Acta Neurophysiologica
ISSN: 2996-7554

Academic Strive
Researcher's perception is our reality

Research Article *Volume 5 Issue 3*

Anti-Ageing of Executive Functions: Insights from a Study on Air Traffic Controllers

Taukari A*

Department of Psychology, KJ Somaiya College of Arts & Commerce, India

***Corresponding author:** Atish Taukari, Professor in Psychology & Dean, KJ Somaiya College of Arts & Commerce, Mumbai, India, Email: atish@somaiya.edu

Received Date: August 22, 2024; **Published Date:** September 11, 2024

Abstract

The study investigated executive functioning in air traffic controllers. Controllers (N=50) whose job involves multi-tasking in dynamic and complex environment showed significantly better executive functioning than general population ($t=8.85$, $p < 0.01$). The negative impact of aging on executive functioning is mitigated in controllers ($R2=0.10$, $F=5.49$, $p < 0.02$) but not in normal. Demand on visuo-spatial abilities seems to boost prefrontal cortex functioning in controllers who were better compared to general population in rule shifting, action planning, spontaneous planning, and allocation of attentional strategies. Further, their job-context demands conscious deliberation and attentional control. Controllers show high adaptability, higher level of attained skill, and better mental imagery. Their ability to detect conflict and predict trajectory, categorize aircrafts in meaningful units might give them advantage in executive functioning. Executive functioning in controllers increased with their increasing job experience ($R2 = 0.11$, $F= 6.15$, $p < 0.01$) whereas it decreased in general population ($R2 = 0.05$, $F=2.83$, $p < 0.09$) though statistically non-significant. Expert controllers showed significantly better executive functioning than novice controllers ($t= 3.15$, $p < 0.01$). This may be due to numerous and various factors such as: their specific experiences in the domain, personal style of controlling air traffic, number and diversity of strategies, increased patterning ability, abstractions, recollection and condensation of occurrences experienced, large data base of chunks, recognition of perceptual patterns, development of templates, retrieval structures, gist of traffic situations, deliberate practice, perceptual structures, traffic situations as dynamic complexes, very specific type of knowledge and mode of perception, organized set of response strategies, metacognitive abilities, qualitative differences in memory performance, and having a large stock of appropriate routines to deal with a wide variety of contingencies. Complete absorption involving total attention on task seems to boost executive functioning in controllers. The various executive functions measured are fractionable, so there is no single omni-competent homunculus.

Keywords: Executive Functioning; Air Traffic Controller

Abbreviations

ATC: Air Traffic Control; BADS: Behavioral Assessment Of Dysexecutive Syndrome; DEX-SR: Dysexecutive Syndrome-Self Rating.

Introduction

In approaching the issue of control and regulation of working memory, various models of working memory, explicitly postulate a central control mechanism with sub- functions

such as attention and inhibition, task management, planning, and monitoring. The production- system models postulate that control and regulation of working memory contents and cognitive behavior emerge naturally as a consequence of the dynamic interaction between productions and working memory elements. Auto-control models view executive control as an emergent property and emphasize the dynamic interaction among the subcomponents or sub modules of the cognitive system [1].

The central executive, though the boss of our brain and super-coordinator is late to mature and early to retire. However, can this early ageing of executive functioning be reversed? The study on executive functions in people who are actively involved in it on a regular basis in real life situation can provide some insight. The study on controllers working in air traffic control (ATC) domain can be the best fit. ATC domain demands totality of human cognitive processes into consideration and how they occur in a co-coordinated manner. Therefore, unified account of cognition is possible to study by understanding executive functioning in controllers. In ATC, routine and automatic activation of behavior is not sufficient and require controlled cognitive processing while planning, decision-making, scheduling novel sequences of actions, and overcoming strong habitual responses. It is evident in the following complex conceptual model of controllers mental processes [2] as it occur when controller works on the radar.

The modules: data, data selection, anticipation, conflict resolution, update, sector knowledge and control operate in the centre of the system the picture, a working memory representing the controlled situation. The information processing cycle comprises, first, the data selection (via radar, flight strips, etc.) and updates adapt the picture to the continuous change of aircraft positions. The second, anticipation cycle, anticipates future states of each attention demanding aircraft or aircraft relation separately to avoid conflicts. In the third, conflict resolution cycle, several steps are initiated in case of an impending conflict where the control module determines the sequence of procedures. The coordination of all these cycles is driven by control procedures. On the basis of the state of picture, control procedures select the most important and most urgent processing demand. Thus, scheduling of processing is determined by the state of the whole mental representation of the traffic situation (Figure 1).

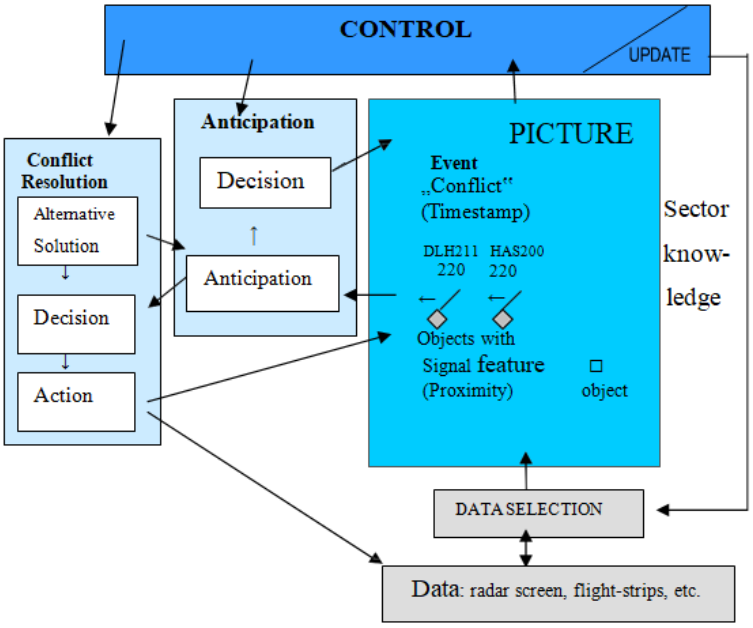

Figure 1: The flow of information [2].

In summary, multiple higher order cognitive processes involved in scheduling and executing of ATC tasks suggest active involvement of executive functioning. The study of relationship between various executive functions to know if they are fractionable can throw light on homunculus problem, i.e. how the little person in the brain makes complex decisions. The study explored whether the aging of executive functioning in controllers can be mitigated, contrary to its

negative effect in general population. The real-life complex task experiences in ATC are expected to enhance controllers executive functioning.

Methodology

Sample

A total of 100 participants were randomly identified. They had no history of mental illness. The first group was of 50 (male) full-performance level controllers. The mean age was 37.84 years and the average level of education of this group was 16 years and average work experience was 13 years. The other group from general population was of 50 (male) with average educational level of 11 years.

Procedure

All tests were administered individually as per standard instructions. The behavioral assessment of dysexecutive syndrome (BADS) battery and dysexecutive syndrome-self rating (DEX-SR) scale took approximately 70 min.

Instruments

BADS: It assesses everyday problems arising from dysexecutive syndrome. It contains following six tests as follows. Rule shift card test: It examines subject's ability to respond correctly to a rule & to shift from one rule to another. Action program test: It is a novel, practical task that required the development of an action plan in order to solve a problem. Key search test: It enables to know subjects ability to plan an effective & efficient course of action. Temporal judgment test: It examines ability to make judgments of time. Zoo map test: It measures the ability of subject to minimize errors by modifying their performance on the basis of feedback. Modified six-element test: It measures attention allocation strategy used in terms of how well the subjects organize themselves in performing various tasks.
DEX-SR Scale: It measures various problems associated with dysexecutive syndrome.

Result & Discussion

The key findings of the study were as following. General population showed mild level of impairment of executive functioning even when influence of aging was removed. Impairments of the executive systems in normal states and non-clinical population have been reported [3]. On the other hand, controllers showed intact executive functioning even when influence of age was removed. Controllers work experience demanding visuospatial abilities in complex hierarchical system seems to boost performance of prefrontal cortex leading to significantly better executive functioning. Controllers were significantly better than general population ($t=8.85$, $p<0.01$) in abilities to respond correctly to a rule and to shift from one rule to another, develop a plan of action in order to solve a problem, plan an effective and efficient course of action and monitor one's own performance, plan spontaneously and minimize errors by using feedback, & allocate attentional strategies in performance of various tasks.

The everyday job-life of general population appears to be not much conductive in enhancement of executive functioning. On the other hand, controllers job predominantly demand attentional control because they must be aware of the changing and evolving traffic situation and important aspects of situation. Further, they need to project future traffic situation so that possible conflicts of aircrafts can be avoided on time. Their content of memory is highly demanding since any minor error could lead to disasters in ATC and hence it is expected to put additional demands on the central executive. Mental imagery of controllers may be more vivid than normal people [4] and they can remember aspects of their mental picture for some time even after radar display failure and can remember key aspects many hours later [5]. Controllers group aircrafts into two categories, conflicting and other into sector events to reduce the representations of aircrafts in working memory by grouping aircrafts into larger and meaningful units [6].

Controllers could remember aircrafts relative to one another in pattern and according to their importance in the task. The aircraft were not remembered by their spatial positions but in relation to each other. They remembered items that were most relevant in doing the task and partly because they are used more frequently in doing the job, but they also remembered them in a way that was organized by and in relation to the task thinking and decisions. The knowledge of the present situation would best be structured in a way that indicates the most relevant comparisons between aircraft, so reducing the amount of mental work to be repeated later [7]. Controllers are capable of employing unique strategies in order to ensure that task performance is not compromised [8]. They have thoughts about themselves and their ability to cope with traffic situation which include factors such as confidence, perception of work load, how situationally aware they feel, which are termed "Picture of Self" in the enhanced information processing model [5]. Thus, controllers show advantage in executive functioning over general population due to the strategies they use to meet demands of complex multi-tasking.

The further analysis of data showed that executive functioning in controllers increasing with their increasing job experience ($R2 = 0.11$, $F= 6.15$, $p < 0.01$), but not in general population whose jobs are not complex. Next, controllers show expert performance in executive functioning as their score (Mean =90.38) is almost two SD (2x13.04= 26.08) above the general

population (Mean=64.82). Further, expert controllers showed significantly better performance than novice (or less experienced) controllers (t=3.15, p< 0.01). With experience controllers become better at scheduling and prioritizing tasks, and learn to cope with higher task demands. Recognizes nuances of problems that affect their categorization and solutions, and learns to plan further in advance and to consider strategic as well as tactical implications. Controllers experience is helpful in the early diagnosis of air traffic problems, in identifying the more extensive consequences of particular actions, and in learning to avoid non-optimum solutions even if their adverse effects are only trivial. Self-monitoring, though never infallible becomes more helpful in error prevention because experience teaches when extra care and cross checking are most needed [4].

Number and diversity of strategies is to be greater for more experienced controllers that enable them to attain performance that was greater than less experienced controllers [8]. Experienced controllers classify the aircraft into two samples based on various parameters. One group contains aircrafts that have to be further analyzed and anticipated in order to check for future conflicts or a further monitoring demand. On the other hand, the other group contains the aircrafts that are separated at that moment [6]. Thus they can attend things that are important to attend at that moment and thus efficiently use limited attentional resources. A highly experienced controller can remember more items because such person knows the task operations efficiently well to recognize patterns between aircrafts rather than remembering each aircraft individually. This increased patterning ability is an important aspect of advanced skill, and can continue to develop over many years of experience [7]. Thus, complex air traffic control tasks are managed by human operator through mental "patterns of organization" developed with experience consistent with Gobet F [9] review of expert memory.

The traffic situations that controllers experience extensively are chunked. Chunks are then developed into templates. Templates, which are specific to certain types of traffic situations, contain at their core a large chunk. Chunks are automatically activated by the constellation on the external radar screen and trigger potential moves that will then be placed in short term memory for further examination, consistent with Gobet F [9] review. Controller's experiences specific to their domain can enhance their executive functioning to the extent of expert level. Expert controllers respond not just accurately but also rapidly in dynamically changing situations. A skilled controller perceives and encodes current situation and also executes action or series of actions rapidly consistent with Ericsson KA, et al. [10] theory of expert performance. The organization of knowledge may allow experts to store the gist of a traffic situation, instead of its perceptual layout. Their memories may be richer and highly organized and that they are more general than specific and may be encoding traffic situations as dynamic complexes rather than isolated pieces. The knowledge gathered during study and practice of the job may develop into controller's perception of a traffic situation as large units and the ability to rapidly zero in on the core of traffic situation. Expert controller's superiority may not be due to a general knowledge of first-order probabilities of traffic situation, but by a very specific type of knowledge that is actualized during the recognition of typical information. The necessary condition to reach master ship includes a schooled and highly specific mode of perception and a system of methods stored in memory and rapid accessibility. Experts differ not only in the quantitative amount of knowledge, but also in its qualitative organization, consistent with Gobet F [9] review.

Expert controller's eye movement's fixation may be shorter, show less variance, cover more of radar screen, and cover more important traffic situations than novices‟ fixation. Access to chunks and templates should be automatic, without recourse to any conscious process, and possible even with very short presentation times consistent with Gobet F [9] review of chess expertise that can fit to air traffic control experts. Expert is able to circumvent limits on basic serial reactions by anticipating events and skillfully coordinating overlapping movements. Consistent with Ericsson KA, et al. [10] theory of expert performance, controller's superior short term memory for aircrafts and their positions and other associated variables may be due to their ability to recognize configurations of aircrafts on the basis of their knowledge of vast numbers of specific patterns of aircrafts. Expert controller's superior memory for aircrafts position on radar even when presented for brief period may not be due to any general mental ability (like photographic memory) but depends critically on subject's ability to perceive meaningful patterns. Next, the acquisition of memory skill in organizing acquired knowledge and refining of procedure and strategies allows expert controller's to circumvent limits on working memory imposed by the limited capacity of short-term memory. The traditional assumptions of basic abilities and capabilities don't generalize to superior performance in specific domain. Laboratory studies have demonstrated an increase in the speed of perceptual motor reactions as a direct function of practice Ericsson KA, et al. [10]. Further, expert show meta- cognitive capabilities that are not present in novices. It include knowing what one does and does not know, planning ahead, efficiently apportioning one's time and attention resources and monitoring and editing one's efforts to solve a problem. Once attained, expertise has to be actively maintained [11].

Controllers executive functioning is increasing with age ($R2 = 0.10$, $B= 0.54$, $F=5.49$, $P < 0.02$) whereas in Controls it is decreasing ($R2 = 0.08$, $B= -0.43$, $F=4.30$, $P < 0.02$).

The process of gathering experience and knowledge counterbalances mental ageing. Experience could mitigate the effect of age-related decline of performance (quantified by time & accuracy) on air traffic control task [8]. Expertise compensates age related declines in resources when the task is highly domain relevant. The decline in expert performance in old age is often relatively slight in many domains and importantly, expert performer's show an ability to maintain a very high level of performance during ages when beginners and less accomplished performers display clear effects of aging suggesting that experts generally age more slowly than other performers, and thus no observable impairments would be expected. However, this seems true (at least) to relevant tasks in the domain of expertise Ericsson KA, et al. [10]. Experts could circumvent many of the intrinsic limitations, in the same manner expert may also circumvent many of the performance declines associated with the natural process of aging. Further, many cognitive functions tend to decline with age; experience and skilled performance tend to increase. Expertise could mitigate certain age-related declines by circumventing certain intrinsic processing limitation [11]. Various executive functions measured by various tests in BADS battery are fractionable as no significant correlation was observed between most of the executive functions (Table 1). Overall, various executive functions are independent and may run parallel. However, all these processes are occurring in single human brain in a coordinated manner. Thus, there is no single almighty Omni-competent homunculus.

BADS tests	T1	T2	T3	T4	T5	T6
Rule Shift (T1)		0.06	-0.15	0	0.06	-0.14
Action Program (T2)			0.15	0.31**	-0.14	0.03
Key Search (T3)				0.27*	-0.01	0.13
Temporal Judgment (T4)					-0.22	0.12
Zoo Map (T5)						0.17
Modified Six Element (T6)						

Table 1: Fractionation of executive functions.

Conclusion

The study shows that controllers show better executive functioning than normal population and executive functioning is significantly improving with increasing job experience that can mitigate the negative impact of aging. Thus, ageing of cognitive (executive functioning) can be arrested and even reversed and domain of air traffic and its‟ expert can provide ways to do that.

References

1. Miyake A, Shah P (1999) Models of working memory: Mechanisms of active maintenance and executive control. Cambridge University Press.

2. Eyferth K, Niessen C, Spaeth O (2003) A model of air traffic controller's conflict detection and conflict resolution. Aerospace Science and Technology 7(6): 409-416.

3. Chan RCK (2001) Dysexecutive syndrome among a non-clinical sample: A study with the use of the dysexecutive syndrome questionnaire. British Journal of Psychology 92(3): 551-565.

4. Hopkin VD (1995) Human factors in air traffic control. CRC Press, London.

5. Issac A, Shorrock ST, Kirwan BC (2002) Human error in European air traffic management: the HERA Project. Reliable Engineering and System Safety 75(2): 257-272.

6. Niessen C, Eyferth K (2001) A model of the air traffic controller's picture. Safety Sciences 37(2-3): 187-202.

7. Bainbridge L (1975) Working memory in air- traffic control.

8. Nunes A (2004) An empirical investigation into the effects of controller experience on conflict detection ability under free flight. Proceedings of the human factors and ergonomics society annual meeting 48(1): 161-165.

9. Gobet F (1998) Expert memory: a comparison of four theories. Cognition 66(2): 115-152.

10. Ericsson KA, Charness N (1994) Expert performance: Its structure and acquisition. American psychologist 49(8): 725-747.

11. Tsang PS (2003) Assessing cognitive aging in piloting. In Tsang PS, et al. (Eds.), Principles and practice of aviation psychology, Lawrence Erlbaum Associates Publishers, Mahwah, pp: 507-546.