ANALYSIS OF DRIVER BEHAVIOUR AND CRASH CHARACTERISTICS DURING ADVERSE WEATHER CONDITIONS

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ABSTRACT

With rapid urbanization, traffic congestion has become a severe problem in Indian cities with people spending a majority of their time stuck in traffic. While there are many reasons contributing to it - like bad road infrastructure, poor traffic management and heterogeneous traffic, a significant cause is identified as irrational driver behavior. These behaviors are mainly caused by various environmental factors like noise (both ambient and persistent honking), pedestrians, heterogeneous traffic, other vehicles not following rules, bad roads etc. The objective of the current study is to examine in particular, two independent but conceptually linked external or environmental factors of honking and lane system on driver behavior. Of particular interest is the correlation between physiological changes, psychological states like anxiety/stress/frustration and decisions. A hypothesis based on observation and understanding of Indian roads, is that honking at high decibels though normalized and adapted by Indian road users is reflected on behavioral responses in addition to long term health effects. While there have been many studies addressing traffic congestion due to external factors, few cover driver behaviors caused due to these factors. In this study, we delve deeper into changes in driver behavior due to one external attribute - that of persistent honking by a trailing vehicle.

There have been studies on the effects of honking and most of them report better traffic flow because of honking. That is, honking is considered as an inter-vehicle or vehicle to pedestrian communication. The studies do not take into account changes in the driver behavior due to honking - both honks of acoustic properties approved by certifying agencies and especially from non-standard honks as heard in traffic conditions in India where the current experiment was conducted. Honking, designed to be a tool for the drivers to communicate effectively and also to alert other road users, is often used on Indian roads as a mechanism to express frustration either due to traffic jams, a purely reflex action, a sense of entitlement (as a function of the cost/power of the vehicle) to the road and right of way etc., rather than to ensure safe driving. To analyze this effect, we looked at driver behavior and his/her physiological measurements in the honking environment. These factors are inter-linked, as lane system in heterogeneous traffic leads to honking as a traffic flow enabler or as aggression towards a smaller slow-moving vehicle.

I. INTRODUCTION

Transportation infrastructure plays a vital role in the traffic system. In developing countries, it is the most significant factor for traffic issues like congestion and the associated effects of pollution. The urban and transport infrastructure inadequacies caused by segregation between work and residential areas lead to some of the traffic issues. In most of the rapidly expanding metropolitan cities, people often work in places located far away from their residential areas as workplaces are generally found in the expensive real estate part of the city. Thus people have to commute long distances daily, increasing the traffic volume substantially, especially during the morning and evening hours. The unplanned expansion of the city limits and shortfalls in addressing affordable and safe public transport has led to increasing personal 2 and 4-wheeled vehicles. This could be seen in the 2011 Census data (Mode of Transportation: 2001-2011) where the use of public transport is reported to be only 18.1% of all commutes in India. According to a report by the Institute of Urban Transport (India) in 2014, public buses constituted 11% of total motor vehicles in India in 1951 which fell to just 1.1% in 2011. Besides this, the goods & services industry also adds to the inner-city vehicle volume and highway traffic, resulting in increased pressure on the road infrastructure.

Road infrastructure:– The quality of road construction, non-uniform dimensions, inconsistency in the number of lanes over a longer stretch are some of the factors which make road infrastructure critically important in deciding traffic congestion. Generally, there is a paucity of a scientific and engineered approach in road technology based on an urban planning roadmap - that is, there is a lack of research about the use or purpose of the road, the type of vehicles that will typically pass through the road, the expected traffic volume and the weather conditions etc., which are required to decide the materials used in constructing the roads. Lack of a well-researched approach to administration and maintenance leads to deterioration of the roads, resulting in the following conditions: Slippery roads, Poor lighting conditions, and Animals or objects on the road.

Traffic Congestion

Traffic congestion is a situation that arises due to increased density accompanied by a decrease in vehicular speeds, thus resulting in long snarls on roads. Scientifically, it is quantified by the flow, which is defined as the number of automobiles passing through a unit area per unit time. Situation like traffic congestion is more complicated in developing countries as compared to developed countries as the latter mainly have homogeneous traffic while the former is saddled with heterogeneous traffic. A study in the Indian city of Kolkata concluded that the average speed during peak hours is as low as 10km/hr.

There have been many studies on traffic flow and infrastructure, but few from the perspective of behavior in heterogeneous traffic. Though infrastructure issues look like the most profound cause of traffic congestion, there have been comparatively fewer studies on the factors affecting traffic congestion. Jams for an extended period result in the increase of frustration/anger in drivers, which in turn could lead to road rage or irrational driving behavior. Driver behavior in heterogeneous traffic is much different that in homogeneous traffic in terms of lateral movement and gap acceptance, which happens when a vehicle 'pushes' in between two vehicles through squeezing. In our study, we explore how people's behavior affects traffic and another person's decisions.

SCOPE OF THE PROJECT

Human behaviour is generally defined as the reaction of a human or a group of humans to a situation or stimulus. It consists of different types of physical actions and emotions of the people, which can be recognized and analyzed. In general, the specific attribute of the individual's behaviour which is related to his/her personality and individuality will not change, as compared to other behaviours which will evolve as the person grows older and gains more experience. Though the age and genetics mostly decide the human reaction, it has been established that behaviour is also a result of an individual's thoughts and feelings. Thus, it reflects a lot about the person's psyche and gives us an insight into his/her attitude and character. The effect of the interactions with the society and the culture can be studied using social behaviour which is a subset of human behaviour.

Driving behaviour constitutes the synchronization of different activities that require multitasking behaviour. We can also realize that most of our driving activities are mechanical and done subconsciously. This is a result of our experiences, and thus we require a low level of attention for these activities. We inherently develop a subconscious arrangement and architecture for driving patterns with time. However, this is developed in an impromptu fashion based on our experiences and day-to-day impressions. This internal structure of responses helps us to get through the daily driving situations such as movement through traffic, crossing the roads, etc. However, this schema does not work in the case of emergencies as these subconscious actions change our behaviour to face emergencies and ultimately fails because we inherently do not have an internal arrangement for that. The study of human behaviour while driving in different situations can be used to create a cognitive/psychological profile of people for the activity of driving. There could be different types of behaviours shown by the driver while driving which including retaliatory, proficient, careful, distressed, sympathetic, efficient behaviour, etc. The practice of new and safe approaches until they become a habit can change the behaviour of the person.

II LITERATURE REVIEW

Many research studies have been performed to analyze traffic operations and safety under rainy weather conditions. In 1991, Palutikof (1991)found that rainy weather was the most significant one among all weather factors that resulted in traffic fatalities. In a study by Sherretz and Farhar (1978) to analyze traffic weather data from seven cities in southern Illinois, USA, it was found that there existed a linear positive correlation between rainfall and traffic crash frequency. Some research studies found that geographical differences could play an important role in determining the impacts of rainy weather on traffic safety. Brotsky and Hakkert (1988), Smith (1982), Codling (1974), and Andrey and Yagar (1993) compared the impact differences of sunny weather and rainy weather on traffic safety and found that rainy weather resulted in 6%, 22%, 52%, and 70% more crash rates, respectively, as compared to sunny weather conditions. More detailed finding about rainy weather impacts on traffic safety are summarized by Andrey, Mills & Vandemolen (2001) and Eisenberg (2004).

In addition, many statistical modeling approaches have been used to develop statistical models to analyze impacts of various factors in the groups of users, vehicles, roadways, and control on traffic safety. Hill and Boyle (2006) used a logistic regression model to predict traffic fatality and incapacitating injury, and they concluded that female drivers older than 54 could have more severe injuries under adverse weather conditions as compared to male drivers in the same age group. Khorashadi, Niemerier, Shankar & Mannering, (2005) used a multinomial Logit model to analyze the severity of truck drivers involved in crashes, and his research found that rainy weather was the key factor resulting in the increase in traffic crash injuries. An Ordered Probit model was used by Abdel-Aty (2003) to predict driver injury severity, and results showed that drivers at signalized intersections could suffer more serious injuries under adverse weather and dark environmental conditions as compared with under other conditions. In a similar study, ordinal logistic regression model and sequential logistic regression model were used to evaluate impacts of rainfall on single-vehicle crashes with the considerations of weather conditions and non-weather conditions (Jung, 2010), and it was concluded that the backward sequential logistic regression model might be the best fit to predict crash severity under rainy weather conditions.

III DRIVER BEHAVIOR IN HETEROGENEOUS TRAFFIC LANE SYSTEM

A driving simulator is a virtual reality application integrated with tactile sensory feedback designed to give a driver the perception of actually driving a vehicle. A high-fidelity simulator will include realistic vehicle dynamics; audio, immersive video and kinetics systems (like a 6-DoF platform) emulating vehicle motion, surrounding scenes, and traffic noises. A setup like this can be used efficiently to test vehicle safety in crash testing effects on driving due to changes in the external traffic system, and importantly in human factor studies. Virtual simulators offer many advantages over real-world experiments, some of them being: (i) Ability to control, replicate, and standardize, that is, traffic conditions can be manipulated according to the research focus. (ii) Data collection is systematic and uniform across participants and experimental conditions. (iii) Driving in risky situations can be simulated without actual physical harm to the driver and with a minimal financial budget. That is, case studies requiring crash testing or event setups to evoke aggressive behaviours. (iv) Simulators allow for feedback recording and analytics, which is very difficult to achieve in a real-world scenario with real traffic. Importantly, it is possible to manipulate, stop, pause or restart a scenario. Hence, driving simulators are important tools that allow the researcher to manipulate the situations.

There are many applications deployed for commercial enterprises and many more designed in research labs to evaluate specific scenarios. One such microscopic behaviour-based traffic simulator is the VISSIM (software package developed by PTV Planning Transport Verkehr AG in Karlsruhe, Germany) to analyse traffic flows. The simulator has a fundamental 3D UI and based on mathematical equations, it can calculate the position of each vehicle in the 0.1-1s range. Objects like vehicles and pedestrians can be assembled in the initial conditions and during run-time.

Modelling and testing driving behaviour in heterogeneous and low-discipline adherence traffic requires flexibility to study culture-restricted behavioural study, for example, variable pedestrian behavior, random changes in road conditions and irrational driving behaviour. Research on modelling traffic flow at a micro-macro level has been exhaustive for homogeneous traffic. In most of the studies, robust mathematical models emulate the vehicle movement programmed to follow rules of interactions, speed, acceleration, situational awareness and leader-follower behaviour as noticed in disciplined real-life drivers

HETEROGENEOUS TRAFFIC SIMULATOR

A simulation was designed in-house and developed for ease of customization to fit the constraints and conditions of heterogeneous traffic. The Unity3D game studio running on a high-end graphics card was used for the rapid prototyping, and the application was formatted for virtual reality head-mounted display, the Oculus Rift. The virtual car was controlled by a steering wheel hardware accessory fitted with an accelerator and brake. The scenarios were presented to the player in a 360-degree view of a 3-lane road with trucks, buses, cars, and autos programmed using simple rule-based artificial intelligence. These AI bots have characteristics of the type of vehicle represented, and behaviour models usually found on Indian roads. For example, a bus moves slower than car, a motorcycle will weave in and out through the gaps between vehicles and a three-wheel autorickshaw occupies any of the lanes but at speeds not above 20km/hr as per its 2-stroke engine capacity and there is no strict regulation on lane-occupancy based on type of vehicle or its utility. But for this simulation, the heavier vehicles were positioned on the left lane while the participant’s car is in the middle lane, and the right lane was populated with car-bots. The two-wheelers are mixed in between the lanes as is usually the case on the Indian roads. A rigid-body collision detection was introduced to depict the collision between the vehicles. In addition to this, naturalistic ambient stereophonic traffic sounds and intermediate honking were also presented. As we are interested in looking at driver behaviour when the lead in the lane is a very slow-moving vehicle, a three-wheeler auto rickshaw was considered for this role.

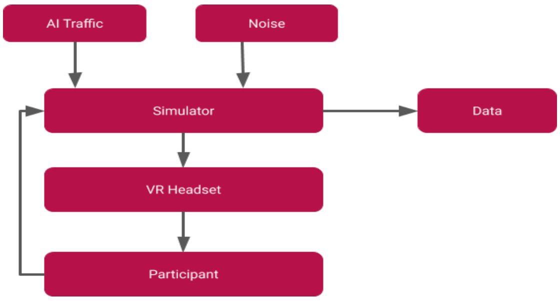


Figure: The schematic diagram of the experiment

This rating was collected only once at the end of testing all scenarios and is combined effect of noise levels and the traffic conditions encountered. The participants report that the irritation level was the highest when lane change was not possible due to the physical barricades, as they were restrained to follow the slow-vehicle till the end.

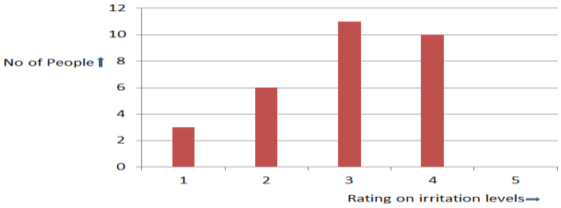


Figure: The rating on sense of immersion on a likely scale of 1-5(x-axis) with 5 being maximum. The y axis denotes the number of participants

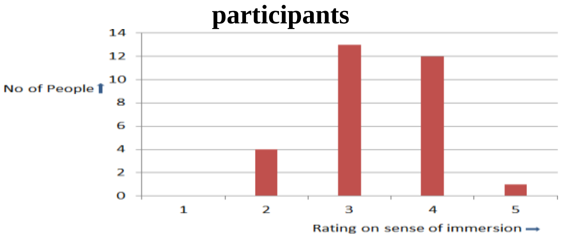


Figure: The rating on irritation levels on a scale of 1-5 (x-axis) with 5 being the maximum. The y-axis denotes the number of participants

The average time for each scenario was calculated for all the participants in each scenario (Table 3.1). A 2-sample T-test was applied to look at statistical significance for the timings from the first two scenarios with 95% confidence level. The p value comes out to be less than 0.0001. The standard error of the difference is 3.875. The statistical significance was estimated only for scenarios 1 and 2, because for the third scenario, the time to reach the finish line was the speed programmed for the slow-moving vehicle by default.

IV BEHAVIORAL STUDY OF HONKING EFFECTS ON DRIVERS

INTRODUCTION

Irrational honking is a persistent problem, especially in countries with heterogeneous road traffic, minimal road infrastructure, traffic flow management, low individual discipline and policy regulation on decibel level. When the development of road infrastructure is not at par with the increase in the number of vehicles being added, the problem is compounded. A study by Vijay et al., in a Nagpur city of India, showed that honking contributed to 2-5 dB increase in ambient noise levels. This is supported by Banerjee et al. and Sheetal et al. and hence the average dB level is higher than permissible limits set by medical and government agencies. They conducted a health survey which concluded that 52% of people felt persistent irritation due to traffic noise, 46% of the people reported hypertension, and 48.6% reported sleep deprivation due to noise pollution.

The term noise refers to an undesirable sound either persistent or intermittent which is unpleasant and causes a hearing disturbance, therefore considered as pollution. There are several reasons for noise pollution, but it mainly occurs due to unplanned urbanization, industrialization and civil infrastructure work using heavy building machinery in residential areas in addition to traffic/vehicle noises. The fast-paced lifestyle in metro cities forces people to take irrational decisions where the end goal (of reaching the destination) overshadows the means. Adding to the base engine noise from a vehicle, it is the frequent and loud honking which are one of the leading causes of noise pollution in many cities across the world. In terms of decibels, the typical traffic sound range is around 0-130 in unregulated traffic conditions as seen in India, with quiet city traffic in the range of 80dB, while noisy honks range from 80-120dB.

Usually, honking is used in case of an emergency or to warn a deviating vehicle or jaywalking pedestrian. When the infrastructure cannot accommodate the vehicle density, honking is applied as a tool to regulate traffic flow locally. However, honking is also a sign of aggression, irritation and anger or egoistic behavior. There have been not detailed studies to examine the effect of honking on driver behavior; thus we present results from a series of tests using a custom-developed VR simulator.

Effects of Noise

Unlike the effects of honking on traffic flow, the effects on an individual are challenging to study and quantify. Haines et al. studied the effects of chronic aircraft noise exposure on children living near airports. They concluded that these children displayed higher levels of annoyance and stress, causing impairments in their cognitive function. Importantly, a study by Stansfeld et al. showed that there is no adaptation and the high levels of annoyance do not decline over time. The study also concluded that noise exposure is associated with an increased level of catecholamine secretion, leading to impairment in reading comprehension and long-term memory loss.

Due to increased sound levels in the workplace environment, there have been cases of hearing deterioration, high blood pressure, somnipathy, irritation and cardiovascular diseases. There have been instances where the noise levels have affected the immune system and caused congenital disorder during birth. Stress-induced in people due to working in places where the noise levels are higher than normal has been associated mainly with the increment in workplace hazards and therefore, increased aggression and unsociable behaviour.

It is reasonable to assume that continuous honking creates a definitive aggravation in a driver or a pedestrian, which might lead to hasty and irrational decisions. There are no studies which have measured the physiological changes indicative of responses like anxiety/stress and correlated the same to driving decisions. Most studies that have focused on honking have made inferences from behaviour analysis. In our study, we are using the physiological analysis for qualitative understanding of the underlying phenomenon for behavioral changes.

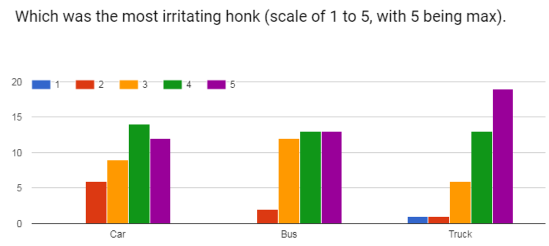
METHODOLOGY

In this section, we discuss our approach, experiment/simulation, scenarios and participants.

Measuring Skin Conductance to Gauge Anxiety/Nervousness

Previous works have studied changing physiological parameters to measure the effects of honking with probable relation to decision making. The physiological phenomenon considered by [60] is the change in perspiration levels during the experiment and computed as a change in skin conductance. A study done by Sim et al. on the effects of different noise types on heart rate variability in men concluded that noises of 45 dB affect the autonomic nervous system (ANS). The ANS is a peripheral nervous system component which regulates smooth muscle, myocardium, external secretion glands, and some internal secretion glands to maintain homeostasis. Noise is shown to be one of the factors affecting the ANS. It has been established that noise exposure augments sympathetic activity. This effect on the nervous system produces anxiety and has been shown to result in bad decisions. Thus, a significant change in physiological properties is correlated with the probability of making bad decisions. We measure skin conductance and pulse rate to estimate the possible change in anxiety levels.

Results



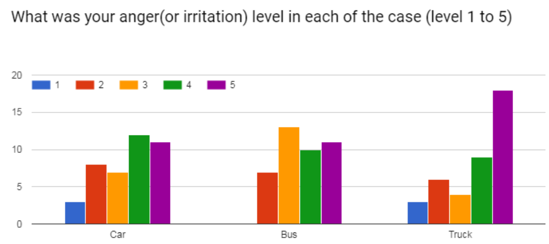


Figure Rating on irritation levels and anger levels for honk type

The data from the survey (questions Annexure 1) are presented in Figure 4.1. As can be inferred, a good percentage of participants gave the highest irritation rating for the truck honk, while around 10-12 participants gave a rating of 4 for other honk types. On anger levels, the truck honk evoked the maximum and other honks were rated high too. The ratings indicate that honking does lead to irritation and hence possible anger in drivers. We gathered extensive feedback about the VR simulator efficiency.

V CONCLUSION

In this thesis, the objective was to study the behaviour of drivers in a) different lane traffic scenarios to find a conclusive result on whether the lane system is efficient method in a heterogeneous traffic condition as seen in India and b) in loud and high frequency honking environment. The behavioral change was measured by decisions in certain conditions. Observations were made in a simulated virtual environment where the participant felt like she/he is in an Indian road scenario and provided sufficient immersiveness to behave as one would in real world. The studies reported in this thesis are the first to show empirical evidence for underlying reasons for erratic driver behavior on Indian roads. While previous studies on heterogeneous traffic were theoretical or survey based, and mostly focused on modeling traffic density or flow as a function of road conditions, there have been no studies which looked at why the lane system fails in Indian traffic. Similarly, there are concerns on the effect of honking on human hearing system due to long exposure to high decibel noise but only few have studied the correlation to impulsive behavior of the driver.

we concluded that the effect of honking is very profound on people's decisions and sudden high pitch and high frequency honks can result in a response like frustration which directly influences drivers' behaviour. It was observed that persistent honking as a function of its decibel levels and type of honk tone forced a few of the participants to make decisions which they were not making initially, like breaking the traffic signal rule. The skin conductance levels of people change significantly during honking which depicts an increase in the nervousness thus external induced anxiety also plays a role in making incorrect decisions. From the GSR data and recorded deviation in decisions, we conclude that there is sufficient empirical evidence of honking resulting in impulsive and risky decisions. The findings point to a honk-standardization implementation. Also, we can conclude that GSR measurement is an effective and an economic way to calculate nervousness.

As mentioned in this study also confirmed that the lane system as proposed for ho- mogenous traffic, requires re-modelling to fit Indian roads and the heterogeneous traffic composition of the traffic, that a slow-moving vehicle can cause disruption in traffic flow velocity leading to pockets of congestion and importantly cause driver frustration and anger. While lane system enforces discipline and also is an extremely safe model, in Indian roads strict adherence to the lane needs to be based on vehicle type and engine capacity in particular. An option would be to have strict demarcation of lanes based on vehicle type. In a no-lane road system, the travel time is effectively the least and the person feels less frustrated which was concluded from the survey conducted on the participants, but this could lead to accidents. Considering the limited options as presented in Indian conditions, especially the cost of horizontal expansion to increase the number of lanes, a vertical expansion with clearly demarcation based on vehicle type and category (commercial, public transport or private) of the road system is a better solution.

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