

Effect Of Age, Experience And Education On Cognitive And Psychomotor Performance Of Locomotive Drivers And The Role Of Compensatory Factors In Mitigating Their Effects On Indian Railways

Vishnu Kumar,

Executive Director/Traffic, Psycho-Technical Directorate, Research Designs and Standards Organisation (Ministry of Railways), Government of India, Manak Nagar, Lucknow-226011, India.

Abstract: Train operation requires various technological inputs maintained and operated by human beings and it makes human reliability inevitable and safety critical. Attributes and acumen of human operators need to be of the highest order, to meet desired level of competence, remaining physically agile and mentally alert, to meet the requirement of responding quickly and taking decisions while driving. Essentiality of complying prescribed safety rules, swiftness in handling equipments and managing different aspects of driving with highest level of attention and alertness makes it inevitable to minimize safety critical risk factors and for attaining this level of precision they need to have requisite potential with respect to cognitive, psychomotor, personality and behavioural abilities, which deteriorates with age. This deterioration in ageing population of locomotive drivers can be compensated by means of their expertise, skills and abilities developed in course of their working and this development gets impacted upon by their education and experience. It is therefore essentially required that their skills be sharpened and experience sustained by means of adequate organisational inputs in the form of training, counseling, various self-awareness and psycho-intervention programmes so that the valuable human resources continue to deliver safely and satisfactorily in the interest of organization.

Keywords: Cognitive, Psychomotor, Attribute, Skill, Ability, Safety, Work ability, Expertise, Automacity.

I. Introduction

Safety critical job of train driving requires a range of abilities and skills. The basic cognitive functions of perception, attention and memory that determine performance of a driver deteriorate with age and the executive functions of reasoning, planning, prioritization, thinking ahead, situational awareness and execution get affected the most by age. Age related decline in physical, cognitive, perceptual, psychomotor and behavioural abilities start declining before a person attains fifty years of age and this decline becomes more pronounced after that. The impact of age on performance particularly in terms of deterioration in reaction time, cognitive processing, decision making, multitasking ability, perceptual as well as psychomotor abilities and work ability ultimately influence train driving and potentially lead to increased risk of unsafe working and accidents. The ability to withstand impact of working in different time schedule, particularly during night also gets reduced, as the critical age for increased intolerance to successive night working is around fifty years. However, several factors do have compensatory roles in reducing the impact of ageing. Education, experience, domain specific expertise, strategies, skills and better job knowledge do compensate the effect of ageing, but this needs to be nourished and nurtured well by the organisations. This is so because not only the old and ageing locomotive drivers, but also the younger ones need to remain mentally active, alert and attentive to meet the requirement of responding quickly in dynamic situation of train operation that demands their attributes and acumen to be of the highest order to meet desired level of expertise and competence, enabling them to acquire analytical ability of differentiating and processing various auditory and visual stimuli, so that they could systematize several sequential and many a times simultaneous activities in a synchronised manner before taking prudent decisions to ensure safety at higher speed.

Objective of the study

Empirical study and analysis of the performance of locomotive drivers with respect to various factors including age, education and experience on safety critical cognitive and psychomotor attributes essential for train operation job to assess their suitability for higher responsibility job as per the operational need and compensatory roles of different factors that could facilitate the proficiency of ageing population of drivers enabling them to endure intricacy of driving and sustenance of desired skills and abilities for maintaining high safety standards of efficiency and safety on Indian Railways.

Experimental Design

1. Data pertaining to performance of 1306 locomotive drivers who work different trains in different environmental conditions of temperature, rain, humidity both during day and at night were collected and compiled for correlation analysis.
2. Essential attributes of reaction time, concentration, speed perception, form perception and alertness/vigilance were assessed using indigenously developed computer aided driver aptitude test system.
3. All the drivers were grouped into four groups on the basis of age (35 to 45, 46 to 50, 51 to 55 and 56 to 60 years), experience (upto 5 years, 5 to 10 years, 10 to 15 years and 15 to 20 years) and education (non-matriculate to Diploma/Degree).
4. Analysis of data related to performance, comparison and statistical correlation with different variables was carried out using ANOVA on statistical software SPSS.

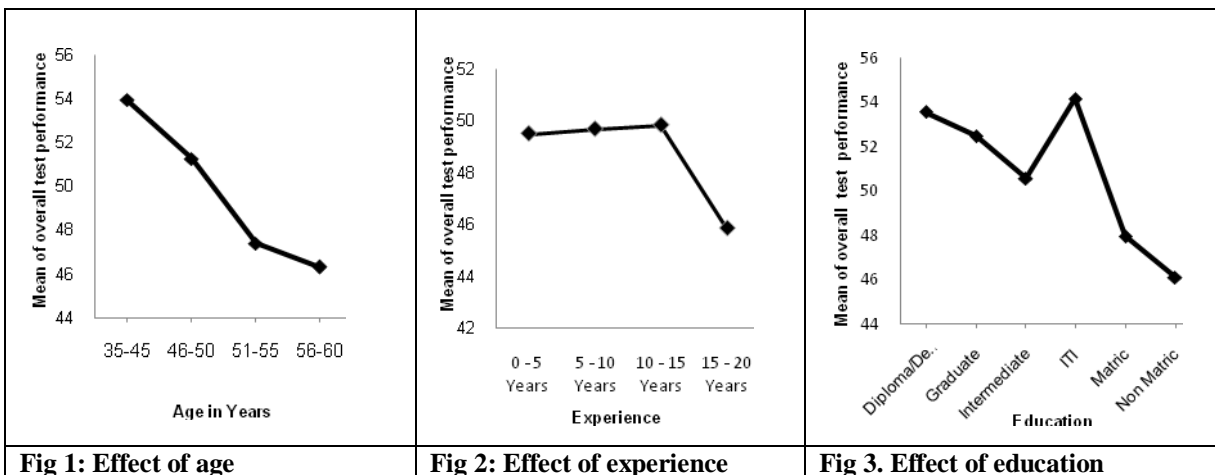
Effect of different factors on cognitive and psychomotor performance:

Effect of age

The effect of age on all the attributes under study was significant ($F=110.469, p=.001$). Drivers in the age groups of 51-55 and 56-60 years did not have significant difference between them in terms of overall test performance, whereas all other groups differed significantly at 0.01 level. Analysis of mean performance indicated that those in the age group of 35-45 years had the best performance, followed by drivers in the age group of 46-50 years as compared to higher age groups. The performance was found gradually declining with increase in age. Reaction time increased with increase in age and drivers in higher age groups had higher reaction time, indicating decline in psycho-motor abilities and poor agility. Those in the age group of 46-50 years had the best judgment of speed, whereas performance of drivers in the age group of 35-45 years was the best on concentration, vigilance and form perception as compared to those in higher age groups, but with increase in age these abilities were found declining progressively. Studies conducted earlier by the Psycho-Technical Directorate of Research Designs and Standards Organisation also indicated that with increase in age there is decrement in alertness level and decline in psychomotor performance (Study Report Nos. PT 72.7 and 89.2) and in cognitive functions (Study Report No. PT 69.5), which could be safety critical in train operations.

Effect of experience

The main effect of experience on overall performance was not significant, ($F=1.968, p=.005$), but analysis of mean indicated that the performance of locomotive drivers with 10 to 15 years experience had been the best, which declined thereafter.



Effect of education

There was significant effect of education on overall test performance ($F=46.616, p=.001$). Tukey post hoc analysis indicated that locomotive drivers having Diploma/Degree/Graduate and ITI as their educational qualification did not have significant difference among them in terms of overall performance, whereas all other groups differed significantly at .05 level. Analysis of mean revealed that the performance of drivers possessing professional and higher educational qualification such as ITI, diploma/degree/graduation had been better as compared to those having less educational qualification and the locomotive drivers having educational background of ITI had better overall performance as compared to those having other qualifications.

Effect of age and experience

The combined effect of age and experience on overall performance was also not significant ($F=0.885$, $p=.005$), but analysis of mean score indicated that those in the age group of 35-45 years and 46-50 years having working experience of 10 to 15 years performed better than those in other age groups and experience. Concentration of drivers in both the age groups with similar experience had similar trend of performance. Decline in performance was noticeable with increase in age, which did not appear to be compensated by their experience of 15 to 20 years.

Effect of age and education

The combined effect of age and education was not found significant ($F= 1.036$, $p=.001$), but the mean score revealed that overall performance in the age group of 35-45 years with higher qualification (diploma/degree/graduation) was better as compared to others. Performance on different attributes declined with age for all the education groups, showing less effect of education when the drivers got experienced and it was only the age that impacted their performance. Performance of drivers in the age group of 35-45 years was best on reaction time, concentration and vigilance, and poor in the age bracket of 56-60 years, irrespective of their educational qualifications. Reaction time of ITI educated drivers in the age bracket of 46-50 was also better, which was comparable with the drivers in 35-45 years of age group. Drivers in the age group of 35-45 and 46-50 years performed better on speed perception as compared to those in other age groups and here too education did not have distinct effect on performance. Performance of drivers in the age group of 35-45 years was better on form perception as compared to other age groups. Across all age groups those having diploma/degree/ITI as their educational qualification performed the best. Performance of non-matriculate drivers across all the age groups was poor and this was more prominent in those falling in the age group of 51-55 years. These findings indicated that the drivers in the age range of 35-45 years, having higher and technical qualification of diploma/degree/graduation/ITI had better overall performance as compared to those having lower educational qualifications and belonging to other age groups. Performance on different attributes declined with increase in age for all the educational groups, indicating that the effect of education in later part of their career was not significant, but their age did have major effect on their performance on different attributes. Non-matriculate drivers performed the worst as compared to their colleagues, except their performance on vigilance.

Effect of education and experience

The combined effect of education and experience on overall test performance was not significant ($F=.524$, $p=.005$). Performance of drivers with diploma/degree/ITI as educational qualification across all the experience groups had been better than the others on all the five attributes of concentration, vigilance, speed perception, form perception and reaction time. Their performance was found to be the best in those having experience up to 10 years. Those with experience of 15 to 20 years performed poorly on concentration and speed perception. The performance of non-matriculate drivers irrespective of their experience was poor.

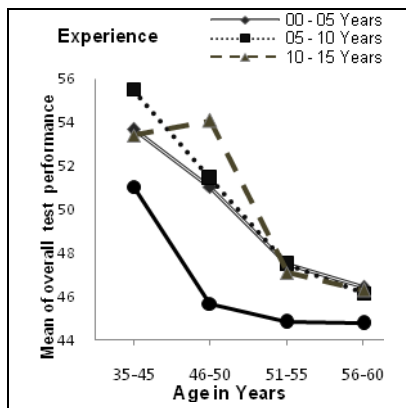


Fig 4: Effect of age and experience

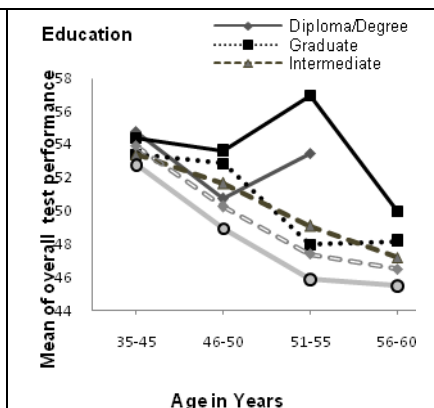


Fig 5: Effect of age and education

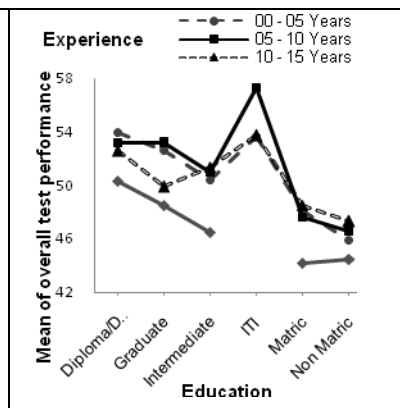


Fig 6: Effect of education & experience

II. Discussion

Impact of age: Cognitive functions and performance are intimately associated with age related changes in structure and function of brain. This relationship between brain and cognition is dynamic and keeps on changing across the lifespan of an individual and changes in these two domains are closely related. Since age related changes in structure and function of brain are not uniform, age related changes in cognition are also not uniform

across all cognitive domains and across all the ageing individuals. The basic cognitive functions that get affected the most due to ageing are attention and memory. Information processing and decision making also get affected by age as these rely on basic cognitive functions and their deficit impairs higher levels of cognitive processes. Impairment of executive functions that manage and coordinate various components of tasks contributes to age related declines in a range of cognitive tasks, because complex cognitive tasks depend on these functions. Safety critical job of train driving, being a high cognitive demand task, requires a variety of skills and abilities that involve high levels of memory, cognitive processing speed and efficient multitasking ability and each of them deteriorate with age. Deficits in four basic abilities to see, recognize, decide and act are critical to driving tasks and performance of a train driver depends on these abilities (Llaneras et al., 1998). Complexity of train operation job and the environment in which it takes place involves interactions between people, tools, techniques and expertise along with a variety of skills and abilities (Popkin et al., 2008). The relationship between age and driving behavior is full of complexities and an older person's ability to drive safely is affected by a number of factors (National institute for occupational safety and health, USA, 2005), including declines in cognitive functioning, slower reaction times, diminishing vision, decrease in muscle strength, fatigue etc. Physical, cognitive, perceptual and psychomotor abilities start deteriorating from some stage in adulthood. Age is significantly related to deteriorations in speed and accuracy in performing complex tasks and older drivers have slower response times when compared to those under 50 (Popkin et al. 2008). The cognitive abilities that decrease with age and limit the driving ability if they degrade include decision making, depth perception, selective attention, attention sharing and information processing (Llaneras et al., 1998) along with working memory, reasoning, attention and processing speed. Working memory deficits are more striking when they process new or complex information or face unfamiliar contexts. Attention and perception decline when attention is divided and old workers face more difficulties especially when they work under severe time constraints and pressures or in situations under which their attention is likely to get diverted. Multitasking, ability to handle visual and auditory inputs simultaneously, cognitive functions and executive functions, such as situational awareness, prioritization, planning, execution, thinking ahead, reasoning etc. get affected the most by age.

In this study the performance of locomotive drivers in terms of cognitive and psychomotor abilities indicated decrement with increase in age, which suggested that for high demanding job of train driving relatively young drivers in the age group of 35 to 50 years appear suitable for better and safer operation of trains owing to their better performance on reaction time, form perception, concentration, judgment of speed and vigilance, as compared to older age groups. It has been reported that cognitive abilities start declining more significantly after 50 years of age (Verhaegen and Salthouse, 1997). WHO has also defined workers aged 55 years and above as old workers, who may be at risk for safety critical jobs including driving trains. But age in itself may not predict driving performance or may not affect their ability to work and also large individual differences do exist (Makishita and Matsunaga, 2008). Influence of age related changes in performance on safety critical work of train driving potentially leads to increase in the risk of unsafe working and accidents, but age alone does not play the role. For any decrease in performance to become safety critical, a number of other conditions including high demand job, unhealthy workforce, lack of expertise and experience and poor adaptation to work contribute. High demand safety critical jobs include specific job demands which comprise a combination of physical, cognitive, social and psychological demands that come collectively under the purview of work ability, which is a dynamic process that changes throughout life (Bohle et al., 2010; Costa & Satori, 2007). The critical factors that predict work ability (Ilmarinen, 1997; Bohle et al., 2010) include physical and cognitive demands of work, physical and psychosocial work environment, stressful work environments, risk of accidents, recognition and esteem at work, upkeep of work-related skills, supportive resources and general wellbeing, health status and functional capacities of individuals.

Work demands and work environment have the strongest influence on work ability. Also, there exists a complex relationship between occupational safety, health and age and the extent of decline in relation to age depends on many factors. Moreover, association between age, performance and working in different time schedule is significantly relevant in the context of driving trains. The critical age for increasing intolerance to night work has been reported to be between 45 and 50 (Bohle et. al., 2010). Work ability is found to be at lower level in the shift workers than in the day workers and this effect is most pronounced in older workers, who remain at greater risk during night working. It is difficult for them to maintain performance during night and they are intolerant to cope with successive night duties (Folkard, 2008). Night and rotating duties make their sleep problematic during daytime, leading to sleepiness on the following night duty and increased risk of accidents at work (Duffy, 2003). The workers who work in different time schedule face a general problem – they experience sleepiness at night and difficulty in sleeping during the day, which is typically worse in older workers because of their reduced ability to sleep at adverse times owing to the effects of instinctive circadian rhythmicity that promotes wakefulness during daytime and sleep during night. The impact of night working on

alertness of drivers has also been found in one of the experimental studies conducted by this Directorate (Study Report No. 38, 2014).

Role of experience

In this study locomotive drivers in the age range of 35-50 years with 10-15 years of working experience performed better on the attributes of reaction time, form perception, concentration and judgment of speed than those having less experience. Among them those who had diploma/degree/ITI as their educational qualification and had up to 15 years of experience exhibited much better on the five attributes across all experience groups, whereas performance of non-matriculate drivers had been poor despite having 15-20 years of experience. The effect of experience on performance has been better as the experienced drivers had developed expertise of train driving through continuous practice, which made their driving skill more consistent. In fact, experience is the knowledge and skill of doing some job and it is gained through exposure to that particular job, whereas learning that leads to experience is a change in knowledge and skill produced by experience. In context of a particular nature of job both supplement each other. Learners and experts differ in their ability to process information which influences their performance and this ability is based on experience that comes through learning. Also, there exists a strong relationship between cognitive ability, job knowledge and performance (Schmidt, Hunter & Outerbridge, 1988; Hunter, 1993; Hunter & Schmidt, 1996). One of the most important mechanisms by which cognitive ability impacts job performance is through learning of job related knowledge and skills, which is possible by experience gained while on job. Learning and experience use cognitive arrangements of both automated procedural knowledge (how things are done) and conscious declarative knowledge (why things work as they do) together to facilitate execution of complex tasks and this helps in counterbalancing the effect of aging (Tsang & Voss, 1996). Experienced persons have well organised mental frameworks that are pattern oriented, hierarchical and multi-layered, whereas learners lack them (Mc Keithen et al., 1981; Wiedenbeck et al., 1993). This difference indicates positive effect of experience on performance and explains why the performance of experienced workers is better.

Role of education

Education facilitates cognitive processing and better cognitive performance. It increases old age memory and executive functioning by developing a variety of cognitive skills that produce improved performance of intellectual ability. Sensitivity to verbal associative and acoustic attributes happens to be more in educated persons as compared to those who are less educated (Hall, 1972). It was found in this study that the performance of drivers possessing professional and higher educational qualification such as ITI, diploma, degree, graduation was better than their counterparts having less education. ITI drivers had better overall performance as compared to others. These results indicate that education is correlated with cognitive performance and are in conformity with findings that education plays an important role in cognitive performance of an individual. Better performance in cognitive domains including working memory, verbal episodic memory, verbal processing speed and verbal fluency is strongly related with the number of years in education. Significant effect of education has been found on most neuropsychological performances, particularly in high-attention-demanding tasks, where improving cognitive skills is needed for successful performance of job. The effect of education is also on the cognitive reserve, which is explained by an increase in controlled processes and conceptualization abilities, the two cognitive components that get influenced by high attention demanding occupations including driving (Le Carret et al., 2010). In the present study it has been noticed that within the same age group, the drivers with higher education performed better than their colleagues having less education, which may be probably due to better cognitive reserve in highly educated group. In contrast to less educated people, highly educated persons engage in intellectual activities, not rigidly predetermined by the structure of task. Cole, Sharp & Lave (1976) observed that it is not differences in the information about the stimuli per se, but differences in what people do with commonly available information that is critical to performance on a wide range of cognitive tasks. Memory training interventions have demonstrated that elders, like young adults, can improve their performance on cognitive tasks including perceptual discrimination, visual search, recognition, recall, and spatial perception (Kramer et al., 2004), as these trainings teach mnemonic strategies, concentration and attention, relaxation, insight, self-monitoring, motivation, feedback and problem solving, that improve memory performance (Owsley et al., 2004). In this perspective the role of education in facilitating trainability of people at their workplace also becomes relevant. Not only that, people with high educational levels have a lower risk of developing dementia than those with low educational level and this protective effect delays the cognitive and functional expressions of neurodegenerative illnesses.

Compensatory factors

Cognitive and physical abilities decline with increase in age, but these do not necessarily have a negative impact on performance at work. Age and experience are highly correlated and it is difficult to disentangle their separate effects on performance (Becker & Milke, 1998). It is not inappropriate to assume a simple correlation between age, cognitive declines and driving performance. Experienced people conceptualize their capabilities and task (Norman, 1983) and use the mechanisms of mental models to understand domain specific knowledge, commit very few errors and solve the problems in a better way (Staggers & Norcio, 1993). They compensate for age related changes using their expertise, domain specific experience and automaticity which get developed through continuous practice and experience. These abilities in an experienced workers have their own advantage – they require little attentional resources, do not get affected by cognitive control and make the constituent processes of tasks autonomous, quick and efficient. Severity of the impact of age on cognitive and psychomotor performance is mitigated by several factors including experience, education, job knowledge, domain specific expertise, automatic and knowledge based crystallized abilities that increase with age and experience (Silverstein, 2008) and have compensatory roles. Adaptations to work and workplace also play an important compensatory role. Performance of experienced workers does not get much affected by ageing effect on cognitive decline also because they formulate strategies based on experience, education, high motivation, better judgment and job knowledge to acquire new skills and learning (Schweiger et al., 1985) in such a way that they compensate reduction in their capability and reduce cognitive demands for some job specific situation. Moreover, there exist large variations between the functional capacities of individuals having the same chronological age, because age in itself is not a strong determinant of health, cognitive and physical abilities, safety performance, work ability and productivity (Yeomans, 2010). Age related declines in physical and cognitive ability could be safety critical, but do not necessarily have negative impact on performance, particularly when the abilities are matched with job requirements and expertise is taken into account. Older drivers can adapt to change, perform new skills and remain capable of learning, the speed of which may be slow on account of age, but additional time, tailored support, education and training can be helpful in enhancement of abilities related to learning speed, reasoning and memory (Yeomans, 2010). Age related deterioration in cognitive and psychomotor performance can be compensated with efficient management strategies and expertise developed through experience and training on domain relevant tasks (Taylor et al., 2005). Psychomotor abilities may not be as critical as cognitive abilities and accuracy in decision making, as they can be reduced by automatic transmission facilitated by technologically advanced and user friendly electronic equipments. In the present study compensatory role of experience in older drivers belonging to the age group of ≥ 50 years with > 10 years of working experience could not be traced on overall performance, which indicated the need of effective training, counselling, skill development and psycho-intervention programmes for enhancing the compensatory role of experience in aging population of drivers, which could improve their perceptual, cognitive and psychomotor abilities, making them equitable with younger locomotive drivers.

III. Conclusion

Abilities and skills of locomotive drivers for interacting with various auditory and visual stimuli, quick differentiation and discrimination for prompt processing of various information, organising appropriate sequence of activities, many of them being simultaneous, and taking prudent decisions while driving trains as per the stipulated safety rules and procedures becomes determining factors for efficient train operation. Human reliability becomes safety critical with respect to cognitive, psychomotor and behavioral abilities so as to ensure safety in train operation. In this perspective it needs to be ensured that the drivers possess adequate mental skills and are capable of their application by synchronising cognitive, psychomotor and personality attributes with technological advancements for maintaining excellent safety standards. Old age impact the abilities of locomotive drivers, but its impeding effect can be compensated well by development of expertise and skill, which if nourished and nurtured by organizational ingenuity can be advantageous. The attributes simply form strings of mental framework which need strengthening by means of developing expertise and automaticity through adequate driving experience. Acquaintance with technological advancements, training and organizational initiatives for better work-life balance, enabling them to maintain good mental health and sustenance of cognitive attributes, may be of great help in facilitating cognitive processing, situational awareness and quicker response.

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