U.S. Department
of Transportation
**National Highway
Traffic Safety
Administration**

NHTSA
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DOT HS 808 399

February 1994

Final Report

The Effects of Motorcycle Helmets Upon Seeing and Hearing

This document is available to the public from the National Technical Information Service, Springfield, Virginia 22161.

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
DOT HS 808 399		

4. Title and Subtitle	5. Report Date
The Effects of Motorcycle Helmets Upon Seeing and Hearing	February 1994
	6. Performing Organization Code
7. Author(s) A. James McKnight and A. Scott McKnight	8. Performing Organization Report No.
9. Performing Organization Name and Address National Public Services Research Institute 8201 Coporate Drive Suite 220 Landover, MD 20745	10. Work Unit No. (TRAIS) 11. Contract or Grant No. DTNH22-92-P-05282\05258
12. Sponsoring Agency Name and Address National Highway Traffic Safety Administration NTS-23 400 Seventh Street SW Washington DC 20590	13. Type of Report and Period Covered Final Report April 92/December 93 14. Sponsoring Agency Code

15. Supplementary Notes

Diane Wigle served as Contracting Officer's Technical Representative

16. Abstract

This study assessed the effects of motorcycle helmets upon seeing and hearing by having 50 riders operate over a test route, changing lanes in response to an audible signal under three helmet conditions: none, partial coverage, and full coverage. Half of the subjects were assessed for the degree of head rotation during lane changes, while the other half were assessed for hearing threshold (decibel level at which they first responded to the signal). Results showed that subjects in the vison study increased the degree of head rotation in proportion to the vision restrictions imposed by the helmet, though not to the full extent of the restriction. Subjects in the hearing study evidenced no differences in hearing thresholds across the three helmet conditions. The authors conclude that the effects of helmets upon the ability to see and hear are, at most, far too small to compromise the safety benefits offered by head protection.

17. Key Words	18. Distribution Statement
Motorcycle helmet Auditory Threshold Visual Search Motorcycle Safety	Available from the National Technical Information Service Springfield, VA 22161

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	16	

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

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Introduction

Motorcycle crash statistics indicate that helmets are about 29 percent effective in preventing crash fatalities. That is, on average, riders wearing a helmet have a 29 percent better chance of surviving a crash than riders without a helmet.

However, opponents of mandatory state motorcycle helmet laws have suggested that, although effective in reducing injuries, helmets may increase a rider's risk of crashing due to their effect on the motorcyclist's ability to see and hear surrounding traffic.

This study addressed the question of increased crash risk by measuring the effect of wearing a helmet on motorcycle riders' abilities to (1) detect traffic sounds when operating at normal highway speeds, and (2) detect the presence of vehicles in adjacent lanes before initiating lane changes.

Methods

Fifty motorcyclists, of varying age and riding experience, were recruited to serve as test subjects for the study. Subjects rode their own motorcycles along a prescribed test route. To assess the effect of helmets on vision, subjects were instructed to perform periodic lane changes in response to an audible signal from a following vehicle. Riders were to turn their head to check traffic in the adjacent lane, then make the lane change in their normal manner. The route was driven three times, once with full coverage helmet, once with partial coverage helmet, and again with no helmet. In each case, the degree of head rotation required to check traffic was measured through onboard instrumentation.

To measure the effect of helmets on riders' ability to hear surrounding traffic, the volume of the sound signal used to prompt a lane change was systematically varied. The minimum sound level which the rider was able to hear was recorded for each of the helmet types and without a helmet. Twenty five riders were tested for vision effect and the other 25 for hearing effect. To prevent bias, subjects in the hearing experiment were told that their head rotation was being measured, while those in the vision study were told that their hearing was being measured.

To account for possible differences in riders' vision or hearing ability and any variation between motorcycles, a within-subject research design was used. This design focuses on the effect of the various test conditions on individual subjects, rather than comparing subjects with one another.

Results

The study indicates that helmets do not restrict the motorcyclist's ability to hear and insignificantly restrict lateral vision in surrounding traffic. In the hearing tests, no significant difference was found in rider's ability to hear traffic, either between helmet types or between helmet and no helmet. Hearing ability was significantly affected by vehicle speed due to increased wind noise. However, for any given speed, helmets did not diminish nor enhance hearing.

The vision tests showed that the minimal amount of the lateral vision (field of view) that is sacrificed by wearing a helmet can be made up by turning the head a little further. Nineteen of the 23 riders who were given the vision tests compensated for helmet use by turning their head a little further before changing lanes. Four riders did not compensate. For those that compensated by turning further, the time required for checking did not increase significantly. In other words, for most riders, helmet use did not result in a significant loss in the ability to see traffic or in the time required check for traffic. Overall, any negative effect of helmets on rider vision appears to be very minor, especially in comparison to the protection offered by helmets should an crash occur.

Introduction

The possible effect of motorcycle helmets upon seeing and hearing has been raised as an argument against helmet use. Some claim that the wearing of helmets blocks auditory signals of overtaking cars, police, or ambulances. Others claim that helmets restrict the field of view, making it less likely that riders will detect the presence of adjacent vehicles when changing lanes. Both sets of opponents argue that wearing a helmet, although reducing accident severity, could actually increase the likelihood of *being in* an accident.

Motorcycle crash statistics establish conclusive evidence that, regardless of any possible effects upon seeing or hearing, helmets reduce the likelihood of fatality and serious injury (Evans & Frick, 1988; Wilson, 1989). The reduction in fatalities resulting from helmet use is estimated to be approximately 29%. It is largely on the basis of such evidence that many States have enacted mandatory helmet legislation.

Research into the effects of helmets upon the two processes, seeing and hearing, has been carried out by different sets of investigators using entirely different methodologies. The two are therefore best discussed separately.

Research on Helmets and Hearing

Of the two potential effects of helmet use, effects upon hearing have been the more extensively studied. Henderson (1975), in a theoretical paper, pointed out that the motorcycle engine and air turbulence produce a "masking" noise and that any auditory signal, to be heard, would have to be louder than the level of the masking noise. He noted that, a helmet should not increase the threshold of perception to a level above the masking noise, and that any signal loud enough to be heard without a helmet should also be heard with a helmet. The helmet should not change the ratio of the signal to masking noise. It should reduce both noises equally.

Harrison (1973), measured sound pressure in the ear of riders and found that at high speeds a helmet was useful in reducing masking noise. The motorcycle used was much louder than the average street motorcycle, accounting for the rather high speed (45 mph) needed for beneficial masking qualities to be realized. Van Moorhem, Shepherd, Magleby and Torian (1977), using microphones placed in the ears of subjects wearing a helmet, measured the noise generated while either operating a motorcycle or riding in a convertible car. From their measurements, they concluded that a rider is never at a disadvantage while wearing a helmet, and at increased speeds wearing a helmet may be advantageous in the detection of a warning signal.

Aldman, Gustaffson, Nygren and Wersall (1983) conducted a similar experiment in which they measured sound pressure in the ear of helmeted and non-helmeted riders. From their measurements, they concluded that signal detection should not be hampered by the wearing of helmets. They also concluded that helmets may provide protection from hearing damage that may be caused by noise. Satsangi (1979) measured the amount of noise created by different helmets and face shields in a wind tunnel and on the road on moving motorcycles. While the focus of this study was on between-helmet differences, measurements were also taken without a helmet and wind noise was found to be greater without helmets.

None of the investigators just cited actually measured perception of sound; they concluded that perception was possible given the physical characteristics of the signal and the masking noise. In an experiment that did actually measure the perception of signals, Purswell and Dorris (1977) had subjects attempt to detect and localize two types of signals, either a car horn or a siren. Each of the six subjects performed the activity three times, once wearing no helmet, once wearing a helmet with a full face shield, and once wearing a helmet without a face shield. This study took place both in the laboratory and outdoors. In both cases they found that wearing a helmet had a detrimental impact on signal detection.

The generality of the Purswell and Dorris findings is limited by the fact that the masking signal, the noise of a motorcycle engine while the vehicle is standing still, does not include the effects of air turbulence. Van Moorhem et al. (1977) and Aldman et al. (1983) concluded that air turbulence accounted for over half of the noise heard by a rider when riding at moderate or faster speeds and that helmets help block some of that turbulence.

One additional study involved helmets and hearing but did not compare helmet and no-helmet conditions, nor did it study the ability to hear sounds of interest in the presence of masking noise. Saunders (1991) studied differences between the amounts of wind noise allowed to reach riders' ears while wearing different types and brands of helmets. These studies were conducted on a moving motorcycle at two speeds. The motorcycle was coasting, so engine noise was not a factor.

In summary, none of the experiments reviewed compared audition with and without helmets under conditions representative of those prevailing in actual motorcycle operation.

Research on Helmets and Vision

Gordon and Prince (1975) investigated the effects of helmets on field of view. Subjects either wore one of two types of helmets (three-quarter coverage or full) or did not wear a helmet. A stimulus was moved along a track toward the center of the subject's vision from one of ten possible directions, spaced about 10° apart. The point at which the stimulus could be perceived by the subjects was recorded. Measurements were made for both the horizontal and the vertical field of view. The subjects rested their chins on a fixed pad to restrict head movements. This study found that subjects wearing a typical three-quarter coverage helmet lost about 3% (6.5°) of the horizontal plane. Subjects wearing the two most restrictive full coverage helmets lost 7.3% (16.9°) and 21.9% (51.7°) of the lateral plane. These "worst case" helmets were approximately equivalent to the restrictions imposed by goggles. The impairment of vision was determined to be too small to be considered a risk.

Hurt (1979), in reviewing motorcycle accidents, concluded that most of the hazards that a motorcyclist must avoid come from the front. McKnight, McPherson, and Knipper (1980) analyzed

Hurt's data for the behavioral contributions to each accident. They concluded that 11% of the accidents (98 out of 899) were related to the rider's field of view. Of that 11%, about half involved a failure of the rider to check to the right and left before crossing an intersection, and half were found to have involved errors of not keeping an eye on adjacent vehicles or parked cars. It is impossible to tell from the data whether any of these 98 accidents involved impairment caused by helmets.

There is no question as to the restriction in peripheral vision imposed by the structure of motorcycle helmets so long as the head remains stationary. However, the head is capable of rotating. The effect of helmets upon visual search at intersections is minimal since riders generally turn their heads far enough to place any vehicles or pedestrians approaching from either direction in the center of their visual field. When changing lanes, however, the effort involved in rotating the head to its limit, coupled with the need to divert attention from the path ahead as little as possible, results in turning the head only as much as is needed to check for traffic to the rear. Here, the visual restriction of a motorcycle helmet could spell the difference between seeing and not seeing an adjacent or overtaking vehicle.

Research Objective

The objective of this study was to assess the effect of wearing a helmet upon the ability of motorcycle operators to (1) detect sounds when operating at normal highway speeds, and (2) to detect the presence of vehicles in adjacent lanes prior to initiating lane changes.

Methodology

To assess the effects of helmets upon vision and hearing, samples of riders drove their own motorcycles along a test route, carrying out periodic lane changes in response to an audible signal from a following vehicle. The route was driven three times, once under each of three helmet conditions: full coverage, partial coverage, and no helmet. In the study of hearing, the volume level of the sound signal was systematically varied to permit hearing thresholds to be identified under each of the three helmet conditions. In the study of vision, the degree of helmet rotation was measured through on-board instrumentation. To prevent bias, subjects in the hearing experiment were told that their head rotation was being measured, while those in the vision study were told that their hearing was being measured. The use of a within-subject design prevented any variation due to characteristics of subjects or the motorcycles they were operating from affecting the comparisons across helmets.

Experimental Variables

The independent variable in both studies was *helmet condition*, characterized by three values as follows: *None* — No helmet, *Partial* — Three-quarter coverage helmet (HJC Model FG-3S), and *Full* — Full face coverage helmet (HJC Model FG-6). In the vision study, it was necessary to use a bicycle helmet for the no-helmet condition. This helmet introduced no restriction to peripheral vision and provided a surface upon which to place markings to measure the degree of subject head rotation. Since subjects in the vision study were told that their hearing was being measured, the bicycle helmet was explained as being a way to provide protection while not affecting hearing. The dependent variable in the study of *hearing* was the decibel level at which a sound signal was sensed by riders, as indicated by their initiation of a pre-arranged lane change response. The dependent variable in the study of *vision* was the degree of head rotation to either side prior to initiating the lane change.

Speed was controlled as a study parameter. Each trial under each helmet condition was conducted at 30 mph over one half of the route, and 50 mph over the other half, the order of speeds being counterbalanced. Subjects furnished their own motorcycles in order to keep any practice effect from being confounded with helmet condition.

Subjects

A total of 50 subjects took part in the experiment — 25 in the hearing study, and 25 in the vision study. Mechanical problems resulted in loss of data from two of the vision subjects and one of the eharing subjcets, reducing the sample sizes to 23 and 24 respectively. Age and years of riding experience are shown in Table 1.

Table 1
Age and Experience of Subjects

	Age			Experience		
	Min	Max	Mean	Min	Max	Mean
Study						
Hearing	21	52	28	2	32	8
Vision	21	52	28	2	32	7

All subjects had valid drivers licenses and were therefore assumed to have 20/40 corrected visual acuity or better. The nature of both studies was described to all potential subjects during the recruitment phase. Any potential subject who expressed having any visual or hearing difficulties was not allowed to participate in the study. Screening subjects for visual or hearing abilities was not considered to be a high priority since the within-subject design of the study would prevent these abilities from confounding effects of helmet conditions. Also, it was thought to be more important to use a sample representative of actual riders than one limited to riders whose visual and auditory abilities exceeded some standard. Riders were permitted to wear eye glasses since they are frequently worn by riders and do not interfere with the *detection* of peripheral stimuli. To qualify as subjects, riders had to be experienced operating both with and without a helmet. Since the study was conducted in a non-helmet law State surrounded by States with mandatory helmet legislation, this condition was not difficult to meet.

General Procedure

When subjects arrived for testing, they completed a pre-test questionnaire and received instructions on how the study was to be conducted. Each subject then operated three times over a prescribed test route 5.5 miles in length. The route consisted of a four-lane divided highway posted at 50 mph. Each trial involved a round trip, i.e., out and back. Subjects were instructed to maintain one of two speeds, either 30 mph, or 50 mph on the first half of the route, and the other speed on the second half. One trial was carried out under each of the three helmet conditions. The order of helmet conditions was counterbalanced, so that across all subjects, each half of the route was travelled an equal number of times at each speed for each helmet condition. Those participating in the hearing study were told that their degree of head rotation would be measured, while those in the vision study were told that their ability to hear would be measured.

In the vision study, subjects were told that when they heard a sound signal, which was demonstrated to them, they were to indicate that they heard the signal by initiating a lane change. Subjects were reminded that since testing was taking place in traffic, it was important to check over their shoulder for the presence of other vehicles prior to changing lanes.

In the hearing study, subjects were told that when they heard the signal, they should turn their heads slowly until they could just see the administrator's vehicle in their peripheral vision. The level of the signal was increased until subjects were observed to turn their heads. Subjects were instructed to change lanes after each trial so that another trial could be performed from the opposite side. Test administrators followed behind the motorcycle in an automobile and activated the sound signal. One administrator operated the test vehicle while the other monitored traffic to the rear and activated the signals, which were never given if a vehicle was observed to be overtaking in an adjacent lane. Subjects were not told this since it might have altered their visual search behavior.

After completing the test route for the final time, subjects were given a short post-test questionnaire which asked for their opinion of the relative difficulty of seeing and hearing hazards under different helmet conditions and for their opinion of mandatory helmet use laws. The purpose of these questions was to assess relationships between beliefs about helmets and dependent variables under study.

Recording Hearing Data

The dependent variable under investigation in the hearing study was the volume level at which subjects first indicated having heard the sound signal, as manifest in their initiation of a lane change. It was not possible to measure the actual sound energy at the motorcycle since any sensing device would experience the same masking effects of engine noise and air turbulence as would the subject. Rather, it was necessary to (1) measure the decibel level of the sound signal at various distances from its source, and (2) estimate the distance over which sound had to travel on each trial.

Signal strength at various distances from the source were measured under static conditions. The distances ranged from 67 to 183 feet. The reason for a range of distances was the need to be further from subjects who were travelling slowly and could hear fairly well, and closer to subjects who were traveling faster and had difficulty hearing, in order to find the threshold for detection of the signal. Experimentation revealed that three distinguishable increases in decibel level approximately 5 db apart would encompass hearing thresholds over the headway range at each speed. Within this range further variation was achieved by varying the distance between the sound source and the subject. For each of the three settings, signal strength was measured with a decibel meter at 10 ft. intervals over the range indicated. The decibel meter was set to measure with a fast response time using the "A" weighting scale. From the results, the decibel level at any distance from the sound source was equal to the expression:

$$db_h = 1.07 db_s + (1473/D^2) - 19.8 \quad (1)$$

where db_h = decibel level of the sound signal at the helmet, db_s = decibel level of sound signal at the source, and D = distance over which sound travels on a particular trial.

In measuring distance, radar or laser distance measuring equipment was unsuitable. The small target represented by the motorcycle prevented use of an external fixed mounted unit while distortion introduced by a curved windshield prevented aiming the equipment from inside the vehicle. However, a video camera mounted atop the vehicle permitted headway to be measured to within 1/30th of a second by counting the number of frames between the point at which the motorcycle and automobile passed any landmark and knowing the speed of the coupled vehicles at that instant. In keeping with the announced purpose of the activity, subjects were told that the function of the video camera was to record their head rotation.

The distance over which sound travelled on a trial (d) equaled the headway (distance between vehicles) plus the distance the motorcycle traveled between activation of the signal and the sound reaching the helmet, as given by the expression

$$d = h + h(s_v / (s_s - s_v)) \quad (2)$$

where: h = headway, s_s = speed of sound at sea level (1,088 fps), and s_v = speed of the coupled vehicles.

The sound signal was generated by a siren driver designed for use in home alarm systems. The driver generated a steady 700 cps tone.

As the signal was activated, the intensity setting (db_s) and the speeds of the coupled vehicles (s_v) were recorded on the video soundtrack. To facilitate data reduction, frame numbers were superimposed upon the video. In analyzing data, it was only necessary to enter from the video record the helmet condition, the vehicle speed, and the frame numbers at which each vehicle passed a selected landmark; the estimated db level for each trial was calculated according to the above expressions by a prepared program.

Recording Vision Data

Two variables defined the relationship under investigation in the vision study: the vision restriction imposed by the helmet, and the degree of head rotation exhibited during lane changes. Vision restrictions imposed by each of the two helmets were measured by determining, with the aid of a specially constructed perimeter, the visual angle at which a stimulus introduced into the periphery was first detected. Each of eight subjects completed two trials on the right and left side under each of the three helmet conditions. They were permitted to move their eyes as they would prior to a lane change. Compared with the no helmet condition, the partial coverage helmet reduced peripheral vision by an average of 25° (± 5.3°) while the full coverage helmet reduced peripheral vision by an average of 18° (±5.5°).

The means by which head rotation was measured during lane changes could not be allowed to interfere in any way with the search behavior itself, eliminating the use of mechanical contrivances affixed to the helmet. Instead, head rotation was measured by means of a small VHS-C camcorder, mounted in a box secured to the seat behind the operator, that recorded a close-up of the back of the subject's head. The top and front of the box were covered with a sheet of mirrored plastic film that made it nearly impossible for the subject to see into the box. The equipment was explained as "sound recording equipment" to measure the decibel level of the sound signal as a means of assessing ability to hear.

To allow the degree of head rotation to be measured, the base of the helmet was graduated with a series of hash marks at 5° intervals. "Unhelmeted" riders wore a small bicycle helmet which imposed no visual restrictions but could be graduated with the same markings as the helmets. A challenge to use of video was finding a way to accommodate changes in perspective that accompanied tilting of the head fore and aft or side to side. However, experimentation revealed that, while displacement of the head altered the position of markings in the video image, the midpoint of all visible markings at any one time corresponded to the rotational angle of the helmet regardless of helmet position. A series of trials in which raters recorded degrees of head turn from a videotape for which the degree of turn was known, showed that it was possible to measure orientation of the helmet to within ± 2.5° in all cases. Time to complete a visual check was obtained by counting the number of frames from the start of head rotation in the direction of lane change to the end of head rotation in the return direction.

Results

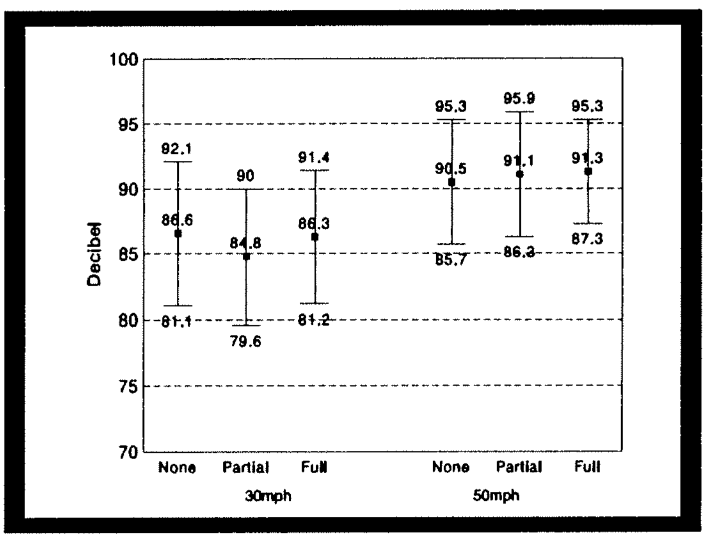
Results of the hearing and vision studies will be reported separately.

Results of Hearing Study

The sample of 25 riders yielded a total of 954 responses to sound signals, for an average of 6.4 responses for each rider under each combination of helmet condition and speed. Slight variation from this average occurred from one rider to another, and from one condition to another within riders, as a result of traffic conditions limiting opportunities for lane changes.

The effect of helmets upon hearing was revealed by the differences in the mean decibel level at which the tones generated were first detected under each of the three helmet conditions: *None* (no helmet), *Partial*, and *Full*. The results are shown in Figure 1.

Figure 1
Mean (±σ) Sound Threshold in Decibels
by Speed and Helmet Condition



Tests of statistical significance appear in Table 2.

Table 2
Analysis of Variance
Tests of Significance for Hearing Threshold Using Unique Sums of Squares

Source	Sum of Squares	Degrees of Freedom	Mean Square	Error Term	F	P
Helmet (H)	160.7	2	80.33	HxR	2.04	.14
Speed (S)	308.5	1	308.52	SxR	6.13	.021
Riders (R)	5561.2	23	241.79			
Helmet by Speed	12.7	2	6.36	HxSxR	.16	.851
Helmet by Rider	1769.1	46	38.46	HxSxR	.98	.531
Speed by Rider	1157.3	23	50.32	HxSxR	1.28	.235
Helmet by Speed by Rider	1810.7	46	39.36	W	2.92	<.001
Within (W)	10925.7	811	13.47	---	---	---

The differences in hearing threshold across helmet conditions turned out to be very small; an analysis of variance showed them falling well short of statistical significance ($F_{2,46}$=2.04, p=.14). The interaction of riders by helmet and speeds were also significant ($F_{46,811}$=2.92, p<.001), meaning that the effects of speed, helmet, and combinations of speed and helmet varied from one rider to another.

The with-subjects analysis employed in assessing helmet effects does not permit an a test of significance for differences among riders. However, a one-way Analysis of Variance showed significant inter-rider difference ($F_{23,931}$=14.91, p<.001). Rider variance accounted for 27% of total variance. The differences among riders were relatively small in absolute magnitude, yielding a standard deviation of only 5 db across all riders. The lack of greater inter-subject variability is surprising in view of the large variation in characteristics of motorcycles likely to affect detection of external sounds, such as engine noise and presence or absence of a fairing.

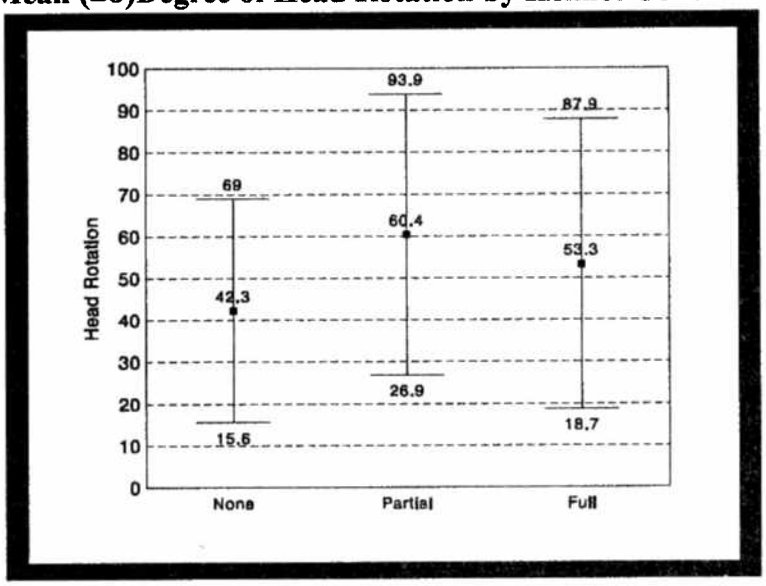
That the criterion measure was truly sensitive to sound thresholds was evident in the significant difference between mean decibel levels at the two operating speeds, 30 mph and 50 mph ($F_{1,23}$=6.132, p=.021). This difference averaged approximately 5 db and was essentially constant across all decibel levels.

The single largest source of variation simply was random error, as reflected in variation from one trial to another within the same rider, condition, and speed. This source accounted for 51% of total variation. Contributing to these differences could be unsystematic varation in air turbulence, pavement conditions, and other factors that might affect the audibility of tone signals. Doubtless some portion of this error can also be attributed to errors in estimating decibel level from source level, distance, and speed.

Results of Vision Study

The 23 riders furnishing complete data yielded a total of 944 responses. Of primary interest in the vision study are the results involving the degree of head rotation associated with each level of visual restriction. To obtain this number, the mean degree of head rotation for each condition was obtained separately for each rider, and then averaged across riders. The results are shown in Figure 2.

Figure 2
Mean (±σ)Degree of Head Rotation by Helmet Condition



Analysis of variance in degree of head rotation appears in Table 3.

Table 3
Analysis of Variance
Tests of Significance for Degree of Head Rotation Using Unique Sums of Squares

Source	Sum of Squares	Degrees of Freedom	Mean Square	Error Term	F	P
Helmet (H)	41632.20	2	20816.10	HxR	22.53	<.001
Rider (R)	660713.53	22	30032.43			
Helmet by Rider	40656.01	44	924.00	W	3.83	
Within (W)	211942.99	879	241.12		—	—

The differences among helmet conditions are highly significant ($F_{2,44}$=22.53, p<.001). A relationship can be found between the mean degree of head rotation and the vision restriction imposed by the helmet. The *partial* coverage helmet with a 25° restriction in visual angle yielded (60.4 - 42.3 =) 18.1° more mean head rotation than to the no-helmet condition. The *full* coverage helmet, with a 18° vision restriction yielded (53.3 - 42.3 =) 11° more head rotation than the no-helmet condition. With both helmets, the degree of head rotation fell short of fully compensating for the vision restriction.

Underlying the overall mean differences between helmet conditions were marked differences across individual riders, as evidenced by a significant interaction between degree of visual restriction and rider ($F_{41,879}$=4.11, p<.001). However, the differences largely involved magnitude rather than nature of effect; for 19 of the 23 riders, wearing helmets resulted in a greater head rotation than riding without a helmet. For the remaining four riders, either or both of the helmeted conditions failed to produce more head rotation than the unhelmeted condition.

Riders differed widely in their characteristic degree of head rotation within any helmet condition, with standard deviations ranging from ±26.7° for the *none* condition to ±34.6° for the *full* condition. A one-way analysis of variance revealed highly significant Rider variance ($F_{22,922}$=98.94, p<.001). Rider variance accounted for 73.4% of total variance in head rotation, while helmet vision restrictions accounted for only 4.4%, a difference of more than 15 to 1.

It is noteworthy that the correlation between the extent of head rotation and the time to complete the visual check was small and non-significant (r=.2, p>.05). Differences in time-to-complete across the three helmet conditions were not significant (F=.04, p=.96). These results mean that the additional head rotation required by the full and partial coverage helmets did not increase the period of time during which the rider's gaze was diverted from the path ahead.

Rider Characteristics

The interrelationship of rider characteristics as well as their relationship to hearing threshold and head rotation, are shown in Table 4.

Table 4
Intercorrelation of Auditory Thresholds,
Head Rotation, and Rider Characteristics

Characteristic	Age	Exp	Use	Hear	See
Auditory Threshold	-.03	-.36*	-.11	-.21	-.03
Head Rotation	-.06*	-.53**	.19	.34	.38*
Riding Experience	.44*				
Helmet Use	-.16	.17			
Restrict Hearing	.36**	-.10	-.39		
Restrict Seeing	.21	-.12	-.44*	.62**	
Fairness of Laws	-.12	.03	.22	-.36**	-.39**

* $p < .05$, ** $p < .01$

Correlations involving threshold and head rotation included only riders participating in the separate studies. Correlations among the remaining factors were based upon results obtained from the total of 48 riders participating in both studies. The largest single correlation was that between the belief that helmets restrict hearing and the belief that they restrict vision (r=.62). Such a correlation was expected. What is perhaps surprising is that the correlation was not any higher. The fact that less than half of the variance was shared (r^2 =.44) means that many of those who thought helmets restricted hearing did not think they restricted vision, and vice versa.

That riding experience correlated negatively with hearing threshold (r=-.36) may reflect the fact that the more experienced riders tended to operate the quieter machines and therefore were to hear the signals better. The negative correlation of experience with head rotation (r=-.53), meaning that the more experienced riders turned their heads less, is not so easily explained. Nor is the fact that head rotation was greatest among those who thought helmets restrict hearing (r=.34) and seeing (r=.38) and that helmet laws are unfair (r=-.48). While degree of head rotation was correlated with opinion about the fairness of helmet laws and the effects of helmets upon seeing, the measured effects of helmets upon head rotation were unrelated to either opinions, as evidenced by non-significant HELMET X OPINION interaction with head rotation (p>.09). That helmet use tended to be lowest among those who felt that helmets restricted hearing (r=-.39) and seeing (r=.44) is not unexpected. Neither is the fact that support of helmet use laws was negatively correlated with the belief that they restrict hearing (r=-.36) and seeing (r=-.39).

Summary

The results indicate that wearing helmets restricts neither the ability to hear horn signals nor the likelihood of visually detecting a vehicle in an adjacent lane prior to initiating a lane change. With respect to hearing, differences in hearing threshold across helmet conditions are not only non-significant, but almost nonexistent. The significant increase in the hearing threshold with increased vehicle speed indicates that the experimental procedure was capable of detecting true effects upon ability to hear. While helmets did not degrade hearing, neither did they enhance it.

When it comes to vision, riders appear to compensate partially for restrictions in lateral vision by increasing head rotation prior to a lane change. The degree of head rotation fell short of fully compensating for head restrictions and 4 of the 23 riders evidenced no tendency to compensate at all. The increased degree of head turn did not result in increased durations of head turn. However, dwarfing the differences in head rotation attributable to helmet condition were large and consistent differences in the extent of head rotation across helmet conditions. Overall, intersubject differences accounted for almost 15 times the total variance in head rotation as did type of helmet. The extent of head rotation was the greatest among riders both the least experienced, those who thought helmets restrict vision, and those who believed that helmets are a good thing. If the small effect of helmets upon vision have any impact upon safety, that impact is extremely small in comparison to the protection offered by helmets should an accident occur.

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