A Controlled Study on Young Motorcyclist's Cognitive Function

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Abstract

Young motorcyclists are exposed to high noise exposure which can affect their cognitive function. This study was designed to evaluate the cognitive function of undergraduate University students (aged: 19-25) which ride a motorcycle as a primary mode of transportation. Total of 60 motorcyclists participated which were divided into two groups: an experimental group which performed neuropsychological battery test under motorcycle noise (≤90 dBA) and control group under controlled laboratory noise (≤65 dBA). The result showed significantly better cognitive performance ($p < 0.05$) of a control group. The results demonstrated that motorcycle noise significantly decreased the cognitive performance of the experimental group ($p < 0.05$).

Keywords: Motorcycle noise; Motorcyclists; Neuropsychological assessment; Reaction-time

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1. Introduction

Motorcycle drivers are exposed to high noise levels (>90 dBA) (A Ali, Hussain, Abdullah, & Dom, 2018). Besides being exposed to the engine noise, they also experience turbulent airflow (wind noise) around the helmet ranging from 90 to 103 dBA (Jordan, Hetherington, Woodside, & Harvey, 2004) as a function of driving speed. Such high-intensity noise can lead to auditory (hearing deficits), and non-auditory health effects consisting of varying physiological and psychological detrimental impacts (Basner et al., 2013; Liebl & Jahncke, 2017).

A motorcycle is a complex machine which requires mind and body coordination, and holistic emphasis on mind, machine and environment. All these factors play an important part for the safety of the riders. Lack of reflex and physical coordination poses a potential risk of accidents among motorcyclists because motorcycle operation requires motor skills and physical coordination and balance (Mannering & Grodsky, 1995). It is also articulated that it is a hazardous mode of transportation which should be driven safely (Hsu, Tien-Pen & Dao, 2003). Similarly, Mannering and Grodsky (Mannering & Grodsky, 1995) postulated that motorcycle operation requires counterintuitive skills like counter steering, along with different mechanical applications of the front and rear brakes and opening the throttle on turns. Any negligence or fault from motorcycle riders poses a greater risk magnitude for accidents than car drivers.

Motorcycling requires alertness, attentiveness and mental performance to carry out the task at the right moment. There is a need to accurately assess the cognitive parameters associated with driving safety (León-Domíngueza, Barrio-Álvarezc, Martínd, & León-Carrióne, 2016). Mental performance is a composite of alertness, learning, task management and reaction-time (Alimohammadi, Soltani, Sandrock, Azkhosh, & Gohari, 2013). It has been reported that high-noise exposures impair mental performance (Jahncke, Hygge, Halin, Marie, & Dimberg, 2011; Trimmel, Atzlsdorfer, Tupy, & Trimmel, 2012). However, some studies indicated that noise has no effect, and in some cases, it improves the mental performance (Mehri, Alimohammadi, Ebrahimi, Hajizadeh, & Roudbari, 2018). In general, it has been reported that high noise exposures impair cognitive functioning because it increases the overall workload associated with a particular stimulus and it does potentially affect the visual performance (Parsons, 2000). Also, auditory distraction impairs working memory and comprehension of written materials (Trimmel et al., 2012). In contrast, it was indicated by (Helton, Matthews, & Warm, 2009) that vigilant performance tends to be better under noise conditions and it also increases self-reported task-engagement. A recent study reported that young motorcyclist's (19-25 years) demonstrated increased physiological stress reaction due to motorcycling both in field and controlled experimental studies (Anila Ali, Dom, Hussain, & Abdullah, 2017)(Anila Ali, Hussain, Abdullah, & Dom, 2018) and weak audiometry profile (Anila Ali, Dom, Hussain, Karuppannan, & Abdullah, 2018). Previously, studies relating to physiological and psychological profile of young motorcyclists are scarce, while no studies have quantified any relation between motorcycling noise and cognitive function. Therefore, the effects of high-intensity motorcycle noise on driver's cognitive assessments remain to be studied.

Loewenstein Occupational Therapy Cognitive Test (LOTCA) (Katz, Elazar, & Itzkovich,

1995) battery was developed as a measure of basic cognitive skills and visual perception which provides an in-depth assessment of basic cognitive abilities and skills required for everyday function including orientation, visual perceptual and psychomotor abilities, problem-solving skills and thinking operations. It Includes standardized developmental data on the performance of normal children ages 6 to 12, and adults ages 20 to 70. The LOTCA permits use of domain-specific scores rather than just a global score, allowing for assessment of many aspects of the client's cognitive and perceptual abilities. The internal consistency was reported with alpha coefficients of 0.85, 0.87 and 0.95 for in the areas of Thinking Operations, Perception and Visuomotor Organization (respectively) and also reported excellent inter-rater reliability for subtests of the LOTCA, with Spearman's rank correlation coefficients ranging from 0.82 to 0.97 (Katz et al., 1995). Test administration requires minimal verbal interaction. It is most widely used instruments for assessing the cognitive functioning (Katz et al., 1995). It provides a profile of the respondent's cognitive status to establish a baseline for monitoring and planning (Alghadir, Gabr, & Al-eisa, 2016). This instrument assesses the underlying cognitive skills required for everyday functioning such as orientation, visual perception, psychomotor skills, problem-solving skills and thinking operation. It has been used as a tool for assessing the cognitive functioning of healthy individuals (Alghadir et al., 2016) addicts (Rojo-mota et al., 2017), etc. Some research projects have proved the satisfactory psychometric properties across a diversified population and geographic areas (Rojo-mota et al., 2017).

The purpose of this study was to understand the impact of high noise exposure on the cognitive functioning of young motorcyclists. Motorcycle rider's psychological health profiling is scarce while cognitive assessment of young motorcyclists under motorcycle exposure has not been investigated previously. Therefore, this study is aimed to determine the effects of noise-induced cognitive functioning and its associated reaction-time among young motorcyclists. Also, to analysis the known-group validity of LOTCA when administered with and without noise exposure.

2.0 Methodology

2.1 Study participants

This experimental study was conducted at Universiti Teknologi MARA Selangor, Puncak Alam campus, Malaysia. Participants were undergraduate students, aged between 19 - 25 years, who had been riding the motorcycle as their primary means of transportation for a minimum of one year. A simple random technique was adopted for sampling across the different faculties, that were represented from all over Malaysia (Masuri, Dahlan, Danis, & Isa, 2017). Inclusion criteria set for samples was (i) aged between 19 to 25 years old (Norfazila, Mustaffa, & Ghazali, 2017); (ii) nonsmoker; (iii) absence of any chronic diseases and CGPA (Cumulative Grade Point Average) above 2.5. A set of structured questionnaires which consisted of study information sheet and respondent's demographic survey were distributed among 301 motorcyclists, while total participants recruited in the experimental phase were 60 (43 male and 17 female) based on inclusion and exclusion criteria. All participants endorsed the written consent form of participation before the commencement of the experiment. Experimental procedure and design was approved by Faculty's (Health Sciences) Internal Ethical Committee (600-FSK (PT.5/2)), Universiti Teknologi Mara, Malaysia.

2.2 Instruments

2.2.1 Demographic Information

Participants demographic data were obtained through a self-reported questionnaire. The information consisted of data related to age, gender, years of motorcycling experience (as a primary mode of transportation), faculty, the semester of enrolment, CGPA of proceeding semester, motorcycle license, usage of the helmet, smoking habit and presence of any chronic diseases (diabetes mellites, hypertension, asthma).

2.2.2 Sound Level Meter (SLM)

Laboratory sound level during test administration was measured using the SoundPro SE and DL sound level meter (SLM) of class/type 1 (serial no BEI040002) from Quest Technologies Oconomowoc, WI, USA. Type 1 sound level was used to measure the ambient noise as the experimental group was exposed to artificially induced noise of the motorcycle. Sound levels were measured before and during the test administration.

2.2.3 LOTCA

LOTCA (Lowenstein Occupational Therapy Cognitive Assessment) neuropsychological battery test, Second Edition (Katz et al., 1995) was used for assessing cognitive performance of the motorcycle riders. LOTCA mainly consists of six domains, which are further divided into 26 subtests, and scored on a four- or five-point Likert scale. Domains categorization and scoring range are defined as Orientation subtest consist of two items, i.e., orientation for place and time, scores ranged from 2 to 16 on the eight-point Likert scale. Visual perception subtest includes four items, i.e., visual perception for object and shape identification, figure and ground perception, and object constancy. Subset total scores can range from 4 to 16. Spatial perception subtest consists of three items: directions on respondent's body, spatial relations, and spatial relations on pictures. Subset total score can range from 3 to 12. Motor proxis subtest consists of three items, i.e., motor imitations, utilization of objects, and symbolic actions. Subset total scores can range from 3 to 12. Visual organization subtest examines perceptual-motor integration with spatial components which includes seven items, i.e., copying geometric forms, reproduction of two- and three-dimensional models, pegboard construction, coloured and plain block design, reproduction of a puzzle, and drawing of a clock. Subset total score can range from 7 to 28. Thinking operation subtest consists of seven items. The five-point Likert scale used for three elements: categorization, Riska Object Classification (ROC) unstructured and structured. Sequencing items based on four-point Likert scales consisting of four items: pictorial classification, pictorial sequencing, and geometrical sequencing and logical questions. Subset total score ranged from 7 to 35. Attention and concentration based on overall performance on the LOTCA. Scores range from

1 to 4. Previous studies investigated the interrater reliability coefficients which ranged between 0.82 - 0.97 for all six domains (Katz et al., 1995).

2.2.3.1 LOTCA administration procedure

LOTCA was administered according to test manual provided in the LOTCA kit. The test was started with the Orientation domain and subsequently followed through to the sixth domain. During the test performance, observations were noted by the examiner regarding participant's attention and concentration. The confounding factors like fatigue, tiredness, and restlessness were also taken into considerations. Before scoring each subset, the examiner confirmed with the participant if the task is completed and followed to the next subtest. Duration of the test varied from person to person, but the standard time of completion was from 40 to 45 minutes. LOTCA scoring was based as per instructions from the test manual. The total score is a summation of the scores from all subtests with a maximum score of 123, and a minimum score of 27. A composite score for each domain was calculated by summing the scores of the relevant subtests where higher scores indicate better performance and vice versa. Time each participant took to complete the LOTCA was recorded as a proxy of the participant's information-processing speed.

For laboratory-controlled noise exposure studies, two tables were set up. The right-hand side of examiner's, LOTCA domains subsets organized according to administration sequence on the table while speakers and SLM were placed at the front along with the scoring sheet. Speakers were placed on the right and the left side of the participants. Speakers (Long lorn model SP -MN 019/U, with output RMS 3Wx 2, Signal-to-noise (S/N) ratio 80 dBA) attached to a personal computer for an audio clip of motorcycle noise. Examiner and the examinee were at face to face setting position.

2.3 Experimental Procedure

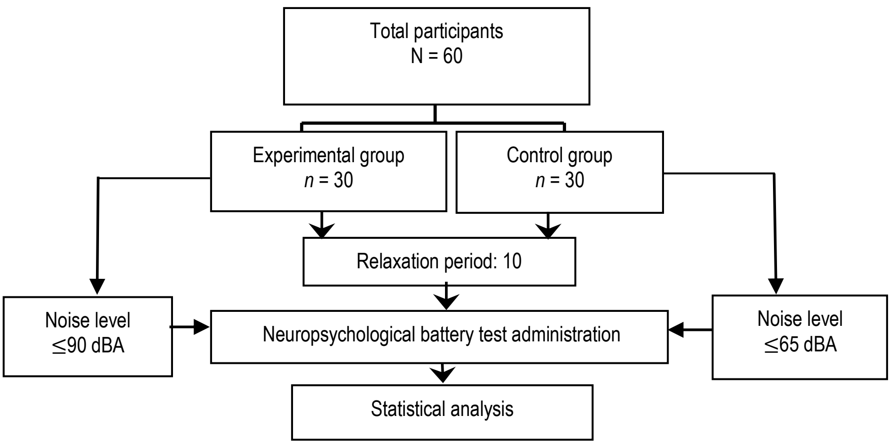

Figure 1: Experimental flow chart of the neuropsychological assessment of young motorcyclists

The experimental study design structured for assessing the cognitive functioning of the undergraduate motorcyclists under controlled laboratory setting. Two groups of respondents were formed: Control Group (CoG) and Experimental Group (ExG) with 30 participants in each group as presented in the flowchart in Figure 1. Upon arrival participants of both the groups were seated in a relaxing environment for 10 minutes and later performed the neuropsychological battery test. CoG LOTCA assessment was conducted during controlled noise exposure (<u><</u>65 dBA) and ExG during high motorcycle noise exposure (85-90 dBA). Testing procedures for both the groups based on the classification of variables as presented in Table 1.

Table 1: Classification of variables

Study groups	**Independent Variables [a]**	**Controlled Variables [b]**	**Dependent Variables [c]**
	Noise exposure	Neurological tests	Performance
Experimental Group	YES	YES	Score's on test
Controlled Group	NO	YES	Score's on test

Note: [a] artificially induced background motorcycle noise up to ≤90 dBA; [b] neuropsychological battery tests (LOTCA; [c] performance on the neuropsychological battery tests (LOTCA), higher the score better the performance

2.4 Statistical Analysis

Participants information data and LOTCA test scoring data were tabulated and logged on excel worksheet for database and computed for statistical analysis through Statistical Package for Social Sciences, IBM SPSS (Version 22 Inc., Chicago, IL). Descriptive data of variables, i.e., age, gender, semester enrolment was obtained through frequency table while the relationship between variables computed through cross-tabulation. Statistical significance was obtained by Independent sample t-test to determine the difference between experimental and control group's LOTCA performance on all domains and to evaluate the difference in reaction time (seconds) among groups performance on different domains. Bar charts were plotted to demonstrate the differences in the performance among groups across all LOTCA domains and reaction time. An alpha level of 0.05 used for subsequent analysis.

3.0 Results

3.1 Descriptive profile of the participants

Table 2 presents the demographic profile of the participants (n = 60) recruited in the laboratory experiment for exploring the effects of noise-induced cognitive function and reaction time (seconds). Participation was dominated by male riders with 71.7% (n = 43) than female riders (n =17, 28.3%). Participants mean age was 22.02 (SD = 1.17) which ranged from 19 to 25 years. The undergraduate motorcyclists ranged from semester 1 till 8, with the mean of 4.65 (*SD* = 1.54) while the driving experience ranged from 1 to 12 years (*M* = 6.78; *SD* = 2.55). The CGPA of the participants ranged between 2.7 to 4 (*M* = 3.22; *SD* = 0.26).

The Control group consisted of 80% males (*n* = 24) and 20% females (*n* = 6). Participants mean age was 21.87 (*SD* = 1.41) which ranged from 20 to 25 years. Participation of respondents represented from semester 1 to 7, with a mean semester of 4.57(*SD* = 1.56) while driving experience ranged from 1 to 12 years (*M* = 6.67; *SD* = 2.88). The average CGPA of the participants was 3.17 (*SD*= 0.26), ranged from 2.7 to 3.6. Experimental group constituted of 63.3% of males (*n* = 19) and 36.7% of female riders (*n* = 11). Participants mean age was 22.2 (*SD* = 0.87) which ranged between 19 to 24 years. Participation of motorcyclists enrolled from semester 2 till 8 (*M* = 4.7; *SD* = 1.55) while driving age ranged between 2 to 11 years of experience, with a mean driving age of 6.9 (*SD* = 2.25). The average CGPA of the motorcyclist's students was 3.26 (*SD* = 0.26), ranged between 2.7 to 4.

Table 2: Demographic profile of motorcyclists who participated in the field experiment

Variables	**Total** *N* **= 60**	**Control Group** *n* **= 30**	**Experimental group** *n* **= 30**
Gender (M/F)	43 / 17	24 / 6	19 / 11
	***M* + *SD*, range**	***M* + *SD*, range**	***M* + *SD*, range**
Age, (yrs.)	22.02 + 1.17, 19 - 25	21.87 + 1.41, 20 - 25	22.2 + 0.87, 19 - 24
Semester	4.65 + 1.54, 1 - 8	4.56 + 1.56, 1 - 7	4.7 + 1.55, 2 - 8
Driving age	6.78 + 2.55, 1 - 12	6.67 + 2.88, 1 - 12	6.9 + 2.25, 2 – 11
CGPA	3.22 + 0.26, 2.7 - 4	3.17 + 0.26, 2.7 - 3.6	3.26 + 0.26, 2.7 - 4

3.2 Descriptive analysis of LOTCA assessment

Table 3 presents the detailed descriptive and statistical analysis of the ExG and CoG LOTCA assessment across all domains and reaction-time (seconds). The first domain of LOTCA i.e., Orientation was found significantly higher in CoG (*M* = 15.80, *SD* = 0.55) as compared to ExG (*M* = 15.35, *SD* = 0.92), *t* (47.36) = -2.379, *p* = 0.021. Figure 2A shows the difference in Orientation performance between ExG and CoG. The results indicated that motorcycle noise (≤ 90 dBA) lowered performance of the ExG participants on Orientation domain of LOTCA, as compared to CoG participants who performed the test under controlled noise exposure (≤ 65 dBA). Noise exposure (≤ 90 dBA) affected the awareness of self in relation to one's surroundings among ExG participants compared to CoG (≤ 65 dBA), since Orientation requires consistent and reliable integration of attention and memory (Itzkovich, Malka, Elazar, & Averbuch, 2000).

Visual Perception, the second LOTCA domain was found significantly higher in CoG (M = 15.63, *SD* = 0.61) compared to ExG (M = 15.13, *SD* = 0.82), t (58) = -2.673, *p* = 0.010. *Figure 2*(B) shows the difference in Visual Perception domain of LOTCA among ExG and CoG, presenting significantly a better performance by the participants of CoG as compared to ExG. The results revealed that the influence of noise (≤ 90 dBA) on Visual Perception tends to decrease the process of actively searching for information and distinguishing the features to make an appropriate opinion, compared to when performed under low-noise levels (≤ 65 dBA).

The third LOTCA domain i.e., Spatial Perception was also found significantly higher in CoG (M = 12, *SD* = 0) compared to ExG (M = 11.86, *SD* = 0.82), *t* (29) = -2.112, *p* = 0.043. *Figure 2* (C) presents the Spatial Perception assessment difference between ExG and CoG, indicating better performance by the CoG. The results showed the decreased Spatial Perception among the participants performed under high-noise exposures (ExG, ≤ 90 dBA). The results suggested that high noise level effects the Spatial Perception by decreasing its efficiency of distinguishing and comparing with other objects in space.

The LOTCA's fourth domain relates to Motor Praxis which was also found significantly higher in CoG (M = 11.93, *SD* = 0.25) as compared to ExG (M = 11.09, *SD* = 0.91), *t* (33.51) = -5.039, *p* = 0.000. *Figure 2* (D) reflects the higher performance by the CoG than ExG in Motor Praxis. The results indicated the negative influence of noise (≤ 90 dBA) on participants (ExG) Motor Praxis ability and flexibility, while under low noise exposure (≤ 65 dBA) the performance tends to be better (CoG).

The fifth LOTCA domain i.e., Visuomotor Organization was found significantly higher in CoG (M = 27.1, *SD* = 0.80) compared to ExG (M = 24.42, *SD* = 1.83), *t* (39.733) = -7.207, *p* = 0.000. The reaction-time associated with completion of Visuomotor Organization subtest (seconds) was found significantly higher in ExG (M = 443.67 seconds, *SD* = 157.82) as compared to CoG (M = 311 seconds, *SD* = 151.7), *t* (58) = 3.319, *p* = 0.002. *Figure 2* (E) shows the better performance by the CoG compared to the participants of ExG based on average score. *Figure 2* (F) shows the difference in the reaction-time (seconds) between the two groups (CoG and ExG) indicating the higher reaction-time by ExG participants. The results revealed that CoG (≤ 65 dBA) had better performance with perceptual activity combined with motor response and spatial component with speeded reaction-time in completion of Visuomotor Organization.

Thinking Operation, the sixth LOTCA domain was found significantly higher in CoG (M = 29.4, *SD* = 1.63) compared to ExG (M = 27.09, *SD* = 2.30), *t* (58) = - 4.591, *p* = 0.000. The reaction-time (seconds) associated with its completion was found significantly higher in ExG (M = 655.67, *SD* = 239.9) as compared to CoG (M = 444, *SD* = 197.4), *t* (58) = 3.731, *p* = 0.000. The overall results for average scores and reaction-time (seconds) associated with performance of Thinking Operation domain indicated that noise (≤ 90 dBA) was a negative impact and hinders the efficiency of the thinking. *Figure 2* (G) shows the differences in the performance between CoG and ExG the Thinking Operation showing a better score for participants of CoG. *Figure 2* (H) presents the reaction-time (seconds) associated with performance of Thinking Operation domain of two groups, where ExG (≤ 90 dBA) showed affected ability to identify discrete features of objects, for arranging them in hierarchically and classify them onto basic category compared to the participants of CoG (≤ 65 dBA).

In the Attention and Concentration domain of LOTCA, CoG participants also had significantly higher scores (M = 3.9, *SD* = 0.31) compared to ExG (M = 3.47, *SD* = 0.51), *t* (58) = - 4.009, *p* = 0.000. *Figure 2* (I) shows performance scores of the two groups where CoG showed better Attention and Concentration while performing the LOTCA assessment. The results indicated that noise (≤ 90 dBA) had degraded the Attention and Concentration of ExG participants.

The cumulative score of LOTCA domains was found significantly higher in CoG (M = 111.9, *SD* = 2.8) as compared to ExG (M = 104.9, *SD* = 4.3), *t* (49.7) = - 7.355, *p* = 0.000. While the total time (seconds) consumed in completion of LOTCA assessment was found significantly higher in ExG (M = 3176 seconds, *SD* = 353.36) compared to CoG (M = 2192 seconds, *SD* = 419.47), *t* (58) = 9.826, *p* = 0.000. These results suggested that the effect of high-noise exposure (≤ 90 dBA) had affected the performance of the participants (ExG) by scoring lower on each domain along with higher reaction-time (seconds). *Figure 2* (J) and (K) present the average score performances of LOTCA and reaction-time (seconds) of ExG and CoG respectively.

The internal consistency of LOTCA (26 items) for control and experimental group was Cronbach alpha of 0.658 and 0.596 respectively. Overall, the results suggest that the high noise-exposure (≤ 90 dBA) does influence cognitive functioning and reaction-time compared to < 65 dBA. The results revealed that when motorcycle riders are exposed to high noise levels (≤ 90 dBA), their cognitive function and reaction-response to cognitive demanding stimulus tends to decrease.

Thinking Operation, the sixth domain of the LOTCA assessed on its average score which was found significantly higher in CoG (*M* = 29.4, *SD* = 1.63) as compared to ExG (*M* = 27.09 *SD* = 2.30), *t* (58) = - 4.591, *p* = 0.000. The reaction-time associated with its completion was found significantly higher in ExG (*M* = 655.67, *SD* = 239.9) as compared to CoG (*M* = 444, *SD* = 197.4), *t* (58) = 3.731, *p* = 0.000. The overall results for average score and reaction-time associated with the performance of Thinking Operation domain indicate that the noise impacts the negative effects and hinders the efficiency of the thinking. Figure 2G shows the differences in the performance between CoG and ExG on Thinking Operation while indicating a better score of CoG. Figure 2H presents the reaction-time
(seconds) associated with the performance of the Thinking Operation domain between the two groups, where ExG took larger time in completion of the domain as compared to CoG.

The Attention and Concentration based on overall performance were also found significantly higher in CoG (*M* = 3.9, *SD* = 0.31) as compared to ExG (*M* = 3.47, *SD* = 0.51), *t* (58) = - 4.009, *p* = 0.000. Figure 2I presents the difference between the two groups where CoG showed better Attention and Concentration while performing the LOTCA assessment. The results indicate that the effect of noise had degraded the Attention and Concentration of participants during the assessment.

The cumulative score of LOTCA domains was found significantly higher in CoG (*M* = 111.9, *SD* = 2.8) as compared to ExG (*M* = 104.9, *SD* = 4.3), *t* (48) = - 7.355, *p* = 0.000. While the total time (seconds) consumed in completion of LOTCA assessment was found significantly higher in ExG (*M* = 3176, *SD* = 353.36) as compared to CoG (*M* = 2192, *SD* = 419.47), *t* (58) = 9.826, *p* = 0.000. These results suggest that the effect of high-noise exposure had affected the performance of the participants by scoring lower with higher reaction-time. Figure 2J and 2K present the average score performances of LOTCA and reaction time of both the groups respectively.

Overall our results suggest that the high noise-exposure does influence cognitive functioning and its associated reaction-time. The results revealed that when motorcycle riders are exposed to high noise levels, their cognitive functioning and reaction-time response to cognitive demanding stimulus decreases.

Table 3: Descriptive and statistical analysis of the LOTCA assessment

LOTCA Domains	Possible range	Groups	Mean ± SD	Range	Minimum	Maximum	*p*-value
Orientation	2-16	ExG	15.35 ± 0.92	4	12	16	0.021
		CoG	15.80 ± 0.55	2	14	16	
Visual Perception	4-16	ExG	15.13 ± 0.82	2	14	16	0.010
		CoG	15.63 ± 0.61	2	14	16	
Spatial Perception	3-12	ExG	11.87 ± 0.82	1	11	12	0.043
		CoG	12.0 ± 0	0	12	12	
Motor Praxis (Score)	3-12	ExG	11.09 ± 0.91	3	9	12	0.000
		CoG	11.93 ± 0.25	1	11	12	
Visual Organization (Score)	7-28	ExG	24.42 ± 1.8	7	21	28	0.000
		CoG	27.1 ± 0.80	2	26	28	
Visual Organization (Time)	-	ExG	443.7 ± 157.81	750	270	1020	0.002
		CoG	311 ± 151.7	620	160	780	
Thinking Operation (Score)	7-35	ExG	27.09 ± 2.30	10	21	31	0.000
		CoG	29.4 ± 1.6	7	24	31	
Thinking Operation (Time)	-	ExG	655.7 ± 239.9	940	320	1260	0.000
		CoG	444 ± 197.4	760	260	1020	
Attention and Concentration	1-4	ExG	3.47 ± 0.51	1	3	4	0.000
		CoG	3.9 ± 0.31	1	3	4	
LOTCA (Score)	27-123	ExG	104.9 ± 4.3	17	93	110	0.000
		CoG	111.9 ± 2.8	11	100	111	
LOTCA (Time)	-	ExG	3176 ± 353.4	1500	2400	3900	0.000
		CoG	2193 ± 419.7	1380	1500	2880	

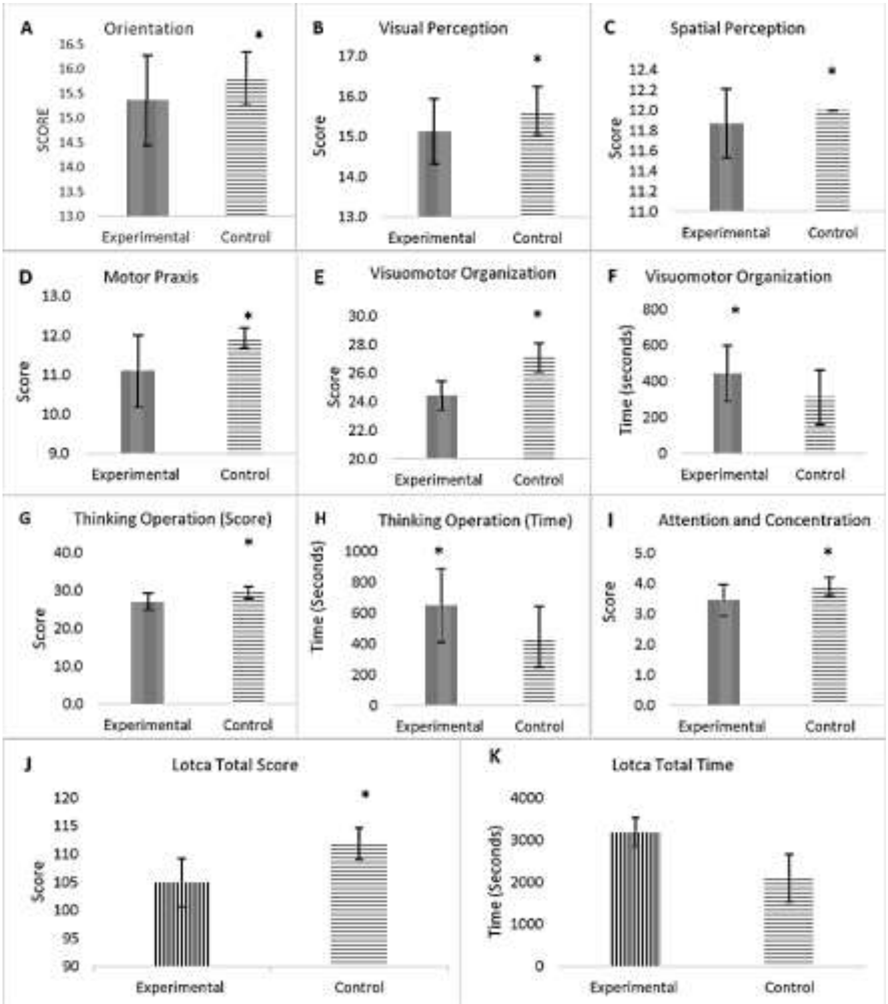

Figure 2: LOTCA domains differences between Experimental and Control group:
(A) Orientation; (B Visual Perception; (C) Spatial Perception; (D) Motor Praxis; (E) Visuomotor Organization (score); (F) Visuomotor Organization (time); (G) Time Operation (score); (H) Time Operation (time); (I) Attention and Concentration: (J) LOTCA Total Score: (K) LOTCA Total Time. Note: (*) p-value < 0.05 between experimental and control group

4.0 Discussion

This study compared the cognitive performance of young motorcyclists as they performed the LOTCA assessment under motorcycle noise exposure (ExG, $\leq$90 dBA) and controlled laboratory noise (CoG, $\leq 65\text{dBA}$). LOTCA is a relatively systematic test attributed as a useful test for an initial assessment of neurobehavioral problems such as addiction, intellectual disabilities, head injuries, exercising effects on cognitive abilities etc for different age groups such as children, young adults, older adults. LOTCA possesses the characteristics of the good instrument for cognitive screening. However, its use among the current population, i.e., young motorcyclists has never been established. Therefore, this study aimed to determine the differential effect of noise using the LOTCA assessment for cognitive profiling of motorcyclist with respect to performance and reaction time (seconds). The results showed (Table 3) significantly ($p < 0.05$) better performance on the LOTCA by the CoG participants compared to ExG where the ExG had a longer reaction-time (seconds) to complete the LOTCA test compared to CoG participants ($p < 0.05$). Affected performance (LOTCA) both in scores and reaction time (seconds) by the ExG participants imply a reduction in performance due to exposure to the high intensity (≤ 90 dBA) motorcycle noise.

Overall, both the groups (ExG and CoG) obtained the average scores very close to the maximum possible (Table 2) in each LOTCA domain (average score) and showed a significant difference ($p < 0.05$) in the performance of ExG participants which can be attributed to the effect of noise exposure (≤ 90 dBA). Hence, it can be concluded that LOTCA is a simple cognitive test but the difference in performance and reaction time (seconds) quantifies the effect of noise exposure (≤ 90 dBA). Other experimental studies performed on different populations also evaluated the effect of noise on performance and showed a significant relation of noise with impairment performance (Jahncke et al., 2011)(Waye et al., 2002). The findings of this study are in contrast with the recent study reported (Mehri et al., 2018) in which it was investigated a relation between complex task and simple task under high traffic noise exposure (< 80 dBA) among introvert and extrovert participants. Results reported by Mehri et al. that there was no significant effect of traffic noise on simple or complex task on both extroverts and introverts' participants. Mehri et al., also assumed that the performance of such study may get affected by the cognitive assessments of the individuals (Mehri et al., 2018). Cognitive assessment refers to the evaluation of the situation and can affect on the overall performance of the test. In this study, the participants were presumably aware of the effects of noise on mental performance as they all were undergraduate students. Other experimental studies also evaluated the effect of noise (office noise and low frequency noise) on mental performance on different population showed the significantly impaired performance (Jahncke et al., 2011)(Waye et al., 2002). Precise comparison with other research is difficult because other studies source and level of noise were vastly different as well as the nature of cognitive test used to assess the cognitive performance.

Figure 3 shows the difference between the LOTCA scores of CoG and ExG, expressed as percentage. Higher percentage scores of CoG as compared to ExG displays its better overall performance. The differences in the performance refer to its known-group validity (Jang, Chern, & Lin, 2009). Visual Organization domain was the most sensitive domain for detecting the difference in performance between CoG and ExG. The CoG showed ~11% better performance in Visual Organization compared to ExG. This is followed by Thinking Operation with the difference of ~9%. Motor Praxis was the third highest LOTCA domain with the difference of ~8%. Approximately 7% of CoG participants performed better on LOTCA average score as compared to ExG. The less sensitive domains, which were Orientation and Visual Perception, showed ~3% higher scores from CoG. While on Spatial Perception performance, CoG showed only ~1% higher scores.

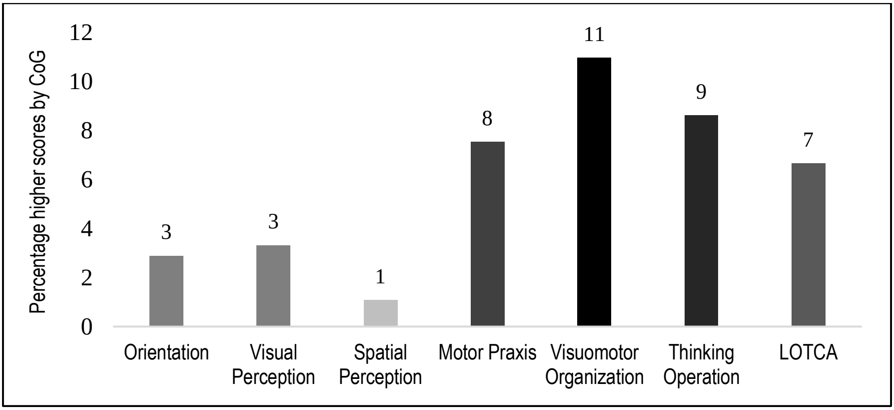

Figure 3: Percentage higher performance by CoG as compared to ExG

Visuomotor Organization of LOTCA comprises of drawing, coping, building and assembling. This domain has a spatial component which involves perceptual activities with motor responses (Uyanik, Aki, Ger, Gonca Bumin, & Kayihan, 1999) as required for driving a motorcycle. Disparities in drawing a symmetrical object reflect the unilateral neglect and a person's ability to process the spatial relations (Cooke, Mckenna, Fleming, & Darnell, 2006) which also underlie the basic trait required during the careful assessment of situations while riding a motorcycle. Visual attention hurts daily activity functioning, mainly that require integration of visual details that are associated with the dynamic environment such as riding a motorcycle (Warren, M., Pendleton, H.M. and Schultz-Krohn, 2006). Building and assembling difficulties tend to indicate the constructional problem that hinders daily activities of any complicated kind (Jang et al., 2009). According to Parsons (Parsons, 2000), visual performance is affected by high-intensity noise. Therefore, it can be concluded that with motorcycle noise exposure, motorcyclists Visuomotor Organization (cognitive function) can be affected and therefore, can pose a safety risk associated with motorcycling.

Thinking Operation domain of LOTCA involves higher mental abilities of problem-solving, concept shifting, abstraction, executive functions, logical operation and calculations (Itzkovich et al., 2000). Performance by the motorcyclist participants on the Thinking Operation during noise exposure (ExG, ≤ 90 dBA) showed lower average scores compared to CoG (≤ 65 dBA). The affected performance by the high noise-exposed group (ExG) presumably imposes the risk of distraction and safety motorcycle riding. It has also been reported that prolonged noise exposure degenerates cognitive function which can increase the risk of accidents.

Motor Proxis domain involves motor planning which measures the ability to execute motor functions consisting of motor imitations, utilization of objects, and symbolic actions (Itzkovich et al., 2000) Participants imitated the movements made by the examiner; showed how to use of common objects, and demonstrated symbolic use of actions. It was observed that ExG showed affected performance in this domain also where ExG participants had ~8% reduced performance. Hence, motor imitation and symbolic action as a part of motorcycling, can be affected by noise exposure on motorcyclists. It has also been reported that prolonged noise exposure degenerates cognitive function and increases the risk of accidents (Anila Ali et al., 2016).

Time pressure can affect the judgment of workload by a decline in performance (Etkin & Wager, 2007). During this experimental study, time administration of the LOTCA cognitive test was kept flexible and relaxed for task completion of each LOTCA domain for both the ExG and CoG groups. However, significant difference ($p < 0.05$) was found in reduced reaction-time (seconds) for the LOTCA domains, i.e., Visuomotor Organization and Thinking Operation among ExG participants who exhibited delayed task performance. Overall ExG average LOTCA reaction- time (seconds) was also significantly ($p < 0.05$) reduced compared to CoG. The difference in reaction-time in completion of the domain and overall LOTCA test between the two groups *hence* can be attributed on the effects of noise (≤ 90 dBA) on mental performance.

Figure 4 shows an increased reaction-time (seconds) by the ExG as compared to CoG on Visuomotor Organization, Thinking Operation and total time utilized for completion of cognitive test (LOTCA). Among the LOTCA subtests, CoG participants performed ~ 32% better in reaction-time from ExG on Thinking Operation, while ~ 30% better in Visuomotor Organization. On overall LOTCA completion reaction-time (seconds) CoG was ~ 34 % was more efficient then ExG participants. Since motorcycling involves constant high noise exposures (> 90 dBA), it can be stated that on real life-situation, a difference in reaction-time (seconds) can bear negative impacts on the cognitively demanding situation for the motorcyclists. It has been reported that motorcycle accidents have resulted from human errors (Theofilatos & Yannis, 2015) but the precise factors responsible for such errors has not been addressed so far.

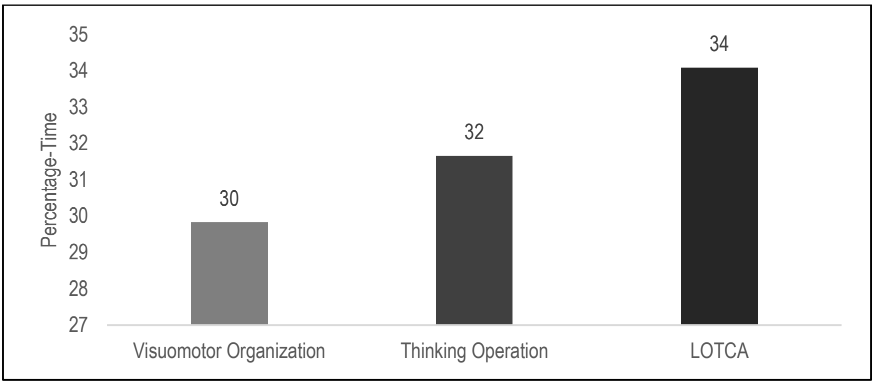

Figure 4: Reaction-time (seconds) difference between the groups on the average score of LOTCA and its domains

A review study by Liebl & Jahncke, 2017 on the effects of noise on cognitive performance reported that individuals with lower working capacity are more vulnerable to noise effects. Another review by Tzivian et al., 2015 stated that noise is associated with several indicators of neurocognitive function, mood disorders and neurodegenerative diseases on long-term noise-exposed population. In another study performed on motorcyclists Health-Related Quality of Life was revealed that motorcyclists with high noise sensitivity suffer from degraded Quality of Life(Anila Ali, Hussain, Dom, & Rashid, 2017). In the controlled laboratory study, it was also revealed increased that motorcyclists cortisol secretion was significantly ($p < 0.05$) higher among the noise-exposed group (≤ 90 dBA) compared to controlled noise-exposed group (≥ 65 dBA) (Anila Ali, Hussain, et al., 2018).

Policymakers should emphasis on assessing the cognitive abilities that are required for driving motorcycle prior to driver's license and should be re-administrated over time. While in the case of minor or major road accidents, motorcyclist's cognitive assessment should be enforced as a law. The limitation of this study was the incomparable population with other studies. The second limitation was that participants administration time could not have been standardized because of their class schedules. The strength of the study was the diversified demographic participants and larger sample size. For future studies, the individual parameters such as personality type, subjective noise measurement, socioeconomic levels, and annoyance should be included to draw the comprehensive effects of noise on cognitive functioning.

5.0 Conclusion

The effect of motorcycle noise exposure on neuropsychological performance was investigated in this study in a controlled laboratory experiment. Results revealed the affected cognitive performance including orientation, visual perception, motor praxis, thinking operation, visuomotor organization, attention and concentration along with decreased reaction time under motorcycle noise exposure which acts as a source of the stressor for the motorcyclists. Performance comparison between the participants who performed under control noise levels (≥ 65 dBA) and high noise exposure (> 90 dBA) validates the negative influence of noise on cognitive function. It further requires more in-depth investigation as to what extent does motorcycle noise can affect the cognitive function and overall mental health of young riders. It also invloves the development of standardized methods and protocols for future cross-sectional and epidemiological references.

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