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Insufficient headway and unforeseen greater stopping distance as combined factors in traffic accidents

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Abstract

Most traffic accidents come of collisions between two objects in the road transport system. It was assumed that the driver's failure to stop before a collision is caused by a combination of insufficient headway and unforeseen greater stopping distance, and that the human factors which lead to accidents comprise both the driver's tendency to exhibit an unusual delayed reaction or cognition, and a tendency to maintain an insufficient headway. On the basis of this hypothesis, the driver's choice reaction times and the tendency to hasten were measured. Accident-prone drivers showed higher scores on the hastening test than non-accident-prone drivers, and/or accident-prone drivers showed more irregular reaction times than non-accident-prone drivers. It can be concluded that the human factors leading to collisions while driving are the driver's irregularity in reaction times, which can result in a sudden delay in reaction and a stopping distance than usual, and the driver's tendency to hasten, which can result in a shorter headway being maintained.

1 Mechanism Involved in the Occurrence of Traffic Accidents or Collisions

Most traffic accidents come of collisions between two objects in the road transport system. The collisions occur when the stopping distance is greater than the headway (Fig. 1). This condition is a result of an unexpected lengthening of the stopping distance or a sudden shortening of the headway. If drivers frequently experience an increase in their stopping distances, they will maintain sufficient headway to avoid collisions. If drivers often do not maintain sufficient headway, they will cause frequent collisions and will lose their driving licenses. Therefore, it can be surmised that collisions are

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                          ACCIDENT (COLLISION)
                                    ↑
                STOPPING DISTANCE  >  HEADWAY  DISTANCE
                          ↑                     ↑
 -SUDDEN GREATER STOPPING              -SUDDEN INSUFFICIENT HEADWAY
  DISTANCE                                IN RELATION TO SUDDEN
   ↑-SUDDEN GREATER                      GREATER STOPPING DISTANCE
   | BRAKING DISTANCE                     ↑-IMPULSE TO BE AHEAD
   | ↑-SUDDEN DROP OF                       OF OTHER CAR
   | | FRICTION BETWEEN                       ↑-PSYCHOLOGICAL FACTORS
   | | THE TIRES AND THE ROAD                 | ↑-HASTY PERSONALITY
   | ↑-SUDDEN DROP OF                         | ↑-INSUFFICIENT
   | | BRAKE POWER                            | | INTELLIGENCE
   | ↑-SUDDEN HIGHER SPEED                    | | (INSUFFICIENT MEMORY
   ↑-SUDDEN GREATER                           | | OF EXPERIENCES)
     THINKING DISTANCE                        |-ENVIRONMENTAL FACTORS
     ↑-DRIVER'S SUDDEN GREATER                | ↑-DELAY FROM EXPECTED
       DELAY OF COGNITION OR                  | | TIME OF ARRIVAL
       REACTION                               | ↑-TRAFFIC JAMS
         ↑-PHYSIOLOGICAL FACTORS              ↑-KNOWLEDGE FACTORS
         | ↑-FLUCTUATION OF                     ↑-INSUFFICIENT
         | | AWARENESS                          | KNOWLEDGE IN
         | | ↑-BIOLOGICAL                       | RELATION TO
         | | | RHYTHM                           | EFFICIENT DRIVING
         | | ↑-FATIGUE                          ↑-INSUFFICIENT KNOWLEDGE
         | | ↑-DISEASE                            OF DEFENSIVE DRIVING
         | | ↑-DRINKING
         | ↑-MALFUNCTION
         |   OF THE EYES
         ↑-ENVIRONMENTAL FACTORS
         | ↑-LOW VISIBILITY OF OBJECTS
         ↑-PSYCHOLOGICAL FACTORS
           ↑-MENTAL DISPERSION
           | ↑-MULTIPLE TASKS
           |   ↑-DIVORCE
           |   ↑-FAMILY TROUBLE
           |   ↑-FRICTION WITH
           |     OTHER PEOPLE
           ↑-LOW MOTIVATION
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Fig. 1. Factors in relation to accidents or collisions which occur while driving.
The stopping distance comprises the latency distance (the distance covered by a vehicle from the time of the first appearance of an obstacle or a sudden change in the surroundings to the time when the driver hits the brakes), and the braking distance (from the initial braking action to the actual stopping of the vehicle).

caused by the combination of a sporadically greater stopping distance, and the driver's failure to maintain sufficient headway.

2 The Stopping Distance, the Latency Distance, and the Braking Distance

The stopping distance comprises the latency distance and the braking distance. The latency distance is the distance covered by a vehicle from the time of the first appearance of an obstacle or a sudden change in the surroundings and the time when the driver initiates the braking action. The braking distance is the distance covered by a vehicle from the time of the initial braking action to the time when the vehicle actually stops. An unexpected greater stopping distance is caused by a sudden lengthening of the reaction distance and/or a sudden lengthening of the braking distance.

3 Factors Leading to a Sudden Greater Braking Distance

Sudden lengthening of the braking distance is caused by a sudden drop in friction between the tires and the road or a sudden drop in the braking power. It is reported by the Police Bureau of Japan that more collisions occur at the beginning of the rainy season and the snowy season.

4 Factors Leading to a Sudden Greater Latency Distance

A sudden greater latency distance is caused by an unusually greater delay in reaction to the obstacles or changes in the surroundings. The cognition and/or reaction time is affected by an individual driver's physiological characteristics, psychological characteristics, and low visibility within the environment (Matsunaga, 1985).

Matsunaga (1988) reported that a group of accident-prone drivers showed a greater variation (standard deviation) in choice reaction times than non-accident-prone drivers (Fig.2), although the two groups did not have significantly different mean reaction times (Fig.3). Accident-prone drivers therefore will encounter situations in which their normal awareness of changes in their surroundings is suddenly delayed (Fig.4).

Using the values of the standard deviation of the reaction time test and the scores of the hastening tendency test, eighty-four percent of accident-prone drivers and eighty-one percent of non-accident-prone drivers were identified by the discrimination analysis (Matsunaga, 1988).

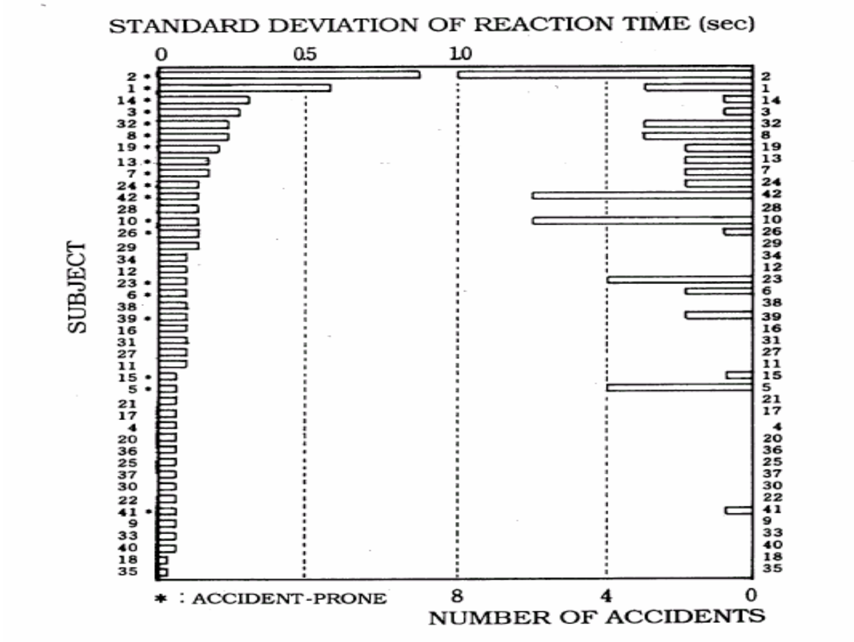


Fig. 2. Individual subjects' standard deviations of reaction times (left bars) against the number of accidents (right bars) which they experienced during a 2-year period (Matsunaga, et al., 1985).

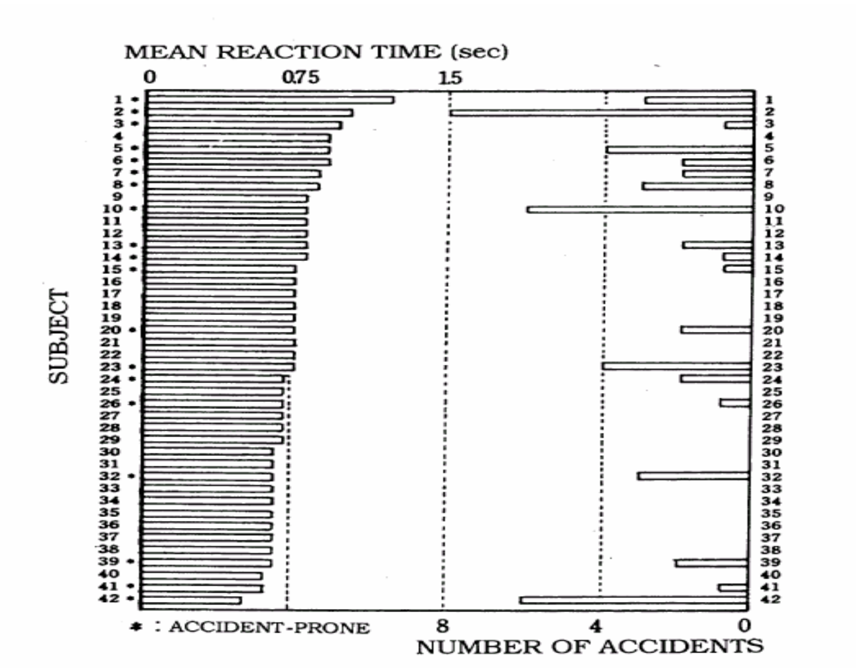


Fig. 3. Individual subjects' mean reaction times (left bars)against the number of accidents (right bars) which they experienced during a 2-year period (Matsunaga, et al., 1985).

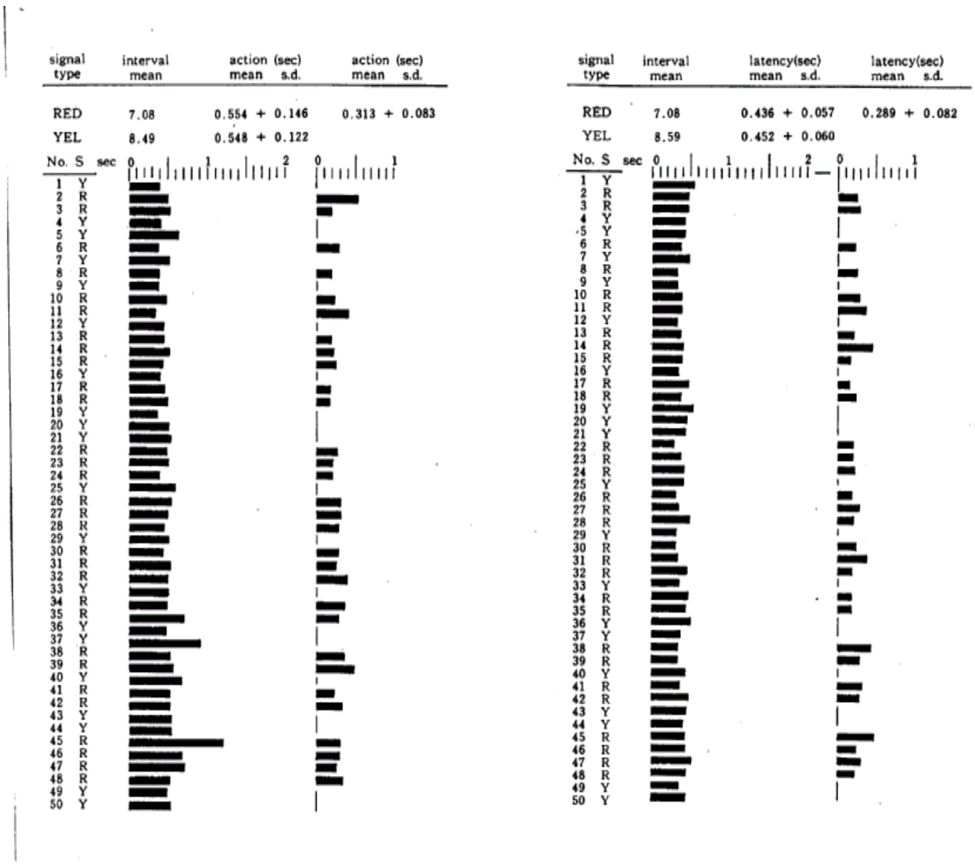


Fig. 4. Examples of measurements of reaction time for an accident-prone driver (left) and for a non-accident-prone driver (right). The reaction times from the time of the appearance of the red disc or the yellow disc to the time the foot was removed from the accelerator pedal (the left side bars in both figures), and the time the foot was transferred from the accelerator pedal to the brake pedal (the right side bars in both figures) are shown. The stimulus presentation and the choice reaction time measurements were both under the control of a personal computer (NEC: PC-9801EX) using the KM choice reaction time measuring software (the KM system; Matsunaga, 1989). The red disc, the yellow disc, and the green disc were displayed on the CRT screen for 3 seconds under the control of a personal computer, in random order, and at random intervals. The red disc and the yellow disk appeared 20 times, while the green disc appeared 11 times during each session. Two foot switches which were similar to the accelerator pedal and the brake pedal of a traditional car, served as the response keys of the computer. The accelerator pedal was held in a depressed position by the subject's right foot prior to the initiation of each trial. When a red disc appeared, the subject was required to remove his/her foot from the accelerator pedal and to press down the brake pedal with the same foot. When a yellow disc appeared, the subject was required only to remove his/her foot from the accelerator pedal. The subject was instructed to do this as quickly as possible. When the green disc appeared, the subject was required to continue pressing the accelerator pedal down (Matsunaga, 1988).

Effect of an Individual's Physiological Characteristics: Cognition and reaction time are affected by a fluctuating awareness level. It is supposed that this fluctuation of awareness in humans is an evolutionary survival trait to save energy, that is suitable to the pedestrian world, but in the world of automobiles this fluctuation of awareness level is now one of the causes of loss of human life.

When drivers drink alcohol, their reaction time fluctuates, especially 30 minutes after drinking (Fig. 5; Matsunaga, 1988).

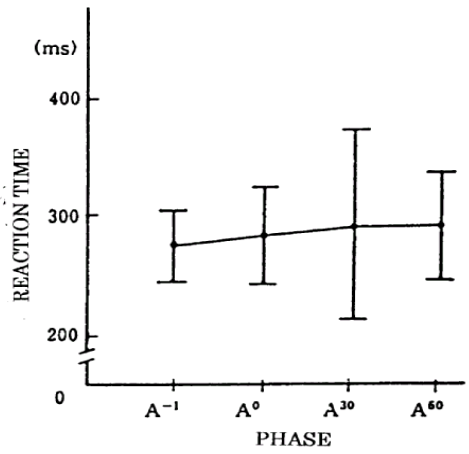


Fig. 5. The fluctuation (SD) in reaction times became greater, especially 30 minutes after drinking 60 cc of whisky. In this figure A^{-1},A^{0},A^{30}, and A^{60} refer to the results measured just before drinking, just after drinking, 30 minutes after drinking, and 60 minutes after drinking, respectively.

Effect of Individual's Psychological Characteristics: Delays in cognition and reaction occur when drivers do not concentrate on their driving. It can be assumed that drivers who have an unstable personality, in addition to those drivers who are experiencing difficulty in human relations (e.g. divorce, problems at work etc.) are not able to concentrate on their driving. The drivers who have unstable personalities will share their capacity of information processing (a dual task) with something not related with the driving. Therefore, their cognition and reaction times will fluctuate more than those of drivers with stable personalities, who can concentrate on their driving.

Effect of Low Visibility of Objects (Environmental factors): When illumination is insufficient, the cognition and reaction times fluctuate (Fig. 6). Similarly, when the contrast between the objects and background is small, cognition and reaction times also fluctuate. Therefore, a low contrast environment is conducive to sudden greater reaction times.

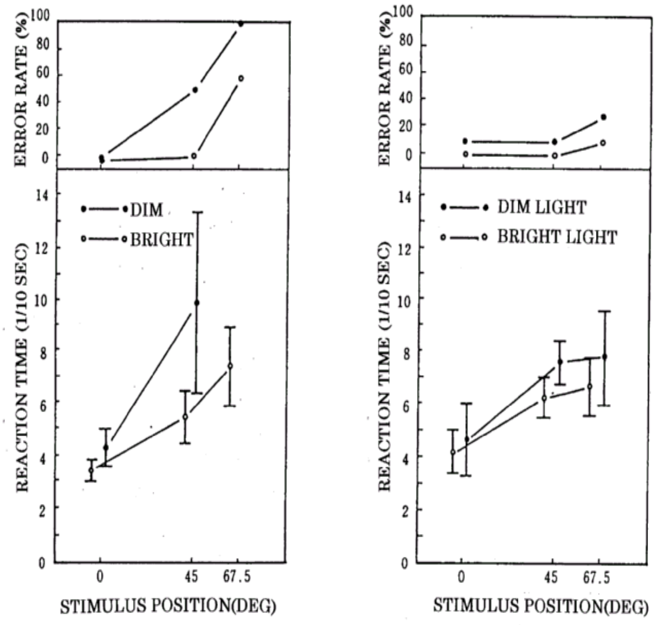


Fig. 6. When illumination is insufficient, the reaction time of objects fluctuates. The fluctuation in reaction times became large when a stimulus was displayed in the peripheral area of the retina (Matsunaga, 1985).

5 Factors Leading to a Shortened Headway (Hastening)

Factors such as those described above, or the driving environment cannot be easily controlled or modified by an individual driver. However, in cases where there are problems involving a delay in reaction time, drivers can avoid collisions simply by maintaining sufficient headway.

In Japan, around 44% of collisions happen at intersections or near intersections, 34% on straight roads, and 19% on the curves of roads (Facts of Traffic Accidents of Japan in 1995). Collisions at intersections could be avoided if the drivers would stop their cars and wait yielding right of way to oncoming vehicles in the opposite lane, allowing them to turn or to go through the intersection. If, on straight roads, they would keep sufficient headway to allow for a sudden greater stopping distance, they could stop without collision.

It has been reported that the modal length of headway time is around 1 second (Wasielewski,1979; Nakajima et al., 1983: Fig. 7), while the modal headway distance is around 20 meters (Nakajima et al, 1981: Fig. 8). These headways are too short to avoid a collision if the car ahead were to suddenly stop. Why do so many drivers fail to maintain sufficient headway?

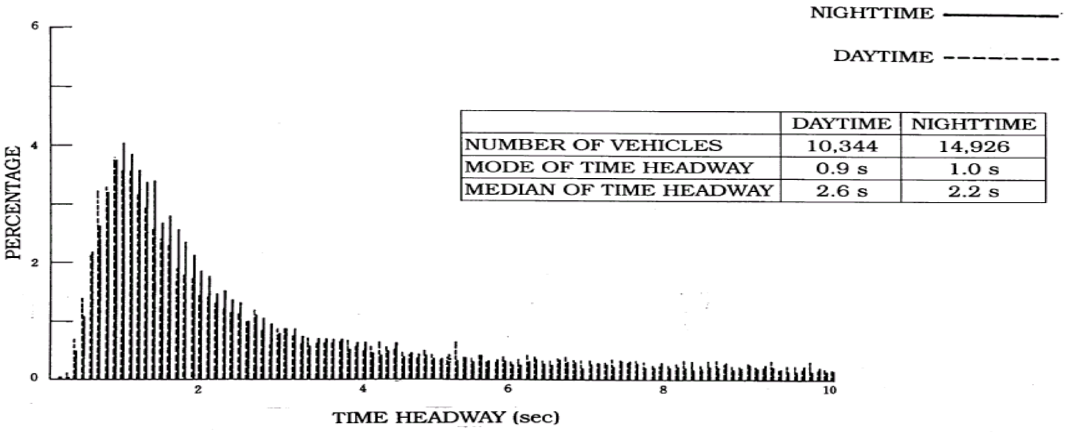


Fig. 7. Distribution of time headways measured at the Tomei motorway. Mode of the time headway is 1 second (Nakajima et al., 1983).

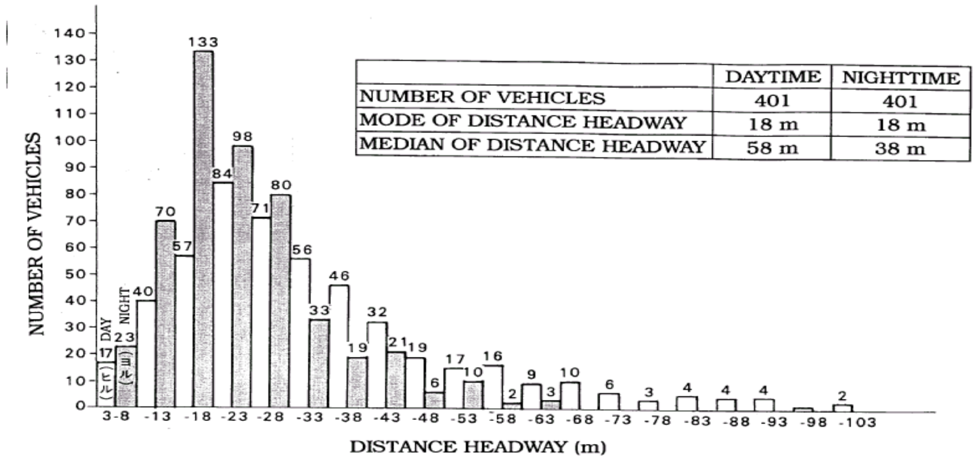
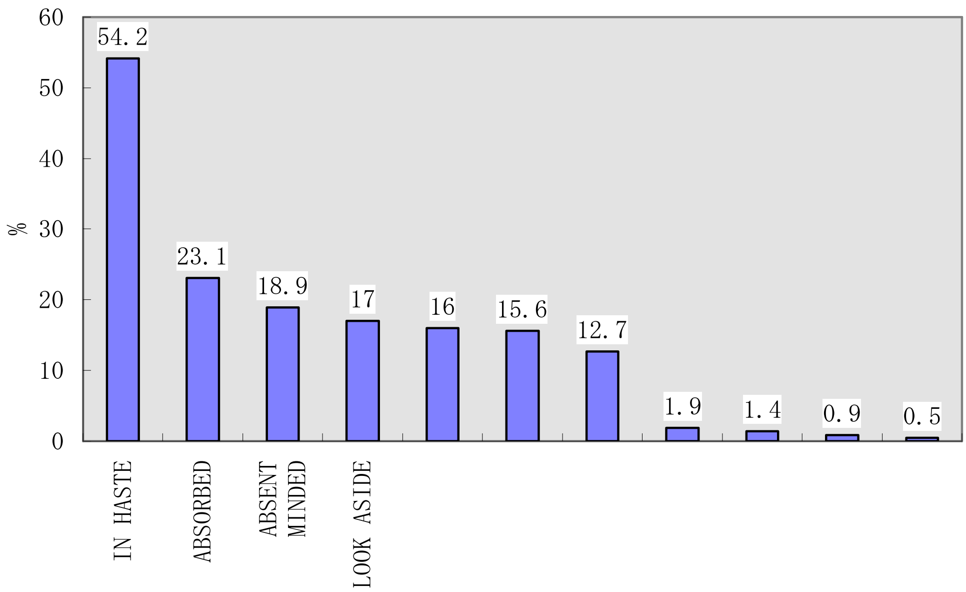


Fig. 8. Distribution of distance headway of passenger cars measured at the Tomei Motorway (Nakajima et al, 1981).

It has been reported that almost half the drivers who have had accidents were hastening (i.e., decreasing headway distance) at that moment (Maruyama, 1982; Fig.9). The idea that a drivers' headway should tend to be shorter when driving in rushing situations, which force drivers to hasten, may be modified by some of the factors mentioned below.



ig. 9. Drivers' mental state just before accidents (Maruyama, 1989).

Delay in Travelling: The tendency of drivers to hasten could be intensified if they found that their journey was taking longer than they had expected, or if they predicted that their journey would be delayed by traffic jams, etc.

Psychological Factors: It is assumed that humans have the impulse to be ahead of other people. People have to have food to survive. When provisions are short, people want to be ahead of others to get food first. Humans have repeated the struggle for existence for many generations. Now we continue to try to be ahead of other people every time without consciously being aware of it.

Nevertheless, a driver's propensity to drive hastily varies from individual to individual. It is known that those drivers who maintain a shorter headway display a more active personality than those who maintain a longer headway (Matsunaga,1986). Drivers who have insufficient intelligence and drivers with insufficient knowledge of efficient driving may also drive more hastily.

6 Relationship between Subjects' Ages and the Rate of Subjects Exceeding the Discriminant Levels of the Reaction Time Test and the Hastening Tendency Test

Figure 10 and Figure 11 show the relationship between subjects' ages and the percentage of subjects exceeding the discriminant levels of the reaction time test and the hastening tendency test. A large number of younger subjects showed greater fluctuations in reaction time and also an increased tendency to hasten than those of other ages. These tendencies may resemble the accident-rate tendency in relation to the subjects' ages.

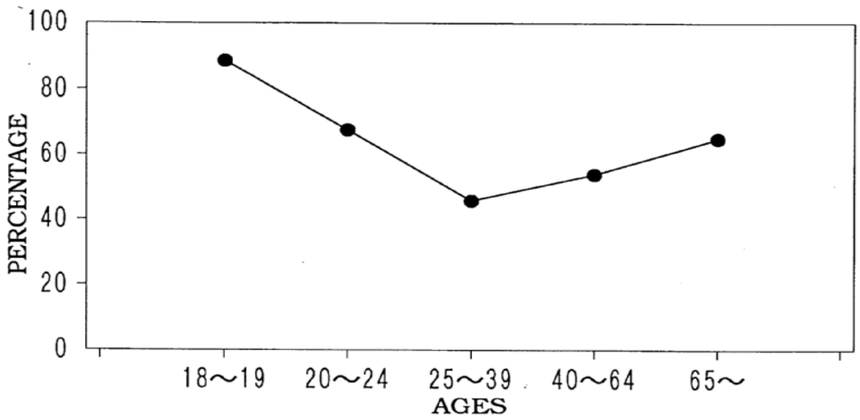


Fig. 10. Relationship between subjects' ages and the rate of subjects whose standard deviations are over the discrimination level of the standard deviation of the reaction time test (Matsunaga, 1994).

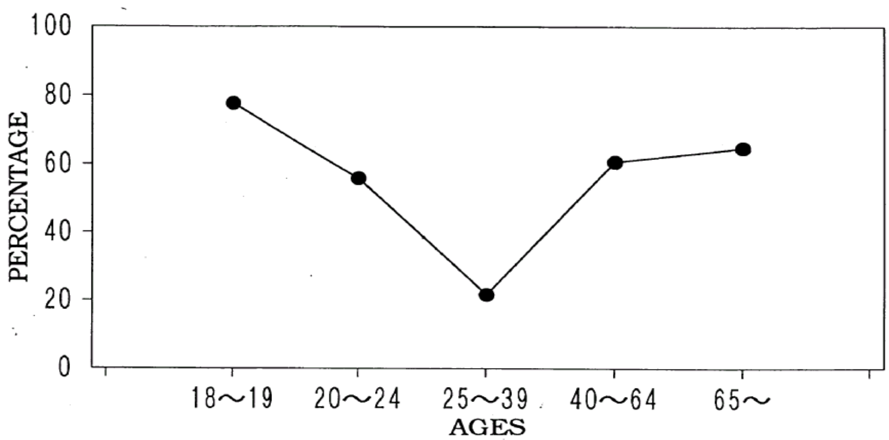


Fig. 11. Relationship between subjects' ages and the rate of subjects whose values are over the discrimination level of the hastening tendency test (Matsunaga, 1994).

7 Is fast driving an effective mode of driving?

The intrinsic tendency of humans to hasten may make it difficult for them to maintain sufficient headway while driving. The original purpose of such a tendency was to ensure that humans could compete with other humans. Would hastening while driving bestow any advantage to either the drivers or their passengers? Table 1 shows some differences between driving fast and driving at an ordinary pace (Cohen and Preston, 1984). Fast drivers arrived at their destinations 2 hours and 48 minutes earlier.

Table 1. Differential effects of normal and fast driving (Swiss experiment; Cohen & Preston, 1968).

	VEHICLE TRAVELLING AT NORMAL SPEED	VEHICLE TRAVELLING AT FAST SPEED	DIFFERENCE
Duration of journey (excluding pause on route)	47 hours, 53 min.	45 hours, 5 min.	2 hours, 48 min.
No. of times a vehicle was overtaken:			
lorry	262	616	51
private car	230	531	301
tractor	42	54	12
No. of times brake was sharply applied (unexpectedly)	7	184	177
Petrol consumption	49 gal.	61 gal .	12 gal.
Wear on tires	1 mm (approx.)	2 mm (approx.)	1 mm (approx.)
Average speed	36 m.p.h.	38 m.p.h.	1.9m.p.h.

The shortening of travelling time by driving fast is not significantly large on ordinary roads or motorways. Drivers have to stop at traffic lights and at four-way-stop intersections on ordinary roads. Drivers cannot commit traffic violations if another car has stopped at an intersection for a red light.

Drivers are more tired and need more rest when driving fast because, during such driving, they drive with greater tension, thus expending more energy, than drivers driving at normal speeds. Therefore, even on motorways, the difference in travelling time between driving fast and driving at normal speeds is not significantly large.

Moreover, fast drivers experienced sharp braking 177 more times, consumed 12 more gallons of fuel, and wasted 1 more millimeter of tire than ordinary drivers did (Cohen & Preston, 1968) . Fast drivers make their headway shorter than the ordinary drivers, and the probability of collision becomes larger. According to these results, it can be said that hasty driving is clearly not an efficient mode of driving. It is apparent that this behavioral mechanism that drives us to overtake others is adaptive in the pedestrian world, but it is not advantageous in the automobile world.

8 Conclusions

As a result, accident-prone drivers showed higher scores on the hastening test than non-accident-prone drivers, and/or more irregular reaction times than non-accident-prone drivers. Accident-prone drivers could be detected by their irregular reaction times and by their scores on the hastening test with a probability of around 84%.

Around 89% of younger drivers 18 or 19 years old and 64.7% of drivers over 65 showed a higher irregularity in reaction time than the threshold, above which around 80% of all drivers were accident-prone. Around 78% of 18 or 19 years old drivers and around 65% of drivers over 65 showed higher scores on the hastening test than the threshold. The degree of tendency to hasten and the fluctuation in reaction times were the lowest among drivers between 25-39 years of age.

It can be concluded that the human factors leading to collisions while driving are the driver's irregularity in reaction times, which can result in a sudden delay in reaction and a stopping distance greater than usual, and the driver's tendency to hasten, which can result in a shorter headway being maintained.

To reduce the number of accidents, drivers should be taught to maintain sufficient headway in order to allow for any unexpected delay in reaction or for an unusually greater stopping distance due to road conditions.

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