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AN EXPERIMENTAL STUDY OF SPEED–PERCEPTION OF THE CAR ON THE ROAD (III)

— SPEED JUDGEMENTS OF DRIVERS IN THE NIGHTTIME —

By

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The subjective judgements of speed in driving a motorcar were investigated in the nighttime using eight amateur drivers by means of the "start-production" and the ratio production method. In the start-production series, the statistically significant differences were not found between the conditions of day and night in comparison with the results of the preceding experiments. As the standard speed increased, the tendency of overestimating the task speed increased generally in the acceleration series. In the deceleration series, underestimation of task speed was observed in contrast with the case of acceleration. It was suggested, further, that although produced speeds might vary with *S*s, the pattern of *S*' responses as a whole showed a similarity to each other within each condition of acceleration and deceleration.

It was inferred from the results of HR data that the *S* became gradually habituated to the experimental driving situation.

To drive a car along the motorway with heavy traffic the driver must control speed continually according to surrounding conditions. Among speed offences which a driver commits, there are, except wilful violations, some offences which seem to result from the distortion of subjective speed judgements of the driver. For example, when a driver turns off into a second-class road after driving at a relatively high speed along the motorway for some time, the speed judged subjectively by the driver shows often considerably lower levels than actual (Barch, 1958; Denton, 1966). The experimental findings to prove this fact has been obtained by Tada, Ohyama, Kitamura & Hatayama (1969, 1970), who had found the tendency to underestimate a task speed when decelerating. Now, the driver does not always look at the speedometer during driving successively. Thus, it is necessary to understand the properties of speed control of drivers in driving a motorcar. These properties will be closely related to the subjective judgements of speed by drivers, or the speed-perception.

We may consider that the subjective judgement of speed or the speed-perception consists of at least two aspects. First there is an aspect of forming a speed-perception,

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in which the functions of sensory levels such as vision, audition and kinesthesis, etc. will principally participate. Secondly, we can think of an aspect of influencing and modifying the speed-perception. This will comprize habituation accompanying the experiences or practices, state of physical health, motivational disposition influencing the arousal levels of organism, difference between night and day, etc. Therefore, it may be considered that "speed-perception" is that process in which a driver recognizes the arousal levels of organism, difference between night and day, etc. Therefore, it may be considered that "speed-perception" is that process in which a driver recognizes mainly information about the speed from inner and outer environments by means of the functions of sensory systems, and which is temporarily modified by the various variables of organism and the conditions of physical environments. "To be temporarily modified" means that "speed-perception" is not a process learned as a function of the number of practices, but a perceptual one which is formed by an organic integration of the functions of sensory systems (Tada, et al, 1969).

Although the factors stated above usually entwine each other in an actual driving situation, an adequate judgement of speed will be formed, to some extent, by the organic functioning of various systems of the driver so he can cope with the situations varying from time to time. Then, in order to examine such properties of speed control by the driver, the experiments by the speed-production method have been attempted, regarding the subjective judgement of speed as a property of integrated response of organism (see Tada, et al. (1970), with respect to the experiments conducted in our research group.).

The first purpose of the present experiment was to investigate the speeds judged by the driver using the method of multiple stimuli and the fractionation method (acceleration-deceleration series). Secondly, the values of heart rate were measured per each trial to trace the relationship between the shifts of arousal levels expressed in the number of heart beats and the judgements of speed. Moreover, by adding the start-production series to acceleration and deceleration series, we tried to examine whether the differences in judgements of speed exist between the conditions of day and night. The present experiments were carried out in the nighttime when the test track had dried up so as to restrict visual inputs and to secure the conditions of road circumstances as uniform as possible.

Method

Subject: The *S*s were eight owner drivers including one woman who had more than three years' driving experience, ranging in age from 22 to 40.

Experimental vehicle: The vehicle used in the present study was a 1963 Toyota RS 41 type Toyopet Crown (a 1887cc passenger car) equipped with automatic transmission, about 50,000 km in the indicator of integrating meter.

Test area: The track utilized was about a 3-km long, flat, almost straight and two-lane divided section paved completely, running from the entrance of Sendai

Fig. 1. Track used in the present study.

Bypass on Route 4 to Sendai Air Port. This section was sparsely-populated, commanded an unobstructed view and had no signalled intersections. Fig. 1 shows the night scene of the track.

Procedure: Just prior to the experiments, *E* instructed *S* in the driving techniques of the vehicle to require *S* to drive actually during the experimental session, and simultaneously *S* was equipped with the electrode for recording pulse rate, using a San-ei Sokki 2D16 type pulse meter, to the right ear lobe. Next, the *S* was allowed to drive over the test area to familiarize themsevles with the car and situation. During the experimental session, the front quarter vents and the door windows were shut up and the speedometer on the car dashboard was masked that the *S* might not look at it. The experiments in this study consisted of two parts: the first part was the start-production series in which the *S* was required to produce the speed judged equivalent to the given task speed from a halt. The second part was called the "acceleration-deceleration" series. The acceleration series required the *S* to double the standard speed as described. The deceleration series required him to halve it. Four task speeds were used for the start-production series and five standard speeds for the acceleration and the decleration series, respectively. These were 30, 40, 50, and 60 km/hr for the start-production series, 15, 20, 25, 30 and 35 km/hr for the acceleration, and 30, 40, 50, 60 and 70 km/hr for the deceleration. Each of them was presented five times to each of *S*s. The order of presentation of these task speeds and standard speeds was randomized using the tables of random numbers.

The speed shown on the tachometer – This was calibrated so that the errors of its speed would remain less than 1.5 km/hr – was recorded as a response of each *S*. The subjective speeds obtained in two parts of the experiment will be called "produced speed". The present experiments were carried on from Nov., 1970 to Feb., 1971.

Results

1) Judgements of speed in the start-production series

The *S*s were required to produce the speed considered subjectively to be the given task speed by the starting of the car from a halt. Fig. 2 shows the speed discrepancies in km/hr between the produced and the task speeds, and these standard deviations. Each value per each task speed is the mean of forty samples from eight *S*s. As the task speed changes from high to low speed, the discrepancy between the produced and the task speed decreases, without any differences among the standard deviations of produced speeds per each speed condition. Then, we attempted to check up the presence of differential effects on the produced speeds which might result from the difference in the experimental conditions between day and night, comparing these results with those obtained in the previous study (Tada, et al, 1970), especially those for eight members of a transportation troop from JSDF who were thought to hold probably an intermediate position between amateur, and professional drivers such as taxi drivers. The t test was performed on an amateur group in this study and JSDF members. This revealed that the differences in the means between both groups per each task speed were not statistically significant (0→30 km/hr: $t=1.75$; 0→40 km/hr: $t=.23$; 0→50 km/hr: $t=.37$; 0→60 km/hr: $t=.44$, $df=62$)

Next, the results were plotted with trial order as abscissa against the percent changes of produced speed to task speed as ordinate. As shown in Fig. 3, the underestimations of task speed were recognized in any task speed condition. And the higher the task speed, the smaller the degree of underestimation became. It was found, moreover, that the values of percent change in the fourth and the fifth trial tended to be higher than in the first.

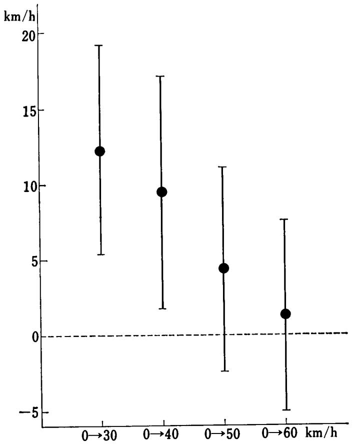

Fig. 2. Speed discrepancies between the produced and the task speeds in the start-production series.

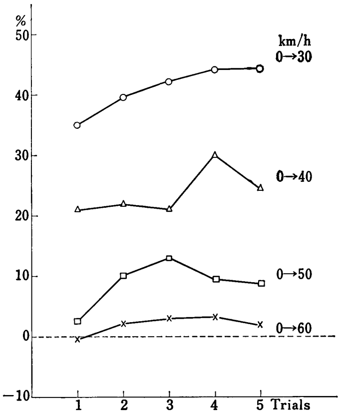

Fig. 3. Percent changes of produced speed to task speed in the start-production series.

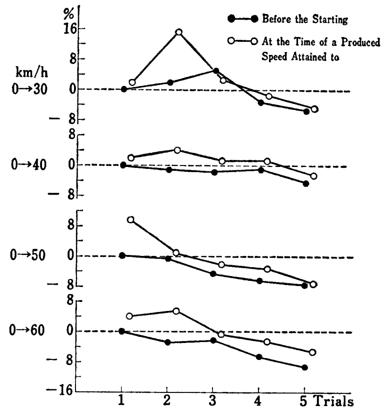

Fig. 4. Percent changes of heart rate values in the start-production series.

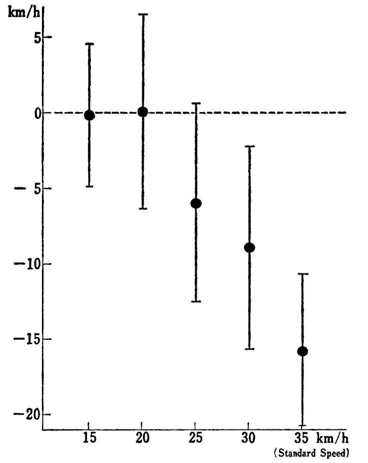

Fig. 5. Discrepancies between the speed judged double a given standard and the task speed in the acceleration series.

On the other hand, the measurement of heart rate was taken immediately before the starting and at the time of a produced speed attained to. These HR values in each of four task speed conditions, by taking the value of the first trial as a basic one, were converted into percent changes per each trial. As seen in Fig. 4, the HR values were generally higher at the time of a produced speed attained to than before the starting, and there were gradual decreases in percent changes in any task speed condition.

2) Judgements of speed in the acceleration-deceleration series

In these series, the *S* was required to produce the speed considered to be double or half a certain standard speed. Fig. 5 illustrates the discrepancies in km/hr between the speed judged double a given standard speed and the task speed concerned. As the standard speed increased, the tendency of overestimating its task speed increased generally, but at low standard speed such as 15, 20 km/hr few discrepancies were shown.

In the deceleration series were computed speed differences in km/hr obtained by subtracting the task speed concerned, from the speed judged half the standard speed (Fig. 6). Underestimation of task speed was obtained in this series. However, when we examined percent changes of produced speeds to task speeds, the degree of these underestimations was substantially constant in any standard speed, and it was found that the speed produced was about thirty percent faster than a task speed. Certain subjective speed ratios (.65) were, therefore, found between produced speed (S_2) and standard speed (S_1) (Fig. 7).

Further, a trend analysis was attempted in order to investigate the possible existence of a linear relation between S_1 and S_2. In the acceleration series (Table 1), even the components except a linear component were highly significant, whereas the

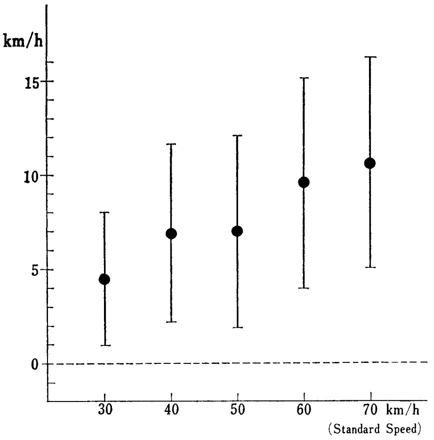

Fig. 6. Discrepancies between the speed judged half a standard speed and the task speed in the deceleration series.

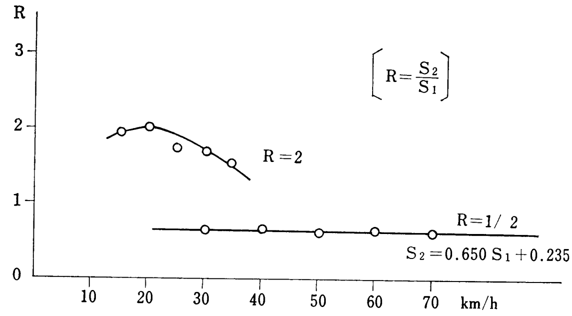

Fig. 7. Ratio of produced speed to standard speed.

Table 1. Analysis of variance for the produced speeds in the acceleration series.

Source	*SS*	*df*	*MS*	*F*
Between Speeds	14916.48	4	3729.12	103.51***
Linear	14376.01	1	14376.01	399.06***
Quadratic	361.61	1	361.61	10.04***
Cubic	27.04	1	27.04	.75
Quartic	151.82	1	151.82	4.21**
Error	7024.88	195	36.03	
Total	21941.36	199		

*** $p<.005$ ** $p<.01$

Table 2. Analysis of variance for the produced speeds in the deceleration series.

Source	*SS*	*df*	*MS*	*F*
Between Speeds	16970.52	4	4242.63	167.28***
Linear	16926.01	1	16926.01	667.43***
Quadratic	.06	1	.06	.00
Cubic	1.69	1	1.69	.07
Quartic	42.76	1	42.76	1.69
Error	4945.80	195	25.36	
Total	21916.32	199		

*** $p<.005$ ** $p<.01$

data in the deceleration series showed only a highly significant linear trend (Table 2). It will, thus, be seen that the speeds produced by *S*s have a linear relation to the standard speeds.

Then, there is an increasing evidence that sensation may frequently be described as a power function of the stimulus intensity that produces it (Ekman & Dahlbäck, 1956; Stevens, 1957). If we are allowed to consider that the speed S_2 corresponds to the

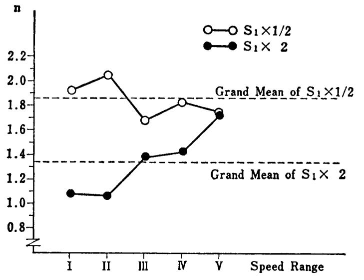

Fig. 8. Mean power index n obtained for each speed range.

sensation which is judged double and half the standard speed S_1, similar law will apply, as Denton (op. cit.) points out, to subjective judgements of speed.

In the present study, since we know the sensation ratio, produced speed S_2 can be expressed as an exponent n when the corresponding speed ratio is obtained. According to Stevens, if s denotes the sensation ratio and r the corresponding stimulus ratio, we can obtain the value of n by dividing log r into log s. Thus the equations of n for doubling and halving the speed were as follows:

$$n=\frac{\log 2}{\log S_2/S_1} \quad (1)$$

$$n=\frac{\log .5}{\log S_2/S_1} \quad (2)$$

Fig. 8 shows mean values of n from eight Ss, obtained by substituting the speeds judged double and half the standard speeds into equations (1) and (2) respectively. A striking difference between both series was seen in that in deceleration, the index value of n was nearly constant (1.85) regardless of the standard speed condition, whereas in case of acceleration, a higher standard speed was inclined to result in a larger value of n. It will be seen, further, that the intersection occurs at the fifth speed range.

Table 3 and Table 4 summarize the results of analyses of variance in terms of speed and subjects. The F value associated with the speed differences was highly significant ($p<.005$) for $S_1 \times 2$ but not significant for $S_1 \times 1/2$. Although subject effects were found to be significant ($p<.005$) in both series, the speed $\times$ subject interactions was not significant.

Fig. 9 illustrates the shift of percent changes, when we take the value of the first trial as basic one, in HR during S' run at a given standard speed. It was found from this figure that percent changes in HR decreased gradually with continued trials.

Moreover, mean percent changes in HR, when we take the mean HR value of the first block as basic one, are presented throughout the whole course of the experiment in blocks of five trials in Fig. 10. It was noticed that percent changes decreased gradually as time elapsed, but had nearly constant values around the twelfth block.

Table 3. Analysis of variance of index values. ($S_1 \times 2$)

Source	*SS*	*df*	*MS*	*F*
Speeds (A)	12.69	4	3.17	19.81***
Subjects (B)	19.81	7	2.83	17.69***
A×B	6.01	28	.21	1.31
Residual	25.69	160	.16	

*** $p<.005$

Table 4. Analysis of variance of index values. ($S_1 \times 1/2$)

Source	*SS*	*df*	*MS*	*F*
Speeds (A)	3.43	4	.86	1.54
Subjects (B)	42.24	7	6.03	10.77***
A×B	9.66	28	.35	.63
Residual	89.65	160	.56	

*** $p<.005$

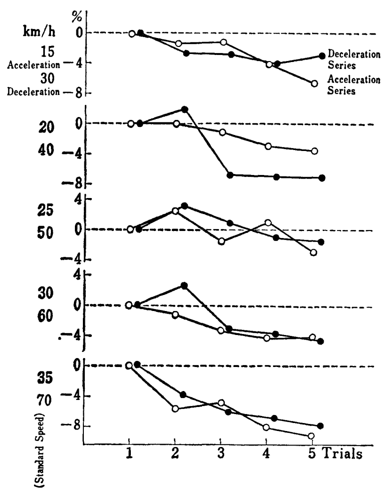

Fig. 9. Percent changes of HR values before the starting in the acceleration-deceleration series.

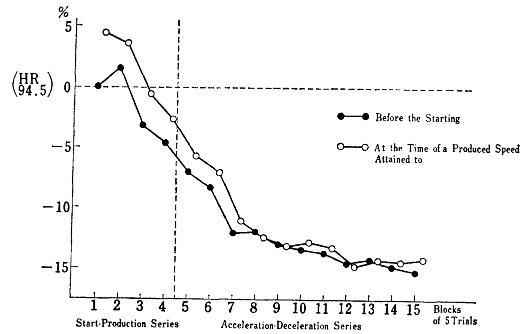

Fig. 10. Percent changes of HR values throughout the whole course of the experiment.

The *F* associated with rank correlation ratios of HR values among subjects was highly significant (F=10.41, df=13.75/96.25; $p<.005$). It may safely be said, therefore, that HR values are related to the number of blocks in the present study.

Discussion

In order to examine how judgements of speed were affected by the difference in the experimental conditions between day and night, the start-production series was prepared in the same manner as in our preceding experiments. It was indicated in this series that the higher task speed formed a relatively accurate judgement on the actual speed of the experimental vehicle, and that if we could regard the tendency of gradual

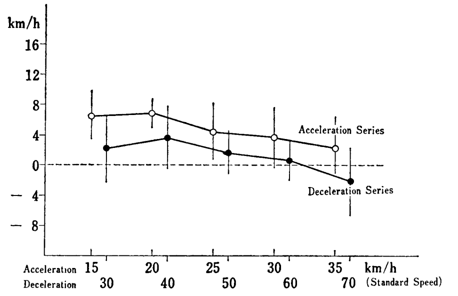

Fig. 11. Discrepancies between the subjective and the objective standard speed.

decreases of percent changes in HR values as the appearance of "habituation" to the driving situation, the habituation here would not always be one of the factors constituting the relatively accurate judgements of speed since percent changes had larger values in the second half of five trials rather than those in the first trial. Further, the tendency of underestimating task speed agreed well with the results obtained in our previous study. In the present experimental situation, it seems, therefore, that little differential effect on the judgements of speed was caused by the difference in the experimental conditions between day and night.

In both acceleration and deceleration series, the discrepancies in km/hr between the produced speed and the task one were calculated. In proportion to higher standard speed in the acceleration series an increasing tendency of overestimating task speed was seen. Apparently, these results appear to contradict with those of Tada, et al. (1969), but this can probably be attributed to the procedure different from that used in this study because similar results were obtained in the deceleration series. In this series, underestimation of task speed was recognized in any standard speed and generally the speed produced was about thirty percent as fast as a task speed. Therefore, the ratio of produced speed to standard speed proved nearly constant (.65).

For the purpose of further analysing the data mentioned above, trend analysis was made of the relationship between produced speed and standard speed in both series. In the acceleration series, the F tests for other trends than linear one also exceeded the value required for the .05 level of significance, whereas the data in the deceleration series showed only a highly significant linear trend. It may be said, therefore, that the deceleration series reflects only the linear trend in the relationship of produced speed to standard one. Therefore, the equation of regression line of produced speeds to standard ones was obtained in the following manner.

$$S_2 = .651S_1 + .195$$

Next, by converting the produced speeds obtained for both series of acceleration and deceleration into index values, analysis of variance was applied to these transformed data. In the acceleration series, there existed the speed effect on power index n, but the subject $\times$ speed interaction term was not significant. Further, the higher the standard speed was, the larger the index value was apt to become. The results of this series suggest, therefore, that at least the index n is affected by standard speed, and the effect on n is considerable under the condition of a higher speed. On the other hand, the facts that both the speed effect and the speed$\times$subject interaction were not recognized, and that the power index was thus nearly constant in the deceleration series, may reveal that the value of n is independent of the condition of standard speed. However, subject effect was found to be significant in both series. In view of nonsignificant interaction terms, these suggest that there is a certain degree of individual difference in produced speeds, but *S*' response pattern as a whole showed a common similarity in the conditions of acceleration and deceleration. It seems that the pattern of shifts of index value n illustrated in Fig. 8 agrees well with that of Denton (op. cit). He describes, roughly speaking, that in a driving situation, sensation is not a simple power function of the stimulus speed because the response evoked is not ascribed to the original stimulus value but to a distorted version of it. However, our result showing the grand mean (1.85) of values of n in decelerating roughly agrees with that of laboratory experiments by Ekman (1.77).

For the purpose of exmaining the problem of "time error", three *S*s* were instructed to produce the speed considered to be the original standard speed following the attainment of the required one. The overall finding obtained from Fig. 11 was that although a certain degree of discrepancies might be recognized under the lower S_1 in the acceleration series, the discrepancies between the subjective standard speed and the objective one were considerably small. Therefore, it seems that speed judgements per se depend substantially on the condition of either acceleration or deceleration, since the original standard speeds were little distorted by "time error".

With regard to HR data, the gradually decreasing tendency in percent changes which was found in the start-production series was also seen in these series and throughout the whole coruse of the experiment. It will be inferred from these results that the *S* becomes gradually habituated to the experimental driving situation.

References

Barch, A.M. **1958** Judgements of speed on the open highway. *J. appl. Psychol.*, **42**, 362–366.

Denton, G.G. **1966** A subjective scale of speed when driving a motor vehicle. *Ergonomics*, **9**, 203–210.

Ekman, G., & Dahlbäck, B. **1956** A subjective scale of velocity. *Rep. Psychol. Lab. Univ. Stockholm*, **31**.

Stevens, S.S. **1957** On the psychophysical law. *Psychol Rev.*, **64**, 153–181.

Tada, H., Ohyama, M., Kitamura, S., & Hatayama, T. **1969** An experimental study of speed-perception of the car on the road (I). *Tohoku Psychol. Folia*, **28**, 1–9.

Tada, H., Ohyama, M., Kitamura, S., & Hatayama, T. **1970** An experimental study of speed-perception of the car on the road (II). *Tohoku Psychol. Folia*, **29**, 14–20.

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* They are *S*s who participated in the experiments conducted in the daytime.