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ORIGINAL ARTICLE

Driving Efficiency: Unveiling the Impact of Secondary Tasks through Design of Experiment (DOE)

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Abstract: In the field of ergonomics, secondary tasks refer to activities unrelated to the primary task when individuals perform multiple concurrent tasks. The allocation of cognitive resources to the secondary task, while ensuring the completion of the primary task, plays a crucial role in this context. Presently, there is a growing interest in understanding how distractions impact the overall driving experience. Hence, the principal aim of this research is to systematically identify the specific secondary tasks that have a discernible impact on the driving experience. Employing a 3-factor, 2-level Design of Experiments (DoE), half of the subjects participated in a real-life driving scenario while concurrently engaging in two distinct secondary tasks. This study also sought to investigate the relationship between secondary tasks and response times. Furthermore, it aimed to pinpoint the optimal secondary tasks that enhance the driving experience as a secondary objective. To accomplish this, an in-situ experiment was conducted, involving 10 volunteer drivers. Following the experimental sessions, participants were asked to provide feedback on their driving experience through a brief questionnaire. the critical role of distance in shaping emergency braking and driving accuracy. These findings contribute significantly to our understanding of cognitive demands, multitasking, and road safety in real-world scenarios.

Keywords: Ergonomics, Secondary Task, Driver Experience, Design of Experiment

1.0 INTRODUCTION

In the realm of road safety, the intricate dynamics of driver behaviour and performance are a subject of constant inquiry[1]. The outcome of one of the most complex cognitive tasks driving depends on a multitude of variables, including age, experience, cognitive demands, and external distractions, all converging to shape the safety of our roadways.

Recent research, as exemplified by studies from [2] and [3] has shed light on the multifaceted nature of this intricate equation, highlighting the diverse factors contributing to variations in road crash involvement across distinct age groups. While the younger demographic often faces risks stemming from underdeveloped cognitive faculties, inexperience, and a propensity for risky behaviours, older drivers confront unique challenges.

Crucial among these skills is the element of reaction time, a fundamental parameter with far-reaching implications for road safety. Extensive research has explored the factors influencing reaction times, encompassing age, gender, physical fitness, distractions, and more. Importantly, [4] emphasize that when mental strain is compounded by distractions, it has the potential to considerably prolong mental processing times, with detrimental repercussions for driving performance. The activation of the parietal lobe, accountable for motor functions integral to driving, may be compromised under the influence of such mental strain, imperilling road safety. This leads us to the phenomenon of multitasking, a ubiquitous facet of modern life that can manifest as either a boon or a detriment in the context of driving performance. The extent to which secondary tasks interact with driving circumstances and their effects on a driver's ability to manage a vehicle remain an intriguing and pressing matter. As underscored by [3] the interference or non-interference of secondary tasks hinges on the specific cognitive demands they impose and the evolving driving situation. In this context, our research endeavours to systematically discern the secondary tasks that exert a conspicuous impact on the driving experience. We aspire to unveil the intricate relationship connecting secondary tasks and response times, probing for patterns and correlations that enrich our comprehension of driving performance. Furthermore, our pursuit includes the identification of secondary tasks that can enhance the driving experience, consequently contributing to road safety.

2.0 METHODS

The subsection will explain the approaches used during the execution of the experiment. This section seeks to provide a clear and accessible exploration of the methodologies which included routes selection, participant selection and experiment protocol.

2.1 Routes Selection

This research commenced by carefully selecting two unique observation sites, each boasting distinct routes. Figure 1(a) illustrates location road A, where the measured distance is precisely 0.5KM, while figure 1(b) showcases location road B, featuring a distance of 1KM. Through thorough observation, it was perceived that both locations road A and road B offer optimal conditions for the study, providing a controlled environment for a comprehensive exploration of the research objectives.

(a) (b)

Figure 1 Location Road used during the experiment.

As can be seen from the Figure 1 above, a distinctive use of colors, each denoting specific activities or instructions assigned to participants as shown in Table 1 below.

Table 1 Instruction assigned for participants responds for each routes.

Actions	Marker Distance A to B (m)	Colours
Emergency brake	10	
Junction	10	

For instance, when participants reach marker A, a bell rings, signalling the commencement of the task (i.e: Emergency brake) while simultaneously starting the stopwatch. Notably, the examiner's location spans a distance of 10 meters from A to B. Participant success is contingent on staying within the pre-measured distance between markers A and B; exceeding this boundary results in a classification of failure.

2.2 Participant Selection and Participation

In this research endeavour, a group of ten volunteers was actively engaged. Our selection criteria for participants entailed individuals falling within the age range of 20 to 26 years. The paramount criteria for participant inclusion comprised active driver status with a valid driving license, robust physical health, and a youthful demographic profile. Additionally, prospective participants were screened for any history of significant vehicular accidents or diagnosed major brain-related issues.

Prior to official confirmation of their participation, potential subjects underwent a screening process. They were asked a series of pertinent questions to ensure they met the study's criteria: (i) How old are you, and do you possess a valid driving license?; (ii) Have you experienced any significant accidents that could potentially impact your driving performance?; (iii)Have you been diagnosed with any major brain-related conditions or impairments?

By adhering to these rigorous selection criteria, we aimed to construct a study sample that would offer valuable insights into the relationship between cognitive factors and driving performance. This approach ensures the credibility and relevance of our findings within the context of road safety and ergonomic research.

2.2 Experiment Protocol

Experiment consists of four sessions in total. The first session was started with ‘’Exposure”. In this exposure session, participant was required drive around the research area and explaining the necessary scenario that might be happened in the next remaining session. Total for experiment expected to be done within one hour (60 minutes). During the experiment, participant they must keep the car's speed under 40 KM/H in accordance with the speed restriction in the research area. Figure 2 below illustrate the experiment design adapted during the experiment.

Figure 2 Experiment design.

This study applies the Design of Experiments (DOE) approach in pursuit of a comprehensive knowledge of the dynamic interplay of essential parameters and their impact on the driving experience, rigorously selecting and adapting variables critical to the analysis. The table 2 below shown summarizes the strategic decisions made in the experimental design, concentrating on three pivotal factors: Screen Size (Inch), Distance (KM), and Song Volume (dB). With each factor characterized by two carefully chosen levels, this deliberate approach ensures a comprehensive exploration of the intricate relationships between these variables and the targeted response.

Table 2 3-factors, 2-levels of DOE adapted in experiment.

Factors	Level	
	1	2
Screen Size (Inch)	6	8
Distance (KM)	0.5	1
Song Volume (dB)	15	80

By applying DOE, the number of experiments required is significantly reduced. Only eight experiments for each participant to review the data. By consideration learning and fatigue effects [5] the order of experiments arrangements in each series was fully randomised for each participant.

3.0 RESULT AND DISCUSSION

As presenting in Table 3 below shows the 2^3 full factorial design for Average of Response Time for Secondary Task.

Table 3 2^3 full factorial design

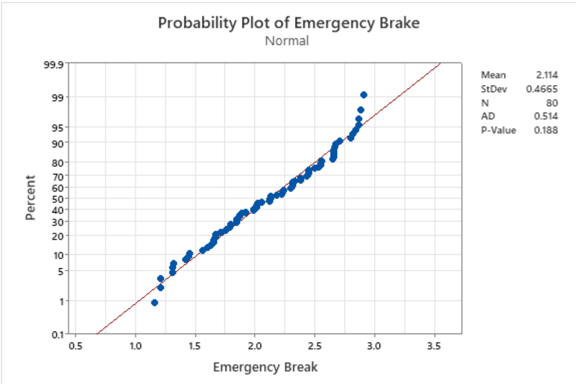
RunOrder	CenterPt	Blocks	Screen Size	Song Volume	Distance	Junction A to B	Emergency Brake
1	1	1	-1	-1	-1	4.97	1.44
2	1	1	1	-1	-1	5.12	1.76
3	1	1	-1	1	-1	5.67	2.30
4	1	1	1	1	-1	5.98	2.45
5	1	1	-1	-1	1	6.21	2.53
6	1	1	1	-1	1	6.45	2.66
7	1	1	-1	1	1	6.85	2.80

8	1	1	1	1	1	7.01	2.87

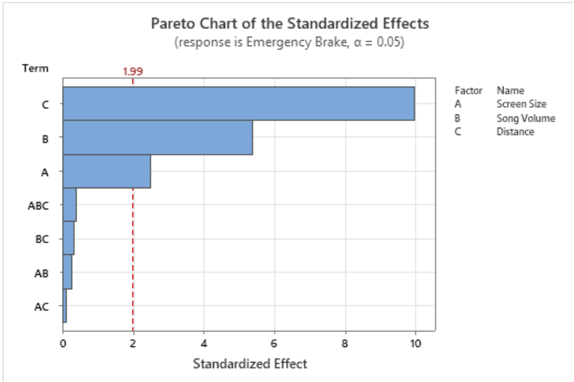
3.1 Experimental Analysis of Secondary Task for Emergency Brake Respond

In the analysis of secondary task for emergency brake respond, the normality test (Figure 3(a)) yielded a p-value of 0.188. This indicates that the Emergency Brake data adheres to a normal distribution, as the p-value surpasses the 0.05 threshold. Consequently, there is no substantial difference between the assumed perfect normal data and the observed data. The lack of evidence to reject the null hypothesis (H_o) suggests that the data can be reliably utilized for subsequent analyses, employing factorial plots to discern main effects and interactions between variables.

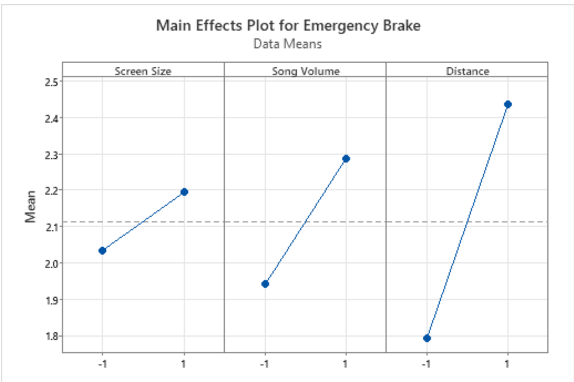
The Pareto Chart (Figure 3(b)) further elucidates the statistical significance of various factors. Bars crossing the reference line (1.993) are deemed statistically significant, with Distance emerging as the factor with the most substantial impact on emergency braking situations. The chart underscores the statistical significance marked by the alpha value of 0.05, also highlighting Song Volume and Screen Size as factors of significance during driving from Junction A to B.



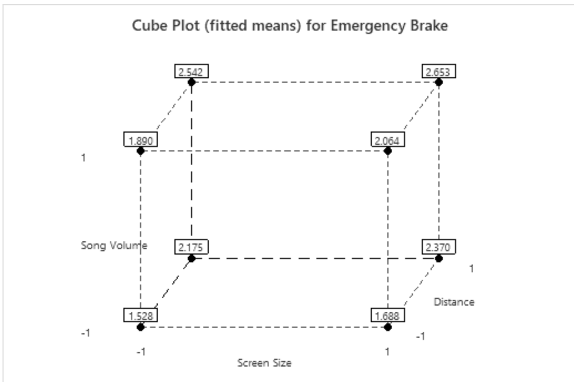
(a) Normality Test



(b) Pareto Chart



(c) Main Effect Plot



(d) Cube Plot

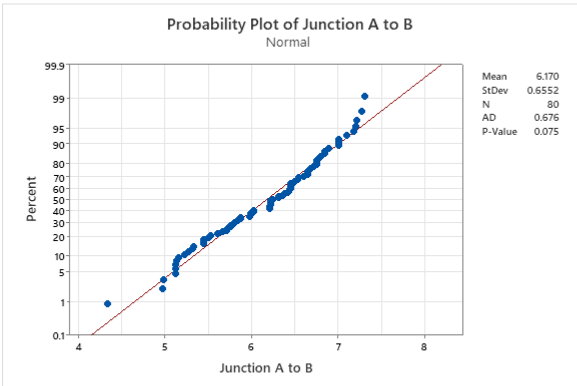
Figure 3 Analysis of Secondary Task for Emergency Brake Respond

The Main Effect Plot (Figure 3(c)) accentuates the influence of Distance, revealing a high slope on the line for Junction A to B, signifying its heightened impact compared to other factors. The reference line represents the overall Average of Emergency Brake. Moreover, the plot illustrates that Screen Size, Song Volume, and Distance slightly elevate the variance value of Junction A to B, with Screen Size exerting the least influence on accuracy.

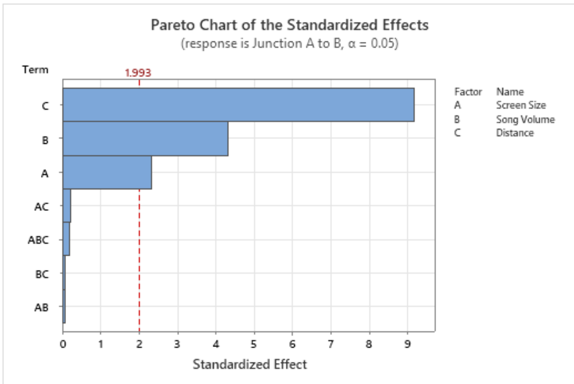
The Cube Plot (Figure 3(d)) provides a comprehensive view of the combined effects of Screen Size, Distance, and Song Volume on response time. The optimal parameter setting, identified as Screen Size (6 inches), Song Volume (15 dB), and Distance (0.5 KM), yields the lowest response time (1.528) for the Driving Secondary Task for Emergency Brake. This parameter configuration represents the most effective combination for minimizing response time, as supported by the fitted means on the cube plot.

3.2 *Experimental Analysis of Secondary Task for Junction*

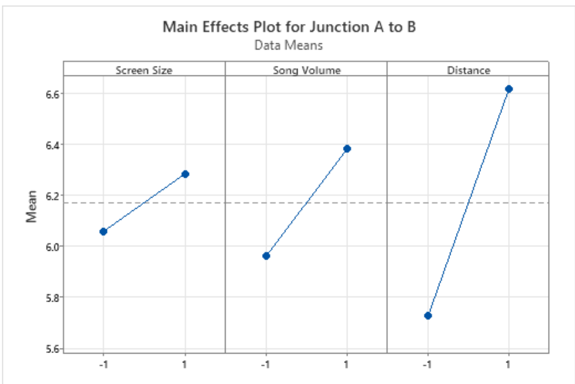
In evaluating the normality of Junction A to B data, as depicted in Figure 4(a), the computed p-value is 0.075. This result indicates conformity to a normal distribution, with the p-value surpassing the 0.05 threshold. The absence of a significant difference between the assumed perfect normal data and the actual data is substantiated, with insufficient evidence to reject the null hypothesis (H_o) due to the p-value exceeding 0.05. Consequently, the confirmed normality of the data permits its utilization for subsequent analyses, employing factorial plots to discern main effects and interactions.



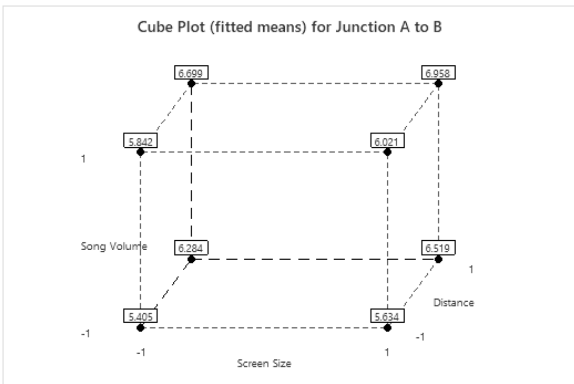
(a) Normality Test



(b) Pareto Chart



(c) Main Effect Plot



(d) Cube Plot

Figure 4 Analysis of Secondary Task for Junction

The Pareto Chart (Figure 4(b)) highlights statistically significant bars crossing the reference line (1.993), with Distance emerging as the factor exerting the most substantial impact at Junction A to B. The statistical significance, marked by the alpha value of 0.05, is mirrored in the reference line, and the chart also underscores the significance of Song Volume and Screen Size during driving at Junction A to B.

Figure 4(c) presents the Main Effect Plot, revealing that Distance exhibits a high slope on the line at Junction A to B, signifying its most significant impact compared to other factors. The reference line represents the overall Average of Junction A to B, and while Screen Size, Song Volume, and Distance slightly elevate the variance value of Junction A to B, Screen Size exerts the least influence on accuracy.

The Cube Plot in Figure 4(d) provides a comprehensive view of the combined effects of Screen Size, Distance, and Song Volume on response time. An optimal parameter setting, identified as Screen Size (6 inches), Song Volume (15 dB), and Distance (0.5 KM), yields the lowest response time (5.405) for the Driving Secondary Task for Junction A to B. The cube plot, supported by fitted means, enables an assessment of model predictions for all factors in the design, solidifying the identification of the most effective combination for minimizing response time.

4.0 CONCLUSION

In conclusion, 2^3 full factorial design for Average of Response Time for Secondary Task, which considers Screen Size, Distance, and Song Volume as combination factors, demonstrates that the secondary task is influenced by distance. The interplay of these variables sheds light on the critical role of distance in shaping emergency braking and driving accuracy. These findings contribute significantly to our understanding of cognitive demands, multitasking, and road safety in real-world scenarios.

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