 1 and level 2)
ii. Responsibility falls on the autonomous driving system (level 3 to level 5)

As of now (March 2022), the level of AV is at level 3 in Japan. For level 3, the driver is a necessity but is not required to monitor the environment. By contrast, for level 4, the vehicle can perform all the driving functions under certain conditions while at level 5, the vehicle can perform all the driving functions under all conditions. This study attempts to show that pedestrian will act differently with level 4 and level 5 of AV.

Based on the White Paper on Land, Infrastructure, Transport and Tourism in Japan [2],the number of road accidents peaked in 1970 and has since decreased by more than a quarter to less than a quarter in 2017 (refer Fig.1). Elderly drivers, on the other hand, were responsible for a large number of traffic incidents, with around half of them occurring while walking or riding a bicycle. For this reason, efforts must be made to prevent further road accidents, and various measures must be applied.

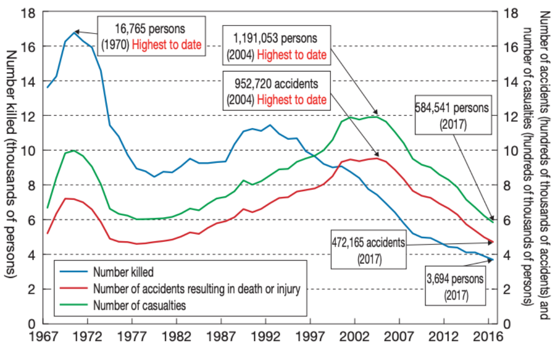

Fig.1 Changes in the Number of Traffic Accidents and Number of Casualties

Moreover, AVs have the potential to reduce fossil fuel consumption, improve safety and provide greater access to transportation. Yet, all these potential benefits depend largely on widespread public acceptance of AVs. Despite the potential benefits of AVs, public doubt over safety is still a major barrier to AV acceptance.

Recent developments in AV have heightened the need for observation of pedestrian behavior when AV is around. This is because AVs are expected to be used in many scenarios including shared spaces, intersections with no traffic lights and parking lots. When a pedestrian encounters conventional car on a narrow road without traffic signals or in a parking lot, the driver can clearly convey their intention and quickly reach an agreement of negotiation with the pedestrians by eye contact, hand gestures and verbal communication. However, the AV does not have this ability to communicate with pedestrians. This matter can create various issues such as safety hazards, inefficient operation and poor pro-socialness. Therefore, there is a need to address the safety problems caused by AV as AV lacks the ability to communicate with pedestrians.

Previous studies in the field of transportation have only focused on either AV or pedestrians only. Although communication between conventional car and pedestrians have been studied intensively, only a few studies have attempted to investigate the impact of AV on pedestrians' behavior. Due to safety concerns, it is better to know the effects of AV on pedestrian behavior in view of the fact that AV is still a new technology that will be implemented in the future. Up to the present moment in Japan, Level 4 cars are not permitted on public roads, however certain limitations are expected to be lifted. This is the main reason why not many scholars do research about AV and pedestrian behavior as it is not officially permissible on all roads.

2. LITERATURE REVIEW

As previously observed by the Ministry of Land, Infrastructure and Transportation Japan [3], 52% of accidents happened at the point of intersection. This is as a sequence of the large amount of transportation that passes through the intersection at the same time. Therefore, the study area of this research will be at the intersection as most of the accidents happened here.

Hoogendorn et al [4] showed that route choice, activity area choice and activity scheduling are simultaneously optimized using dynamic programming for different traffic conditions and uncertainty levels. He concluded that pedestrians will not continuously reconsider their route choice, but only at discrete time intervals. However, pedestrians are inclined to change their route to avoid congestion and narrow passageways.

A study by Gianluca Antonini et al [5] described all the aspects of the behavioral model and illustrated the design of a pedestrian simulator based on one of the estimated models. This study identified that pedestrians tend to keep the current direction. Pedestrians make decision at higher level (strategic level) as can be seen when the pedestrian moved towards the destination and made a decision at tactical level for their route and path. Other than that, pedestrians tend to avoid crowded positions, which have the same conclusion as Hoogendorn et al.

Robin et al [6] validated a model based on discrete choice modeling. Two main types of behavior were identified:

i) Unconstrained (independent of the presence of other pedestrians)
ii) Constrained (dependent of the present of pedestrians nearby)

There was no significant difference in the sense of danger between the behavior of AVs and Heavy-Duty Vehicles (HDVs). However, Kani et al [7] concluded that many pedestrians do not feel hesitant or threatened about AVs even when they make sudden stops. It is possible that pedestrians are overconfident in the AV's avoidance performance, or they may have come to a decision to cross the road with less sense of danger due to the experiment in virtual reality (VR).

Lynn M. Hulse et al [8] concluded that gender, age, and risk-taking all exhibited varying associations with the perceived risk of various vehicle types and general views regarding self-driving automobiles. Males and younger individuals, for example, shown stronger acceptance compared to others. Other than that, from the results of the survey, she concluded that passengers consider AV to be riskier than MV, whereas pedestrians consider AV to be safer than a human-operated car.

Howard D. et al [9] make a survey at Berkeley, California and discovered that people are most interested in possible safety benefits, the convenience of not having to locate parking. On the other hand, they are most concerned about liability, the expense of the technology, and losing control of the car. Men are more inclined than women to be worried with liability and less concerned with control. Individuals with greater incomes tend to be more worried about responsibility, whilst those with lower incomes appear to be more concerned with safety and control. Commuters in single-occupancy vehicles and bikers were most apprehensive about losing control. Costs were a concern for all groups.

2. METHODOLOGY

(1) Modelling framework

Robin et al[6] proposed two types of decisions which resulted in when a pedestrian undergoes operational level for walking.In this study, by using this approach, we propose a way for incorporating pedestrian-vehicle conflicts into the pedestrian behavior model. We extended the pedestrian walking behavior by divided collision avoidance into two categories: pedestrian collisions and vehicle collisions.

We consider potential conflicts among pedestrians, MVs and AVs. We also conducted a simulation analysis to explore how the impacts of AV on pedestrian behavior are different from those of MV. This study provides new insight into pedestrians' behavior by observing their willingness to cross, cross speed and looking behavior while crossing.

We considered that the pedestrian behavior is dependent on the situation inside her visual angle. Fig. 2a. shows the visual angle of the decision maker being divided into 11 cones which decide the direction of the decision maker. Five radial cones that are placed at the center are 10° followed by 15°, 20° and 25°. Fig.2b shows that we considered four regimes of speed:

i) decelerate (between 0.25 to 0.75 times her current speed),
ii) constant (between 0.75 to 1.25 times her current speed),
iii) accelerate (between 1.25 to 1.75 times her speed).

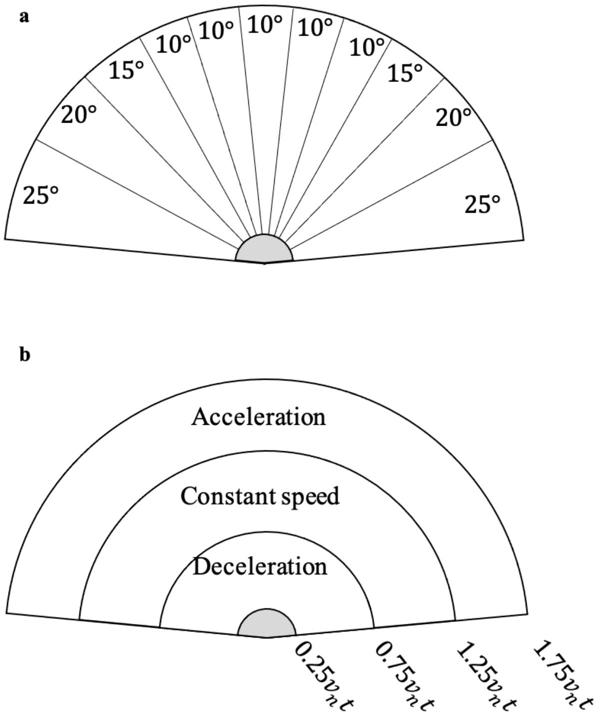

Fig.2 Space quantification, a) quantification of direction; b)quantification of speed

As illustrated in Fig.3, The combination of the direction and speed generated 33 choice sets for the decision maker. We did not consider stop (grey area) when it is below 0.25 because the decision maker has no direction when she stops. Each corresponding alternative pointed out the spatial resolution c_{vd} of the decision maker.

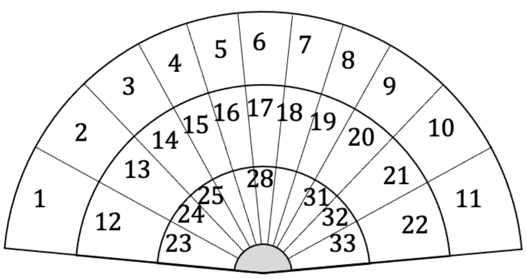

Fig.3 Choice of set with alternatives number

(2) The model

Pedestrian walking behavior can be decided by her changes in direction and speed. The patterns can be defined as 6 patterns. When the decision maker chooses each alternative, it will be considered as terms entering the utility functions. The utilities are captured by the term in Eq. 1. Where all the $\beta, \lambda, \alpha, \rho, \gamma, and\ \delta$ are unknown parameters to be estimated. The next section will describe each of the utility term.

a) Keep direction

Direction was divided into two groups (refer to Fig. 2a), cone with angle 10° representing center by indicator $I_{d,central}$ and cone with angle 15°, 20° and 25° (representing not center by indicator $I_{d,ncentral}$. The term dir_{dn} refers to the angle in degrees between the direction d and current direction d_n as revealed in Fig.4.

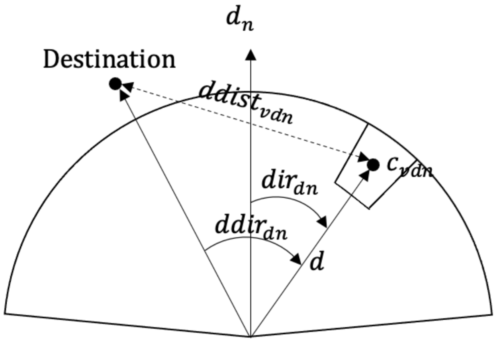

Fig.4 Describe the term use for keep direction and toward destination

b) Toward destination

Toward destination can be defined as the destination the pedestrian wants to reach and captures the tendency of the pedestrian to minimize the angular displacement and the distance to the destination. Where $ddist_{vdn}$ is the distance between the destination and the center of the alternative c_{vdn}, $ddir_{vdn}$ is defined as the angle in degrees between the destination and the alternative's direction d as illustrated in Fig.4.

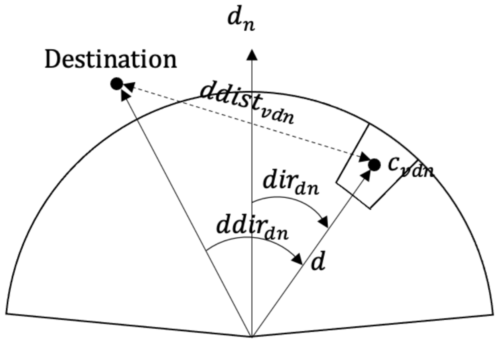

Fig.4 Describe the term use for keep direction and toward destination

c) Free flow acceleration/deceleration

Free flow acceleration shows that the pedestrian prompts to walk at their desire speed. The utility of free flow is assumed to be proportional to the present speed.

Where the first part of expression corresponds to deceleration, whereas others correspond to acceleration. From the data we observed, the maximum speed v_{max} is 5.98 m/s. $I_{v,acc}$ is an indicator when it corresponds to acceleration, meanwhile $I_{v,dec}$ is an indicator when it corresponds to deceleration.

d) Leader follower

$$
\begin{aligned}
V_{vdn} = {} & \beta_{dir_{central}} dir_{dn} I_{d,central} \\
& + \beta_{dir_{ncentral}} dir_{dn} I_{d,ncentral} && \text{Keep direction} \\
& + \beta_{ddist} ddist_{vdn} \\
& + \beta_{ddir} ddir_{vdn} && \text{Toward destination} \\
& + \beta_{dec} I_{v,dec} (v_n / v_{max})^{\lambda_{dec}} \\
& + \beta_{acc} I_{v,acc} (v_n / v_{max})^{\lambda_{acc}} && \text{Free flow acceleration} \\
& + I_{v,acc} I_{d,acc}^{L} \alpha_{acc}^{L} D_L^{\rho_{acc}^{L}} \Delta v_L^{\gamma_{acc}^{L}} \Delta \theta_L^{\delta_{acc}^{L}} \\
& + I_{v,dec} I_{d,acc}^{L} \alpha_{dec}^{L} D_L^{\rho_{dec}^{L}} \Delta v_L^{\gamma_{dec}^{L}} \Delta \theta_L^{\delta_{dec}^{L}} && \text{Leader Follower} \\
& + I_{d,CP} \alpha_{CP} e^{\rho_{CP} D_{CP}} \Delta v_C^{\gamma_{CP}} \Delta \theta_{CP}^{\delta_{CP}} \\
& + I_{d,Car}^{C} \beta_{car} I_{d,Car}^{D} \\
& + I_{d,hiro}^{C} \beta_{hiro} I_{d,hiro}^{D} && \text{Collision avoidance} \\
& + I_{j,ped} \beta_{density} && \text{Density}
\end{aligned}
\qquad (1)
$$

Leader follower can be described as the tendency of an individual to have a leader as someone that makes it easier to go through crowded areas as leaders can make a path for them. The 11 radial cones are expanded to 5 times the radius of the cone ($D_{th} = 5D_{max}$), where D_{max} is the radius of the cone. In each of these cones there are a set of potential leaders and a possible leader will be chosen based on the criteria:

i. in the cone (between d_l and d_r)
ii. not too far from decision maker (maximum D_{th})
iii. walking in the same direction (less than $10°$)

where the enclosing left and right directions of the cone in the option set (defining the region of interest) are d_l and d_r , respectively, whereas d_k is the direction indicating the position of pedestrian k. $\Delta\theta_k$ is the difference between the direction that identifies the radial cone in which k is located, θ_d and the movement angle of the potential leader θ_l. $I_{v,acc}$ and $I_{v,dec}$ are the same as those defined for the free flow acceleration/deceleration. $I^L_{d,acc}$ is an indicator when the leader speed is higher than the decision maker's current speed v_n, while $I^L_{d,dec}$ is an indicator when the leader speed is lower than the decision maker's current speed. D_L is the distance between the decision maker and the leader and ΔV_L represent the difference of speed between decision maker and leader ($\Delta v_L = |v_L - v_n|$). $\Delta\theta_L = |\theta_l - \theta_d|$ is the difference between movement angle of leader, θ_l and the direction that identifies the radial cone in which k is located, θ_d.

Fig.5 illustrates the concept of leader follower. The grey circles represent the potential leaders and black circle represents the leader for the decision maker. Please note that due to insufficient amount of data, we removed the utility function of leader follower for our model.

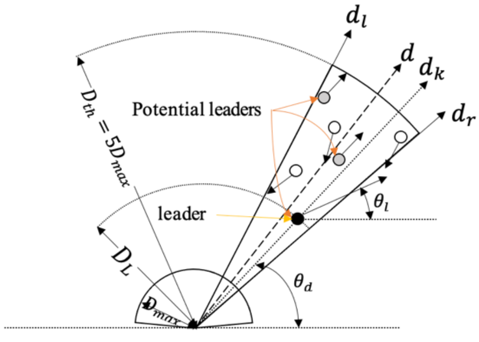

Fig.5 Describe the terms use for leader follower

e) Collision avoidance

Collision avoidance can be described as the tendency of an individual to avoid possible collision. We divided collision avoidance into two parts: i) collision with pedestrian, ii) collision with vehicle.

For collision with pedestrians, the 11 radial cones as shown in Fig.2a, are expanded to 15 times the radius of the cone ($D_{th}' = 15D_{max}$). In each of these cones there are a set of potential colliders. A possible collider that will be chosen based on the criteria:

i. in the cone (between d_l and d_r)
ii. not too far from decision maker (maximum D_{th}')
iii. walking in the opposite direction (less than $10°$)

where the difference between individual k and the center of the alternative is D_k, the difference between the individual k movement direction, θ_k and the θ_d is $\Delta\theta_k = \theta_k - \theta_{dn}$. The distance threshold has now been set to $D_{th}' = 15D_{max}$. We used a higher value than the leader follower model because we believe that the collision avoidance behavior has a longer range interaction that occurs at low densities.

$I_{d,CP}$ is an indicator variable for the existence of the collider, Δv_C=, $v_C + v_n$, where v_C is the speed of the collider and v_n is a speed of the decision maker. $\Delta\theta_{CP}$ is the difference between collider's direction, θ_C and the decision maker's direction, θ_{dn}($\Delta\theta_{CP} = \theta_C - \theta_{dn}$). Fig.9. illustrates the concept of the collision avoidance. The grey circles represent the potential colliders, while the black circle represents the possible collider for the decision maker.

Fig.6 illustrates the concept of the collision avoidance with a vehicle. The vehicle is represented by h and SPL is Subjective Prediction of Location. SPL is defined by the decision maker itself that predicts where he will be in the next step. We did not consider the alternatives in the grey area as there will be no collision occur in the alternatives.

For collision with vehicle, refer to Fig.7, the direction will be filtered by the condition

$$I_d^D = \begin{cases} 1 \ \ if\ \Delta\alpha_1 \times \Delta\alpha_2 \geq 0 \ \ (collision\ will\ occur) \\ \ \ \ and\ |\Delta\alpha_2| \geq 90° \ \ (opposite\ direction) \\ 0 \ \ otherwise \end{cases}$$

where $\Delta\alpha_1$ is the angle between the line that connects the decision maker and vehicle, d_h and the line that connects the decision maker and each alternative, d_c. On the other hand, $\Delta\alpha_2$ is the angle between the line that connects the decision maker and vehicle, d_h and the direction of the vehicle.

Possible location of the collision is decided by the intersection of the direction of the vehicle and the direction i of the decision maker for each alternative j. Then, the time for the vehicle and the decision maker to arrive at the possible location of collision is calculated. The arriving time for the vehicle to arrive at the possible collision location, T_{hit} is calculated by

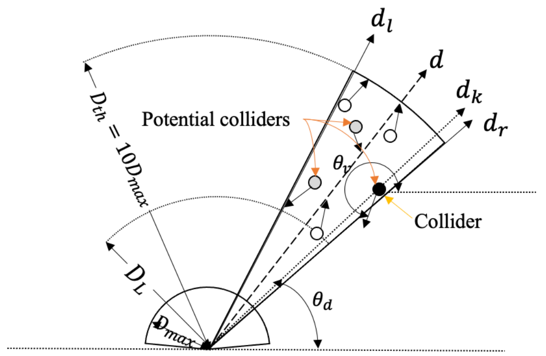

Fig.6 Describe the terms use for collision avoidance with other pedestrians

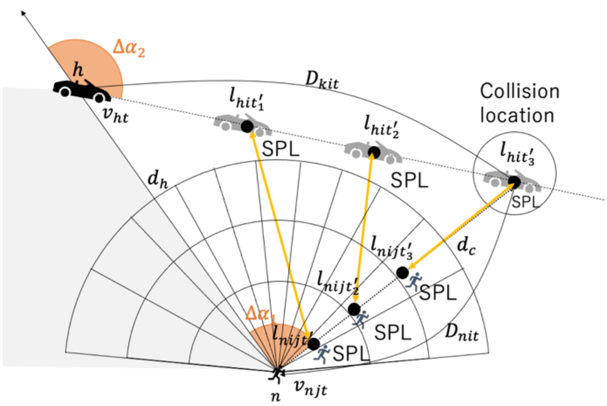

Fig.7 Describe the terms use for collision avoidance with vehicles

$$T_{hit} = d_{hit}/v_{ht} \quad (8)$$

and the arriving time for the decision maker to arrive at the possible collision location, T_{nijt} is calculated by

$$T_{nijt} = d_{nit}/v_{nt} \quad (9)$$

where d_{hit} is the distance of the current position of vehicle to collision location and d_{nit} is the distance of the current position of decision maker to the collision location. While v_{ht} is the current speed of the vehicle and v_{ht} is the current speed of the decision maker.

The time of collision, T_C will be chosen by the shortest time of for the vehicle and decision maker to arrive at the collision location.

$$T_C = \min\{T_{kit}, T_{njit}\} \quad (10)$$

is considered as the location of the collision when the vehicle and the decision maker are arrived at the same point at about the same time. Then the minimum distance between the decision maker and vehicle, D_{min} at T_C will be calculated by

$$D_{min} = \min\{dist(l_{hit'}, l_{njit'}), t \leq t' \leq t + T_c\} \quad (11)$$

where t' is the time for the vehicle and decision maker to arrive at the location of the collision, $l_{hit'}$ is the location of the vehicle at T_C and $l_{njit'}$ is the location of the decision maker at T_C. The possible collision will be chosen based on the criteria:

i. happen in a short time
ii. not too far (between 30m)

$I^C_{d,Car}$ *and* $I^C_{d,hiro}$ are indicator variables for the presence of possible collision with the car and HIROMOBI respectively. $I^D_{d,Car}$ *and* $I^D_{d,hiro}$ are the indicators for the car and HIROMOBI which are in the opposite direction with the decision maker respectively. We expected all of the parameters to be negative.

f) Density

Density can be described as the tendency of an individual to avoid crowded area. The pedestrian is considered as an obstacle for the decision maker. $I_{j,ped}$ are indicator variable for the presence of pedestrian in each alternative. We expected $\beta_{density}$ to be negative.

3. DATA

An autonomous car called HIROMOBI started operation in Hiroshima University on 15th March 2021. By using this opportunity, we recorded the video during lunch time, commute to school time and end of class time throughout the study area.

The video was recorded on 14th December 2021 from the 2nd floor of Science Faculty in Hiroshima University (around 5.2m above the ground). The data consisted of 83 pedestrian trajectories, that we tracked at 30 frames per second, for a total number of 3,128 observations.

Refer to Fig.8, alternative 15 to 19 have the highest proportion of alternative choices and the highest is alternative 17. This shows that an individual tends to choose center and constant speed.

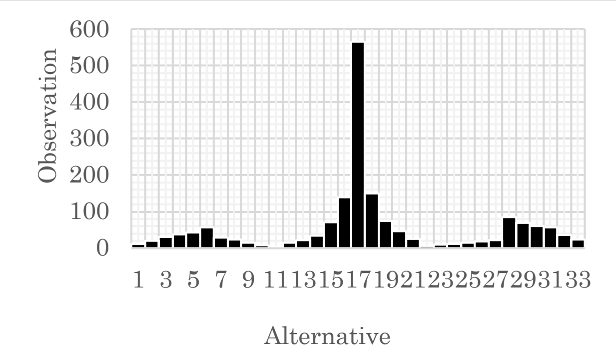

Fig.8 Choice of alternatives

5. ESTIMATION RESULTS

Table 2 shows the estimation results obtained from Multinomial Logit Model (MNL) and Table 3 shows the estimation results obtained from Cross Nested Logit Model (CNL).

Based on Table 2, the coefficient of $\beta_{dir_{central}}$ is positive while $\beta_{dir_{ncentral}}$ is negative. This shows that an individual tends to keep their direction. As previously stated, the majority of pedestrians selected center. However, for the CNL model the coefficient for the center variable ($\beta_{dir_{central}}$) is unlikely to be positive, hence it is considered to be not significant. This indicates that an individual prefers to keep their angular displacement from their current direction as minimum as possible. The coefficients of β_{ddir} and β_{ddist} are both negative. It shows that pedestrians tend to change their angular and distance displacement when they are nearer to their destination.

Deceleration variable (β_{dec})is significant at level 90% for MNL model. The coefficient is negative and this shows that the pedestrian does not prefer to lowering their speed. As mentioned before, most of the pedestrians chose constant speed. Nevertheless, for acceleration variable (β_{acc}), the coefficient is not likely to be negative for MNL model and is thus estimated to be not significant. However, for CNL model, β_{dec} and β_{acc} are both negative, indicating a preference for the constant speed alternatives. λ_{acc} is negative denotes a reduction in the attraction of accelerations as the speed increases while λ_{dec} is positive denotes a reduction in the attraction of accelerations as the speed decreases.

Parameter for density (β_{ped}) is negative as expected, where the decision maker tends to avoid the pedestrian in front of them, who are not acting as a

Table 1 Estimation results for MNL

Variable name	Coefficient estimate	t value	Pr(>t)
$\boldsymbol{\beta_{dir_{central}}}$	9.5×10^{-4}	0.229	8.2×10^{-1}
$\boldsymbol{\beta_{dir_{ncentral}}}$	-1.0×10^{-3}	-0.744	4.6×10^{-1}
$\boldsymbol{\beta_{ddist}}$	-4.0×10^{-2}	-13.95^{**}	2.0×10^{-16}
$\boldsymbol{\beta_{ddir}}$	-1.4×10^{-3}	-1.48	1.4×10^{-1}
$\boldsymbol{\beta_{dec}}$	-1.20	-1.77^{x}	7.7×10^{-2}
$\boldsymbol{\beta_{acc}}$	1.3×10^{-2}	0.837	4.0×10^{-1}
$\boldsymbol{\lambda_{dec}}$	2.22	2.58	9.9×10^{-3}
$\boldsymbol{\lambda_{acc}}$	-9.8×10^{-1}	-3.56^{**}	3.7×10^{-4}
$\boldsymbol{\beta_{ped}}$	-6.0×10^{-1}	-1.05	3.0×10^{-1}
$\boldsymbol{\beta_{car}}$	-7.97	-6.67^{**}	2.6×10^{-11}
$\boldsymbol{\beta_{hiro}}$	-6.0×10^{-2}	-0.10	9.2×10^{-1}
Sample size = $\mathbf{1838}$			
Number of estimated parameters = $\mathbf{11}$			
Initial log-likelihood $= \mathbf{-6426.58}$			
Final log-likelihood $= \mathbf{-6301.27}$			
$\boldsymbol{\bar{\rho}^2 = 0.018}$			

Table 2 Estimation results for CNL

Variable name	Coefficient estimate	t value	Pr(>t)
$\boldsymbol{\beta}_{\boldsymbol{dir}_{\boldsymbol{central}}}$	-5.4×10^{-4}	-0.052	9.5×10^{-1}
$\boldsymbol{\beta}_{\boldsymbol{dir}_{\boldsymbol{ncentral}}}$	-2.6×10^{-3}	-0.781	4.3×10^{-1}
$\boldsymbol{\beta}_{\boldsymbol{ddist}}$	-6.8×10^{-2}	-3.07^{*}	2.1×10^{-3}
$\boldsymbol{\beta}_{\boldsymbol{ddir}}$	-3.1×10^{-3}	-1.22	2.2×10^{-1}
$\boldsymbol{\beta}_{\boldsymbol{dec}}$	-3.83	-1.64	1.0×10^{-1}
$\boldsymbol{\beta}_{\boldsymbol{acc}}$	-3.4×10^{-2}	2.35^{*}	1.9×10^{-2}
$\boldsymbol{\lambda}_{\boldsymbol{dec}}$	3.07	0.667	5.1×10^{-1}
$\boldsymbol{\lambda}_{\boldsymbol{acc}}$	-8.9×10^{-1}	-2.55^{*}	1.1×10^{-2}
$\boldsymbol{\beta}_{\boldsymbol{ped}}$	-7.1×10^{-1}	-0.528	6.0×10^{-1}
$\boldsymbol{\beta}_{\boldsymbol{car}}$	-1.1×10^{-1}	-2.35^{*}	1.9×10^{-2}
$\boldsymbol{\beta}_{\boldsymbol{hiro}}$	1.24	0.878	3.8×10^{-1}
$\boldsymbol{\mu}_{\boldsymbol{dec}}$	2.14	2.62^{**}	8.9×10^{-3}
$\boldsymbol{\mu}_{\boldsymbol{const}}$	2.90	3.45^{**}	5.5×10^{-4}
$\boldsymbol{\mu}_{\boldsymbol{cent}}$	2.63	3.50^{**}	4.7×10^{-4}
$\boldsymbol{\mu}_{\boldsymbol{ncent}}$	1.96	2.66^{**}	7.7×10^{-3}
Sample size = $\mathbf{1838}$			
Number of estimated parameters = $\mathbf{11}$			
Initial log-likelihood $= \mathbf{-6426.58}$			
Final log-likelihood = $\mathbf{-5811.55}$			
$\bar{\boldsymbol{\rho}}^{2} = \mathbf{0.094}$			

leader and a collider. It is actually possible to expect the coefficient to be positive when the trajectory of other pedestrians' destination are the same with the decision maker.

What stands out in the table is that both of the parameters for collision with vehicle (β_{car} and β_{hiro}) are negative for MNL but pedestrians tend to trust HIROMOBI more than a car. The most likely cause of this is the slow speed of the HIROMOBI at about 15m/s and it will stop whenever it detects an object around it. While for a car, it is difficult to predict the behavior of the driver, because the driver can choose to stop immediately in front of the pedestrian. However, for CNL, coefficient for HIROMOBI is positive but statistically not significant.

μ_{dec}, μ_{const}, μ_{cent} and μ_{ncent} represent nest for deceleration, constant center and not center respectively. Note that the parameter associated with the deceleration nest μ_{acc} was clearly insignificant due to insufficient data, thus it was set to 1. As shown in Table 3, all of the coefficient for nests are significant at level 99%. It is proven that most of the pedestrians tend to have constant speed and keep their direction when walking.

6. CONCLUSIONS

The aim of the present study was to examine the pedestrian behavior of other pedestrians and vehicles especially when Autonomous Vehicle (AV) is around. The most obvious finding to emerge from this study is that pedestrians feel safe when AV is around compared to conventional car. The AV's slow speed of about 15 m/s, as well as its ability to stop when it detects an object nearby, provide a sense of security to pedestrians. In the case of MV, however, it is impossible to predict the driver's actions because the motorist may choose to stop in front of the pedestrian. Prior to this study it was difficult to make predictions of how pedestrians' behave when AV is around. This new understanding should help to improve predictions of the impact of AV in the future.

One source of weakness in this study which could have affected the measurement of the model, was due to the insufficiency of the data. Due to the pandemic, the collected data size is small and this reduces the significant of the results and increases the margin error simultaneously. Although the current study is based on a small sample size, the findings suggest that the speed of AV can be changed to higher speed as pedestrians get used to it.

It can be said that the concept used for this study is not applicable to all crossing roads. For collision avoidance and leader follower, it is suitable to be applied at the busy crossing roads such as Shibuya Crossing. The study area for our study is quite wide for the number of pedestrians, hence the study should be repeated using larger sample size by taking the data during graduation ceremony or entrance exam.

Further research could also be conducted to determine the relationship of the pedestrians' destination and collision avoidance. In this study, we did not consider the pedestrians' destination for collision avoidance. Therefore, further research should be undertaken on the alternative that will only have collision and at the same time block their way to their destination.

As AV's will be implemented in the future, therefore, a definite need for greater efforts is needed to ensure the safety of the pedestrians. Continued efforts are needed to make AV more accessible to everyone.

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