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# Braking Performance of Experienced and Novice Motorcycle Riders - Results of a Field Study

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## 1 Abstract

Motorcycle riding becomes more and more popular. Since beginning of the 1990s the number of registered motorcycles rose by almost 200% in Austria. Restrictive measures for novice motorcycle drivers could prevent a significant increase of accident numbers. But still, motorcycle riding is seven times more dangerous than car driving. While development and introduction of new passive and active safety features makes car driving safer, powered two wheelers (PTWs) still show increasing numbers of accidents, deaths and injuries. It is assumed that poor braking performance of motorcycle drivers is one of the predominant reasons.

Trucks have to be fitted with ABS for many years, most passenger cars on the market have ABS as standard equipment. But most of the mopeds and motorcycles still are delivered with the same braking technology like 100 years ago: Two independent braking devices with two handles.

Recent studies found that braking performance of motorcycle drivers stays far behind the capabilities of their vehicles which are better than - or at least equal to - those of passenger cars. It is supposed that ABS is the most effective solution to encounter this fact and its underlying psychological reasons.

A field study has been carried out including almost 800 brake test rides in total. A device for measuring deceleration - without the need for any modification on the vehicles used - was developed. The braking performance of 134 experienced motorcycle riders has been compared between test rides with their own vehicles and brake tests with an ABS-equipped motorcycle. 47 trainees were tested with the motorcycle they used during the training and compared with deceleration when braking with an ABS-equipped scooter. All the results were evaluated with respect to personal data of the participants, e.g. age, driving experience and attitudes.

Finally, an epidemiological analysis of motorcycle accidents has shown that ABS would be effective in reducing PTW accident numbers.

## 2 Introduction

The construction of powered two-wheelers (PTWs) faced enormous improvements in the recent years. Reduction of weight at the same time as raising the engine power up to about 180 HP rapidly improved maximum speed and acceleration of the vehicles. Wheel suspension was improved as well as the power of the brakes and their handling properties. But mostly, PTW still have the same braking system they have since the beginning of the history of the motorcycle: a hand brake for the front wheel and foot brake for the rear wheel.

Several studies proof that the average motorcycle driver is not capable of handling two different brakes at the same time, particularly in emergency situations. The poor average deceleration that was detected for the average motorcycle driver is supposed to be caused by the motorcycle driver's fear to block one of the brakes (in particular the front wheel brake), skid and fall off.

It is evident that anti lock brakes (ABS) would solve this problem. This study aims to qualify and quantify, how ABS improves brake handling of the average motorcycle driver in an emergency braking manoeuvre.

## 3 Study Design

### 3.1 Probationers

The study should cover both novice and experienced drivers.

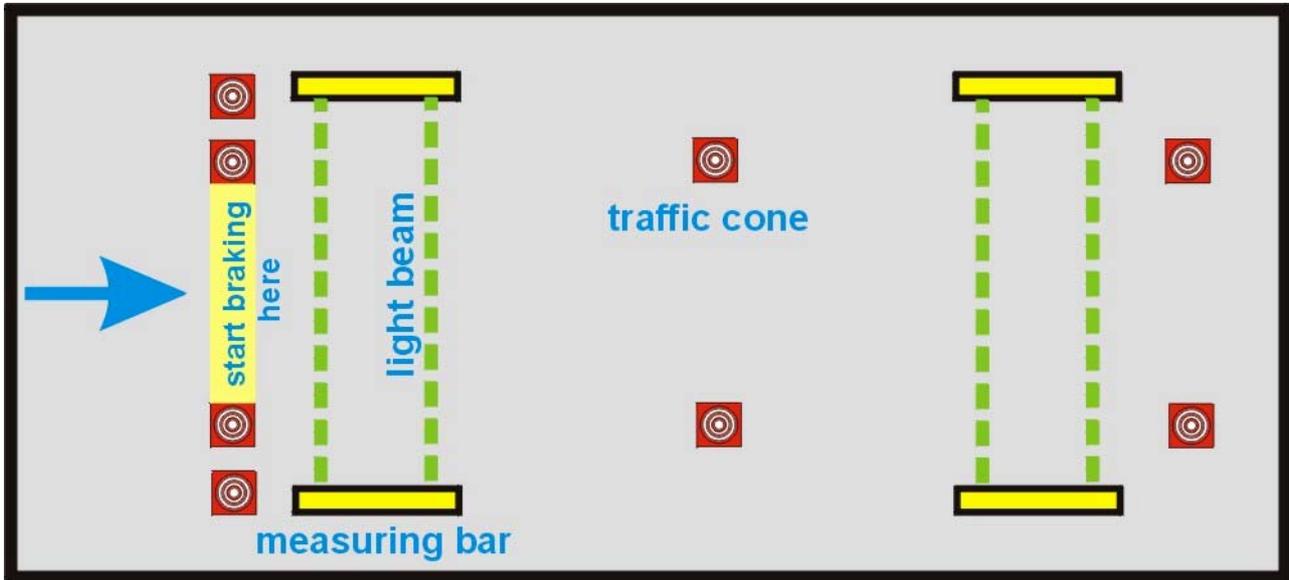
Holders of a driving licence category B in Austria may obtain a licence for category A1 (motorcycle with max. 125 cm<sup>3</sup> capacity and max. 15 HP) after passing a practical instruction of 6 hours. 47 persons passing this training participated in the deceleration test at the end of the training session.

132 participants of track-based motorcycle safety training (voluntary) passed the deceleration test during their training session as the experienced driver group.

### 3.2 Measuring Device

Previous studies found an average deceleration between 6 and 6,5 m/s<sup>2</sup>. But these results suffered from the fact that the test rides were carried out using an instrumented vehicle, which is not the one, the test persons are used to. It was necessary to develop a deceleration measuring device independent from the vehicle used.

A light beam based concept was chosen. Within a distance of about 5 meters, speed is measured twice by two pairs of light beams (yellow bars in the figure left and right of the course contain sender and receiver). The time elapsed between passing the four light beams was measured and deceleration was calculated from the change of velocity).



A yellow floor marking with traffic cones on each side indicated where the test persons should start braking.

The measuring method was tested on a theoretical basis and by practical tests as well and was found reliable. Under extreme conditions the maximum mistake made by supposing constant deceleration in the algorithm and not having it was 5,7%.

### 3.3 Test Procedure

At the beginning of the brake test all probationers were asked to fill a questionnaire containing some questions on their driving experience (even the novices, they had the opportunity of gathering experience with a moped!), attitudes, driving style and mobility habits.

Afterwards, all test persons received an introduction on dangers of motorcycle braking and how to handle these if they should occur during the test. This explanation was necessary to avoid accidents during the test, but was kept short for not influencing the test results.

Then the probationers were asked to exercise two brake attempts, starting at a speed between 50 and 60 km/h and start braking when the front wheel crosses the yellow line. They were asked to come to a complete stop as soon as possible without falling off the vehicle. For these first two runs, the experienced drivers used their own motorcycle. The novices used the motorcycle they had used for training during the recent 6 hours.

Later, the probationers received instructions on correct braking technique, both with and without ABS, the test motorcycle fitted with ABS was explained and each probationer got some minutes to make himself familiar with this vehicle. Then they exercised two more brake manoeuvres with the ABS-motorcycle.

Finally the results of the test were discussed, mostly within a group of probationers.

### 3.4 Test Vehicles

For the ABS test runs adequate vehicles were made available for the probationers (further on called "test motorcycle"). Adequate in this case means that the vehicle fits the class of vehicles they are licensed for or - in case of the novices - the class of license they are applying for.

**3.4.1 Sample Experienced drivers: BMW 650 CS "Scarver"**



figure 2: BMW Scarver

This is a motorcycle frequently classified as "funbike". It is easily handable, the seating position is upright and low enough for most of the probationers. It is fitted with ABS for both wheels but no integrated braking system. The net weight is about 170 kg, the single cylinder 4 stroke engine has a capacity of 652 cm<sup>3</sup> and 50 HP.

**3.4.2 Sample Novice Drivers: Peugeot Elystar 125**

This vehicle represents the typical set-up of vehicles used by persons choosing this license class. It has a net weight of 149 kg. The power transmission is automatic. The brakes are handled by 2 hand levers. The right lever serves the front brake only (with ABS control). The left brake lever serves the front brake with ABS-control and the rear brake as well. The user manual says that for emergency braking only the left brake lever shall be used.



figure 1: Peugeot Elystar

**4 Description of the Samples**

**4.1 Sample Experienced Drivers**

The sample of the experience motorcycle drivers contained a majority of male drivers. The average duration of holding a licence class A was 10,71 years with a minimum of 1 year and a maximum of 45. Their average annual mileage was 5633 km, which is higher than the average annual mileage of motorcycle drivers in Austria (4.500 km). There was a majority of drivers actively driving motorcycles for up to 5 years. The difference between the duration of holding a license and the duration of actively driving a motorcycle is significant. It is due to the fact that many of the license holders apply for the category A license in common with the category B license, mostly at the age of 18 to 19. But they start their motorcycle driving career much later.

Further, the drivers were asked for a self estimation of their driving experience. There were only a few "experienced" and some "not experienced" drivers. A high majority of the probationer indicated mean values for their experience.

The same picture appears in the answers about self estimation of driving style. Predominantly mean values, a hand full of sporty drivers a few driving "not sporty".

About 60% of the probationers indicated that the motorcycle mostly is a leisure time means of transport for them, only five use the bike as a sports kit and rest uses it for everyday transport. Somehow contradicting these values, two thirds of the probationers indicated

age	sex		total
	male	female	
20 - 25	24	3	27
26 - 30	21	6	27
31 - 40	38	6	44
41 - 50	23	1	23
> 50	12		12
total	118	16	134

table 1: number of probationers by age and sex

actively driving a motorcycle	sex	
	male	female
up to 5 years	73	14
5 - 10	17	1
10 - 15	10	1
15 - 20	6	
20 - 25	5	
> 25	4	

table 2: duration of active driving career

to be everyday drivers, one third were weekend drivers.

As an important factor for brake performance the probationers were asked which of the brakes they prefer in everyday driving. 58% used both brakes, 40% preferred the front wheel brake and only 2% mainly used the rear wheel brake.

Two thirds of the probationers were driving a street motorcycle, 25% drive Enduros and the rest drove a Chopper.

8 out of 134 probationers' motorcycles were fitted with ABS. These persons passed the first two brake tests with their own motorcycle, then received instructions on how to correctly handle ABS and afterwards passed another two brake tests with the test motorcycle.

#### 4.2 Sample Novice Drivers

On an average, the sample of novice drivers was older than the experienced drivers sample. This may partly derive from a de facto minimum age of 23 for this kind of driving license.

In total, 73% of the male and 57% of the female probationers already had experience in driving PTWs, i.e. mopeds for which no driving license is necessary. 7 of 47 probationers were currently driving a moped, but most of the others gathered experience from the age of 16 to 18, mostly several years ago.

age	sex		total
	male	female	
20 - 25	3	1	4
26 - 30	4	1	5
31 - 40	8	5	13
41 - 50	10	6	16
> 50	8	1	9
total	33	14	47

table 3: probationers by age and sex

PTW driving experience	experience how long ago? (years)					total
	current	< 5	5 - 10	10 - 15	> 15	
only little		2	1		1	4
< 5 years	2	5	2	5	7	21
5 - 10 years	3				1	4
> 15 years	2				1	3
total	7	7	3	5	10	32

table 4: probationers' driving experience

### 5 Results: decelerations achieved

#### 5.1 Sample experienced drivers

##### 5.1.1 Deceleration values

For an average modern passenger car we can assume that the average deceleration achieved under optimal conditions is about 10 m/s<sup>2</sup>. Modern trucks and busses achieve deceleration up to 8 m/s<sup>2</sup>. Technically the achievable braking deceleration of a modern motorcycle is at least comparable to a modern passenger car.

Despite this, among the experienced motorcycle drivers there were 18 persons (13%) with a deceleration below 5 m/s<sup>2</sup>, i.e. these persons would need twice the braking distance of a modern passenger car.

All deceleration values shown here are calculated from the mean of the both attempts of a test person.

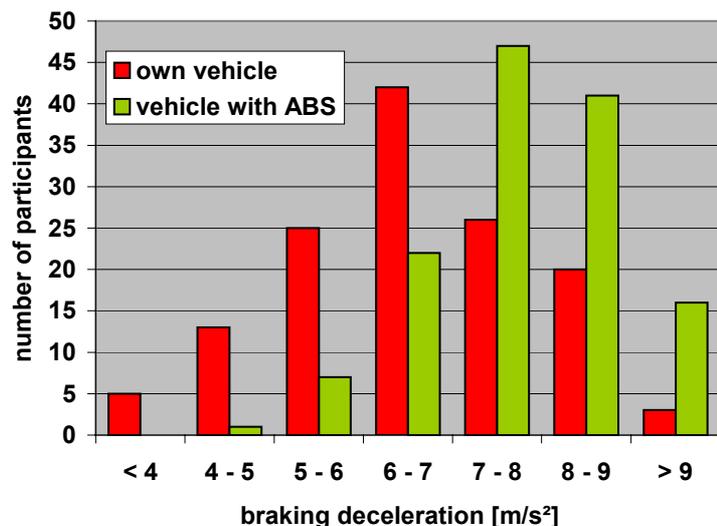


figure 3: decelerations of experienced drivers

The mean value for braking deceleration of all test persons using their own vehicle was 6,6 m/s<sup>2</sup> (std. deviation +/- 1,4).

Using the ABS vehicle, the mean value of braking deceleration rose to 7,8 m/s<sup>2</sup> (standard deviation 1,1). The T-test proved this difference to be significant (p=0,021). 85% of the probationers could improve their deceleration with ABS. The remaining 15% mostly achieved very high decelerations with their own vehicle, an improvement therefore was hardly possible.

Even the probationers having their own vehicle fitted with an ABS improved decelerations when braking with the test motorcycle significantly by 0,9 m/s<sup>2</sup>.

### 5.1.2 Correlation of deceleration and driver data

Neither the deceleration with the own motorcycle nor the ABS deceleration nor the improvement of deceleration were depending on the age of the driver.

Correlations between driver parameters and deceleration results can be found in the table below. Some interesting details:

- Annual mileage was a very important moderating factor. Deceleration with the own vehicle significantly correlated with annual mileage.
- Probationers with higher deceleration using their own bike also achieved better deceleration with ABS.
- Deceleration achieved with the test motorcycle rose together with the duration of active experience and duration of license holding.

	Pearson correlation test	deceleration with own motorcycle	deceleration with test motorcycle (ABS)	improvement	annual mileage	duration of licence holding
deceleration with test motorcycle (ABS)	k	0,587				
	p	0,000				
improvement	k	-0,662	0,218			
	p	0,000	0,011			
annual mileage	k	0,329	0,097	-0,306		
	p	0,000	0,284	0,001		
duration of licence holding	k	0,138	0,175	-0,004	-0,128	
	p	0,113	0,044	0,960	0,157	
duration of active driving career	k	0,164	0,178	-0,032	0,123	0,538
	p	0,061	0,042	0,717	0,174	0,000

table 5: correlation between deceleration values and driver parameters

Some other interesting results of the correlation between driver parameters and decelerations achieved:

- No significant correlation between self estimation of driving experience and any of the deceleration values could be found.
- No significant correlation between self estimation of driving style and any of the deceleration values could be found.
- Everyday drivers significantly showed better brake performance with their own vehicle than weekend drivers. Braking the test vehicle, there was no significant difference between everyday drivers and weekend drivers. Therefore weekend drivers' improvement was higher by 0,45 m/s<sup>2</sup> (T-test for mean equivalence: p=0,035).
- Probationers usually using both brake achieved better results in the deceleration test with their own vehicles and with the ABS-vehicle as well. Obviously "back wheel brakere" were not able to change their habits just by receiving instructions on correct use of ABS.
- No correlation between type of own motorcycle and deceleration parameters could be detected.
- Probationers owning motorcycles with higher engine power achieved better decelerations (p=0,256, k=0,01).

## 5.2 Sample novice drivers

Quite surprisingly, the deceleration the novice drivers achieved with ABS almost equals the experience drivers' deceleration. All of the novices improved their deceleration with ABS. Correlations between any of the deceleration values and any of the driver parameters could not be found.

	without ABS			with ABS			improvement
	1.test	2.test	mean	1.test	2.test	mean	
mean	5,53	5,77	5,65	7,54	7,90	7,72	2,07
standard deviation	1,25	1,15	1,02	1,31	1,20	1,13	1,12
minimum	2,90	3,20	3,85	3,90	5,40	4,65	0,00
maximum	8,20	8,40	8,15	9,90	10,00	9,85	4,95

table 6: decelerations of novice drivers without and with ABS

These results together with the experienced driver results make us suppose that quality of brake handling has to be measured in two different dimensions. On the one hand there are the skills of controlling brake forces having a feeling about driving dynamics and possible decelerations. This seems to be influenced by driving experience. On the other hand there is the ability to trust in technology by suppressing subconscious fears.

## 5.3 Feedback by the probationers

Probationers feedback after the test procedure was not recorded systematically. In the following the impressions of the instructors carrying out the tests mostly gathered during the discussion of the test results are summarised:

- Most of the probationers, particularly the novices, were impressed how easy motorcycles fitted with ABS can be handled during emergency braking.
- Most of the probationers were interested to purchase a motorcycle with ABS if available in their preferred vehicle class and economically affordable.
- Only very few persons denied usefulness of ABS, mostly using emotional arguments.
- Several probationers would like having a motorcycle with ABS, but were afraid that it would not be affordable.
- Several probationers unrequestedly expressed that ABS should be mandatory equipment for all motorcycles.

## 6 Accident statistics

Although the number of licensed motorcycles in Austria constantly rose during the recent 15 years and is now tripled since the late 80s, the number of injured (between 2400 and 3400) and killed (between 75 and 109) motorcycle riders shows no significant trend. At least the recent years show that a lot of the ups and downs which are supposed to be blamed on weather conditions during the year.

In the middle of 1991 a graduated licensing system for motorcycles was introduced in Austria and in 1997 replaced by the EU-model. Growing numbers of injuries and deaths in the age classes 35 to 55 were equalised by a huge reduction of loss in the novice driver segment.

Spornier and Kramlich (2000) by in-depth investigating 610 accidents showed that in 65% of all accidents between motorcycles and cars, the motorcycle driver was able to brake before the collision. In 19% of these cases the motorcycle driver fell off before the collision.

83% of the single vehicle accidents investigated in this study occurred in corners, 40% of them with the motorcycle driver falling off before leaving the road or hitting an obstacle. On straight roads it was 50% of the drivers falling off before crashing into an obstacle or sliding off the road. The authors supposed that in most of the cases, a brake manoeuvre with blocking one or both wheels was responsible for falling off. They concluded that 93% of the single vehicle crashes could be positively influenced or even avoided with ABS.

On an average, they concluded that about 55% of the motorcycle accidents could be avoided or at least positively influenced by ABS.

The shares of accident types found in this study were recalculated for Austria and found comparable.

## 7 Summary and Conclusions

- Experienced motorcycle drivers on an average achieved a braking deceleration of about 6,6 m/s<sup>2</sup>, novices after 6 hours of training 5,7 m/s<sup>2</sup>.
- After an introduction in brake handling and some minutes of exercising experienced drivers improved their braking deceleration to 7,8 m/s<sup>2</sup>, novices to 7,7 m/s<sup>2</sup> driving a motorcycle equipped with ABS.
- Decelerations achieved by experienced drivers are strongly depending on their experience, particularly on the annual mileage.
- Drivers usually driving a motorcycle fitted with ABS are able to improve their brake performance immediately after receiving instructions on correct ABS brake handling.
- Correct use of ABS needs instructions.
- The average experienced motorcycle driver and novice drivers as well do not achieve braking deceleration suitable for road traffic. But if they use a motorcycle fitted with ABS after having received adequate instruction, they do.
- Theoretical and practical instruction on correct emergency brake handling is urgently recommended to be part of the basic driver training. During the basic driver training the candidates should also be made familiar with correct handling of ABS. This shall also help to encourage motorcycle driver to purchase motorcycles fitted with ABS and serve to reduce prejudices against ABS.
- ABS should be mandatory equipment for every powered two-wheeler.

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