

# Brake Reaction Times of Motorcycle Riders

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## Abstract

A long-term study investigated brake reaction times (BRT) using an instrumented motorcycle on a training facility. Test persons were volunteers of all kinds of age and riding experience. Reaction times at the front- and at the rear-wheel brake were measured and statistically evaluated. Riding in a "Ready-to-Brake" position was recognized to be advantageous for a shorter brake reaction time. The influence of several factors on the BRT was studied. While the expected correlation between rider's age and BRT could not be proved, higher riding experience was found to be correlated with shorter brake reaction times.

## 1 Introduction

Braking certainly is one of the most important maneuvers when riding a motorcycle. A proficient and safe braking maneuver starts with a prompt reaction of the motorcyclist. Especially at a low (or medium) driving speed the entire braking distance depends significantly on the distance traveled during reaction time. Therefore this period of time can be crucial. In a dangerous traffic situation a short reaction time at the beginning of a braking maneuver can easily save sufficient braking distance to avoid an accident.

Other than with an automobile, braking with a motorcycle is still a complex, combined perceptual - motor task. Since most motorcycles are equipped with two independent braking systems, riders must actuate and control the front- and the rear-wheel brake at the same time to achieve maximum deceleration. The right hand of a motorcyclist already has to perform several tasks simultaneously during normal riding. It has to support the upper torso of the rider, apply appropriate steering forces to the handlebar and control the twist-grip throttle. Additionally, during a braking maneuver the right hand is highly challenged to perform the difficult motor task of applying optimal control force to the brake lever. Due to the two different tasks which the right hand has to perform, two positions are used during riding: (a) holding the throttle grip with all fingers, or (b) keeping several fingers poised over the brake lever. This brief problem description shows well that we consider a complex topic when we discuss brake reaction times.

Numerous aspects of reaction times have been investigated in the past, see, e.g., (Welford, 1980). Also a number of traffic related publications deal with brake reaction times of drivers in different driving situations, (Liebermann, et al., 1995) and (Taoka, 1989). However, only a few contributions are known to the authors which address the special situation of motorcycle riders, e.g., (Thom, et al., 1985) and the pioneering work by Prem (Prem, 1987). But no recent investigations on brake reaction times had been

available that were based on a sufficiently large number of participants and that were reflecting or at least were comparable to the performance of Austrian motorcyclists. Therefore a long-term field study was initiated in 1992 and carried out over the following years. This paper reports some of the findings with respect to brake reaction times. More details can be found in (Hauer, 1995) and (Ruspekhofer, 1996). Other results from this field study are presented in (Ecker, et al., 2000) and (Ecker, et al., 2001).

## 2 Research Method

The main objective of the study was to carry out a review among Austrian motorcyclists with respect to their braking behavior. Over a period of several years altogether more than 300 individuals were tested and approximately 600 single braking maneuvers were recorded and analyzed. Most of the volunteer test riders were participants of motorcycle safety courses organized by the Austrian Automobile Association OeAMTC. Braking tests were carried out at one of the training facilities of the OeAMTC.

### 2.1 *Measurement equipment*

For an accurate measurement of the brake reaction time while the motorcycle is in motion a special equipment is necessary. For this reason the test persons could not use their own motorcycle but had to use an instrumented Honda CB500 instead, see Figure 1. This conventional, medium weight and medium performance motorcycle is easy to handle and allows fast adaptation of riders not used to this particular model. The motorcycle was equipped with two digital timers to measure brake reaction times on both wheel brakes. The timers were installed in a data acquisition box, mounted on the right-hand-side at the rear of the motorcycle. Figure 2 shows the operating panel of the box. Once started the timers were stopped by operating the front and the rear brake lever, respectively.



Figure 1: Instrumented motorcycle Honda CB500 as used in the experiments.

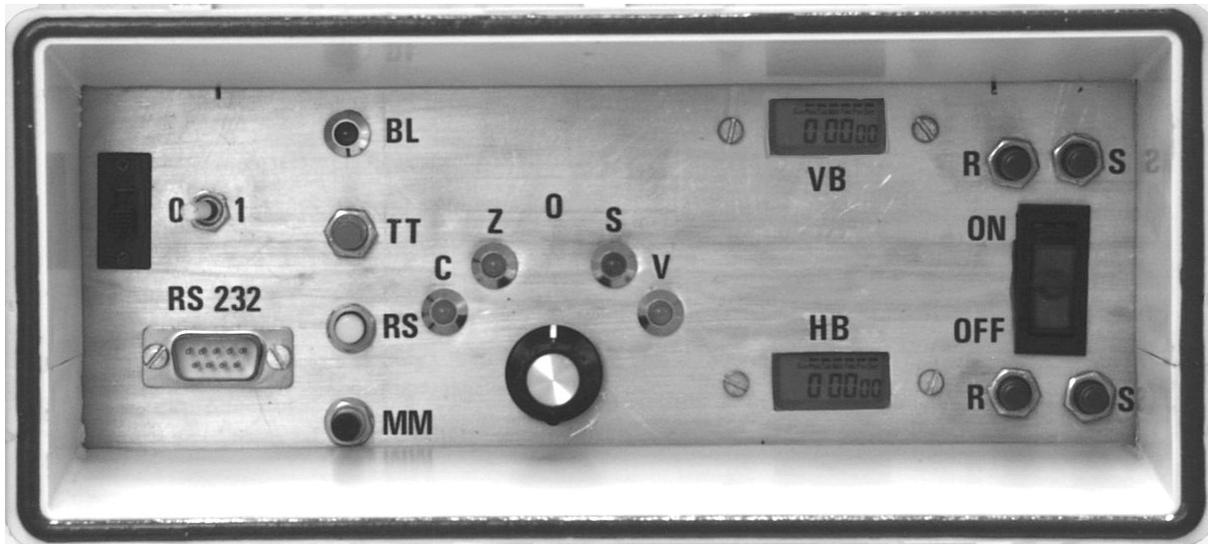


Figure 2: Front panel of the data acquisition box with digital timers VB and HB for front-wheel and rear-wheel brake operation, respectively.

A red signal light was mounted on the instrument panel of the motorcycle, being positioned on the peripheral of the visual field for motorcycle operation, see Figure 3. The light could be activated at any time by the test coordinator via remote control. Thereby the trigger signal for starting the braking maneuver was rather unexpected for the riders. At the same moment the signal light was triggered, the digital timers also were started.



Figure 3: Signal lamp mounted next to the speedometer. Remote control to trigger signal lamp.

As an additional equipment a crash data recorder, located in the data acquisition box, measured the traveled distance, speed and deceleration. These additional data were used to cross-check the measurements with the digital timers and to investigate the rider's action in more detail.

## 2.2 *Test procedure*

Every test started with a familiarization procedure of the test person with the instrumented motorcycle. Each individual was asked to make a couple of braking trials on his or her own, in order to get as much used to the motorcycle as possible within the given time frame. Then the test persons were assigned to drive at a speed of about 60 km/h (37 mph) on a long straight part of the test facility and to make a full stop emergency braking maneuver when the bright red flare of the signal light went on. The test persons were of course aware of the imminent signal to start the maneuver. However, it was possible for the test coordinator to vary the instant of triggering the maneuver via remote control within several seconds so that there was some uncertainty involved for the test persons. The assignment for the test person was "to bring the motorcycle to a stop in as short a distance and time period as possible." Each rider had to perform two braking maneuvers.

## 2.3 *Personal data*

Personal data were taken down from every individual with a questionnaire. Along with general data like age, weight, sex and license ownership also specific data related to the personal use of motorcycles were collected. Some of these data were motorcycle riding experience expressed in years and kilometers, self-characterization with respect to riding behavior and also information about ownership of motorcycles. All data were entered into a database, together with the brake reaction times achieved in the tests.

## 2.4 *Definition of brake reaction time (BRT)*

A definition of the quantity (measure) "brake reaction time" (BRT) as used in this contribution is necessary, since the usage is not uniform throughout the literature. Figure 4 splits up the entire braking time into separable periods of time that are related to different actions of the motorcyclist. Braking time starts with the trigger signal (stimulus). The first period is the "latency period" between stimulus and beginning of muscular action. The second period covers the movement time of the fingers (resp. foot) from a previous position to the first contact with the brake lever. The following period is called "brake response time" and ends with the onset of the braking force. The period of time to reach full effectiveness of the brake is named "pressure build-up time." The final period until the end of the maneuver completes the braking time.

In the course of this investigation the expression "brake reaction time" (BRT) is used for the period of time that starts with the trigger signal and ends when the brake light switch registered a brake application. The BRT therefore consists of the latency period, the movement period and is a minimal portion of the brake response time. It was neither feasible nor advisable to detect the first contact with the brake lever because some riders already had minimal contact prior to the trigger signal. However, the electrical switches at the front-wheel brake and the rear-wheel brake were adjusted for minimal travel of the respective lever in order to minimize the contribution of the brake response time.

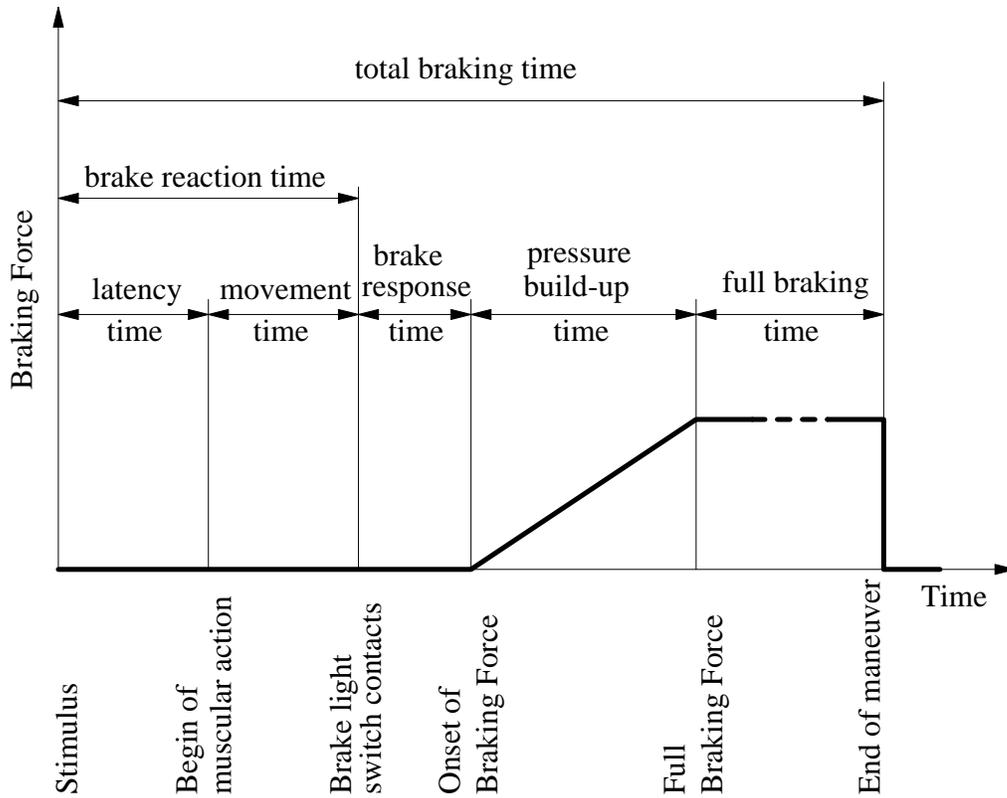


Figure 4: Sequence of events in the course of a braking maneuver.

### 3 Results

Measurements of reaction times of a total of 278 individuals were recorded during the field study. In general each person was asked to perform two braking maneuvers. Occasionally only one experiment was possible, sometimes there was time for more than two tests. In order to equally weight the contribution of each test person in case of multiple tests, mean values for each individual were calculated and entered into the database..

Several riders did not use both brakes, others did apply the brakes before the stimulus and caused erroneous readings. This explains why the total number of samples in the following data analysis is lower than the number of test persons.

#### 3.1 Reaction time at rear wheel brake

Figure 5 shows a histogram of measured brake reaction times at the rear wheel brake. For  $n=260$  samples a mean value of  $t_{\text{rear-mean}} = 0,463$  s and a mean variation of  $s_{\text{rear}} = 0,162$  s were calculated. The distribution of this set of samples as shown in Fig.5 is obviously not a textbook-like normal distribution. However, to estimate a confidence interval for the mean value a normal distribution of the population is assumed. For a probability of 95% the mean value is found to be within the interval  $[0,440 - 0,488]$  s. This rather narrow confidence interval can be put down to the fact of a large number of data.

It is worth to note that there is a significant frequency drop for a reaction time of  $t_{\text{rear}} = 0,46$  s. Since a similar observation can be made for the reaction time at the front wheel as well, an explanation will be given in the next section.

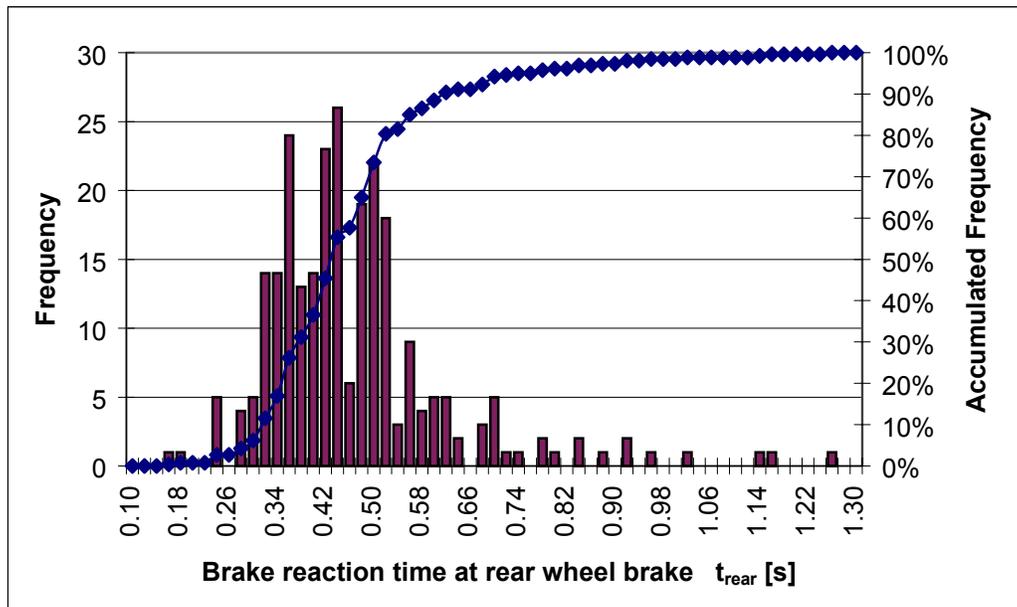


Figure 5: Frequency histogram of rear wheel brake reaction time.

### 3.2 Reaction time at front wheel brake

In Figure 6 the histogram of the BRT at the front wheel brake is shown. For  $n=265$  samples a mean value of  $t_{\text{front-mean}} = 0,423$  s and a mean variation of  $s_{\text{front}} = 0,136$  s were calculated. The confidence interval for the mean value is  $[0,407 - 0,439]$  s. As the confidence intervals for the mean value of the BRT at the two brakes do not overlap, a faster reaction at the front-wheel brake is indicated.

As already announced in the previous section, there is again a remarkable frequency drop at  $t_{\text{front}} = 0,46$  s. A further investigation reveals that this is not an accidental „cut“ into an otherwise normal distribution of the BRT. Actually the distribution of the break reaction time at the front wheel has two peaks; one at about 0,38 s and another one at 0,50 s, separated by the drop at 0,46 s. In consideration of earlier investigations (Thom et al., 1985) it seems reasonable to suppose that there is a correlation between the movement time and this result. To confirm this assumption, a number (50+) of test persons was carefully watched during the braking maneuver whether they had their right hand fingers in a covered position over the brake lever or closed around the throttle.

For undisputed cases the BRT were averaged and the corresponding mean values were  $t_{\text{mean-covered}} = 0,398$  s and  $t_{\text{mean-closedgrip}} = 0,503$  s, leading almost exactly to the two peak values as obtained from the full set of samples.

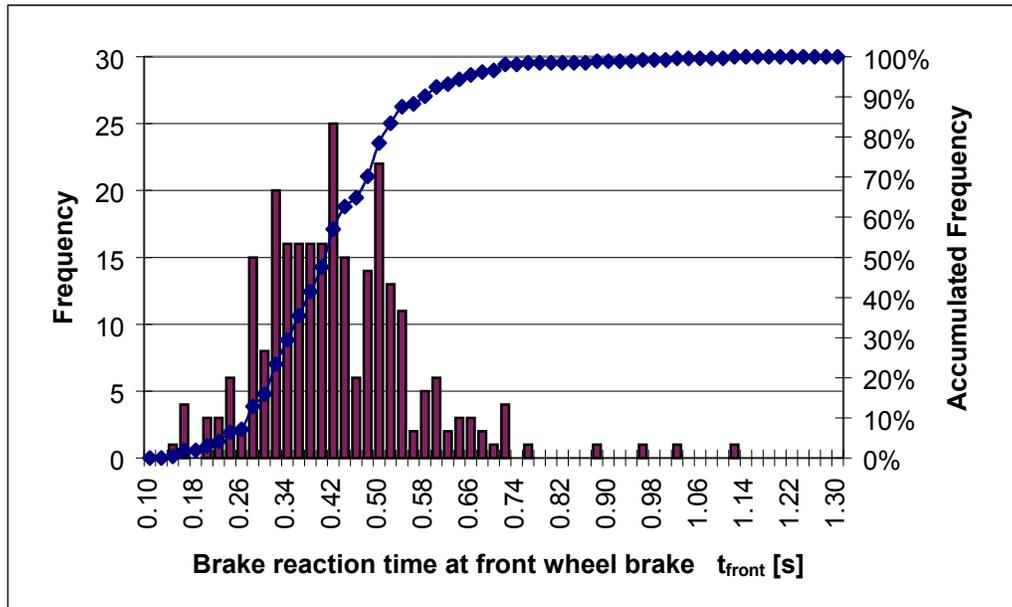


Figure 6: Frequency histogram of front wheel brake reaction time.

### 3.3 Effect of a “Ready-to-Brake” riding position on the BRT

Results from the previous sections indicate that hand- and foot-position during riding can have a significant effect on the brake reaction time. To verify these observations, additional experiments were made in the laboratory with the motorcycle resting on its stand. Only a very small number of individuals were tested; however, each had to perform 50 experiments, see (Hauer, 1995). Other than in (Thom et al., 1985) both brakes were used.

“Ready-to-Brake” means that the rider tries to minimize the movement time by extending his fingers beyond the front wheel break lever or by keeping his foot just above the rear wheel brake lever. Average brake reaction times as obtained from the measurements in the lab were shorter for a “Ready-to-Brake” position. The time difference in favor of the “Ready-to-Brake” position was  $t_{\text{diff-rear-lab}} = 0,12...0,17$  s at the rear wheel brake and  $t_{\text{diff-front-lab}} = 0,16...0,19$  s at the front wheel brake. This result agrees quite nicely with results obtained in a similar manner in (Thom et al., 1985) with average differences in BRT values at the front wheel brake ranging from 0,17 s to 0,20 s.

It is noteworthy that the difference of BRT between the two riding positions was larger in the laboratory experiments than in the field study. For the front wheel brake the corresponding values are  $t_{\text{diff-front-lab}} = 0,16...0,19$  s and for the field study  $t_{\text{diff-front-fs}} = 0,105$  s. But since the test persons who participated in the field study were not tested under laboratory conditions, and since only a very small number of individuals were tested in the lab, a direct comparison of both results is questionable without further investigations.

### 3.4 Reaction time and age

It is well known that reaction time increases with age (Welford,1980). However, up to an age of 50 years this increase is very moderate but starts to become more pronounced for older people, especially for those above 60. For a sample of  $n = 184$  individuals the histogram of age for this study is shown in Figure 7. This diagram shows that the age of the participants ranges from 18 to 56 years, the mean value of this distribution is 33,4 years. The range of age where a significant increase in reaction time can be expected is not covered by our sample of test persons.

The correlation between age and BRT at the front wheel brake can be visualized by a scatter plot, see Fig. 8. It is easy to recognize that the BRT seems to be almost independent of age. A numerical analysis unveils that there is a negative correlation coefficient of -12% for this set of data indicating that BRT decreases somewhat with age. For a different sample of test persons with  $n = 89$  (Hauer, 1995) and with almost identical statistical properties (mean value and standard deviation of age) a positive correlation coefficient of +5% was calculated. Therefore no clear result was obtained, and an increase of reaction time with higher age could not be verified in this case. Although this seems to contradict the results earlier mentioned, one must keep in mind that other factors also might influence the BRT as, e.g., motorcycle riding experience.

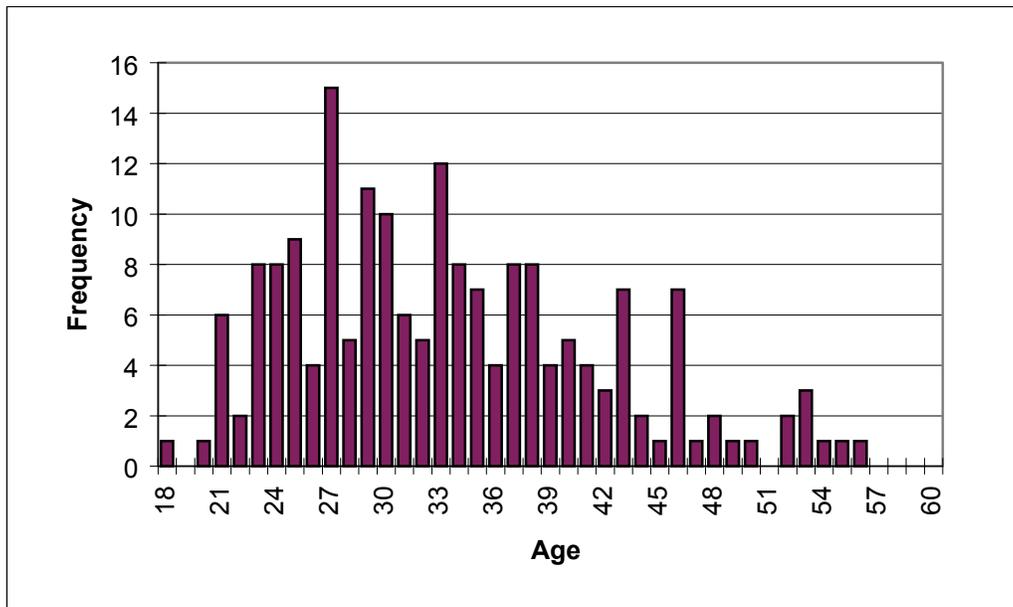


Figure 7: Frequency distribution of rider's age of investigated sample of individuals.

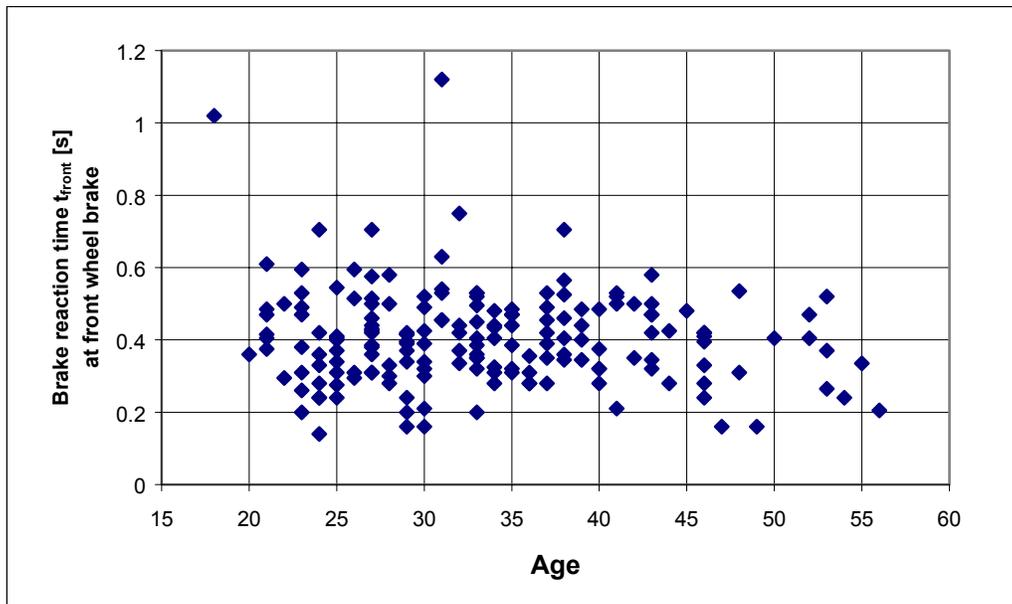


Figure 8: Scatter plot of front wheel brake reaction time vs. rider's age.

### 3.5 Reaction time and other factors

To quantify motorcycle riding experience several measures can be used. Some of them would be meaningful like “total hours on motorcycle” but are hard to be answered by test persons. It turned out that “total driven distance” and “number of years of motorcycle use” were useful criteria. Both parameters show a negative correlation coefficient with BRT on the front wheel brake (and also on the rear wheel) ranging from -8% to -16%. Almost identical results were also obtained for a different sample of test persons. Therefore it can be concluded that riding experience improves the brake reaction time and (at least) compensates adverse effects of age. Since the latency period can hardly be shortened by experience (i.e. training) it can be supposed that the movement period is shorter for experienced riders. A possible explanation could be that experienced riders are more frequently in a “Ready-to-brake” position, it might also be that these riders have better trained muscular actions and therefore a faster response. With the measurement equipment used in this investigation it was not possible to investigate these two possible causes separately.

Finally another interesting influence on the BRT should be mentioned. Brake reaction times for female test persons were found to be higher than for male individuals. For example the mean BRT on the front brake was  $t_{\text{mean-male}} = 0,395$  s for male and  $t_{\text{mean-female}} = 0,552$  s for female motorcyclists. Due to a low number of participants ( $n=26$ ), the confidence interval is rather large for the mean BRT of the females ( $\pm 0,07$  s). Nevertheless, the interval does not overlap with the one for the male motorcyclists. Statistical parameters of the female sample show that the number of young and inexperienced motorcyclists was significantly higher for this sample and therefore one must exercise caution when interpreting these data. On the other hand similar findings were reported in (Thom et al., 1985) and (Welford,1980) and confirm the results obtained in this investigation .

## 4 Discussion and conclusions

The distance traveled during the brake reaction time contributes significantly to the total braking distance, especially at low initial velocities. Even at a speed of 15m/s (54 km/h, 34mph) the distance traveled without deceleration during an average BRT of 0,45 s is 6,8 meters or a third (33%) of the total braking distance of about 21 m (simplified calculation at  $8\text{m/s}^2$  deceleration). In this example every tenth of second of additional brake reaction time lengthens the braking distance by 1,5 meters.

A braking reaction can be split up in a sequence of different time periods. This investigation focused on the brake reaction time which is composed of the latency period and the movement period. There is little a motorcyclist can do to improve his latency period since this time period is mainly determined by biological factors. However, the movement time depends on how fast a muscular action can be performed and therefore can be shortened by training which is usually obtained by riding experience. An even more important possibility to reduce movement time is by correct adjustment of the brake levers and by a “Ready-to-Brake” hand and foot position. Of course it would be inconvenient and, depending on the situation, even not appropriate to remain in this position all the time during riding. Therefore situation awareness plays an important role when riding a motorcycle.

A timely perception and correct judgment are necessary to identify such traffic situations that might call for a prompt action of the motorcycle rider. Not only does this enable the motorcyclist to be on time in a “Ready-to-Brake” position as discussed before, it will also establish a certain level of alertness that prevents the rider to be surprised by a critical situation. Being mentally ahead of time and foreseeing what might happen next is also a key factor in reducing the time period between the advent of a dangerous situation and the stimulus of the braking maneuver. This period was not considered in this investigation and mainly constitutes the difference between a braking maneuver under regular driving conditions and the test situation as created in the experiments.

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