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AGE AND EXPERIENCE BASED NEUROCOGNITIVE PERFORMANCE OF SEAFARERS

ABSTRACT

The main purpose of this study to assess the age-related cognitive decline rates and cognitive performances of the seafarers who belongs the different experience levels and age groups. ANAM4^{R} computerized cognitive test batteries were applied to determine the cognitive competencies and performances of the seafarers. Results were examined separately for each test using descriptive tables, one-way ANOVA test and The Tukey post-hoc test. Significant differences were found among groups in terms of cognitive abilities ($p<.05$). In all tests, oceangoing masters have the lowest mean accuracy score and represent the highest risk group for the possibility of human induced errors occurrence due to cognitive impairment. A direct relationship between cognitive performance decline and aging was detected in all cognitive tests.

Keywords: Cognition, Seafarers, Neurocognitive Tests, Maritime, Cognitive Abilities,

GEMİADAMLARININ YAŞ VE DENEYİME DAYALI NÖROKOGNİTİF PERFORMANSI

ÖZ

Bu çalışmanın temel amacı, farklı deneyim seviyelerine ve yaş gruplarına ait gemiadamlarının yaşa bağlı bilişsel gerileme hızlarını ve bilişsel performanslarını değerlendirmektir. Gemiadamlarının bilişsel yeterlilik ve performanslarını belirlemek için ANAM4^{R} bilgisayar temelli bilişsel test bataryaları uygulanmıştır. Sonuçlar, her bir test için betimleyici tablolar, tek-yönlü ANOVA testi ve Tukey post-hoc testi kullanılarak incelenmiştir. Bilişsel yetenekler açısından gruplar arasında anlamlı farklılıklar elde edilmiştir ($p<.05$). Tüm testlerde, uzakyol kaptanları en düşük ortalama doğruluk skoruna sahip olmuş ve bilişsel bozulma nedeniyle insan kaynaklı hataların oluşma olasılığı en yüksek grubu temsil etmişlerdir. Bütün bilişsel testlerde, bilişsel performans düşüşü ile yaşlanma arasında doğrudan bir ilişki saptanmıştır.

Anahtar Kelimeler: Bilişsellik, Gemiadamları, Denizcilik, Bilişsel Yetenekler, Nörokognitif Testler

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1. INTRODUCTION

The term "human factor" as a multidisciplinary field is mostly identified capabilities and limitations of individuals and interaction of these individuals with each other, equipment, facilities and management systems. This concept aims to generate safe, comfortable, and effective human performance within a task. In maritime domain, in which ninety percent of world trade is carried out, human factor is also an increasingly important topic. Studies consistently emphasize that almost eighty percent of all maritime accidents were attributed to the human factor. These accidents can result in loss of life, environmental damages and serious financial costs at sea. Although international maritime organization (IMO) puts into force strict regulations and international safety management systems (ISM), accidents continue to be repeated in various maritime operations such as navigation, cargo handling, maintenance and ship management [1 and 2].

Maritime human factor researches are typically conducted on analysis of accident reports and they all definitely rely on a fact that humans as operational member of a system- are prone to make error [3]. Errors can be categorized into four groups as slips, mistakes, lapses, and violations. However, the main question is what the risk level of these errors. Answer of this question may be given by understanding of the nature of tasks and assessing the level of criticality of the errors, which is a function of the variables in an operation such as fatigue, environmental conditions, workload and psychological/physical state of the individuals and communication [1 and 4]. In this regard, human-based errors can also be arisen from the loss of information during the information processing cycle in human brain. Thus; sustaining concentration on a duty, performing a given task, perceiving spatial features of objects, storing information or making decisions based on problem is a function of capacity of information processing which can also be defined as cognitive ability [5]. Cognitive abilities of seafarers are likely to play a vital role in maritime operations and the best indicators of occupational and educational performances of individuals [6].

Although cognitive abilities of individuals such as reaction time, learning, spatial processing, memory and attention plays a key role for safe, comfortable, and effective work performance, age-related cognitive decline is a common human fact. In the literature, there is a lack of consensus on when age-related cognitive functioning decline. While some studies state that age-related cognitive decline begins relatively middle age onwards, or even earlier depending on many variables, other ones point out there is no or a little drop in cognitive performance before the sixties [7 and 8]. The reasons of these differences are not fully clarified but researches are mainly carried out on biomedical and neuropsychological fields considering diseases, health conditions, genetic contributions, socio-demographic factors, lifestyles and habits such as smoking, exercise, diet [9]. In the process, each cognitive ability shows different characteristics in respect to rate of cognitive decline [9 and 10]. The usage of standardized neurocognitive tests is the primary way to analyze these differences and evaluate cognitive performances of individuals in an operation [11].

2. RESEARCH SIGNIFICANCE

This paper contributes to the literature on cognition of seafarers who actively working at sea. The aim of this study to comprehensively monitor and compare the age-related cognitive decline rates and cognitive performances of the seafarers who belongs the

different experience levels and age groups. For this purpose, a particular ANAM4^{R} battery consists of seven tests including 2-choice reaction time, code substitution–learning, code substitution – delayed, spatial processing, mathematical processing, running memory - CPT and stroop was applied to oceangoing masters, oceangoing chief officers and oceangoing watchkeeping officers. This paper is divided into four chapters. In the introduction part, the human factor and cognition literature that motivate us for this research are given. Secondly; features of participants, data collection process and statistical method are explained. In the third part, results are introduced. Lastly a brief conclusion is presented.

3. METHOD

3.1. Participants

Research is mainly conducted on three main groups including 35 oceangoing masters (aged from 33 to 54), 46 oceangoing chief officers (aged from 28 to 39) and 55 oceangoing watchkeeping officers (aged from 22 to 31) in order to analyze cognitive competencies and performances of seafarers by using neurocognitive tests. This group consisted of 34 women (mean age:27.2, range:22-36 years) and 102 men (mean age:33.0, range:22-54 years). These individuals have same education level (graduate) and no significant history of neurologic injury or disease. All participants are volunteers and received no immediate benefits from participating in this study.

3.2. Data Collection and Procedure

Data were collected by Automated Neuropsychological Assessment Metrics (ANAM4^{R}) which is computer-based software cognitive test library patented by the U.S. Army in the late 1970s. ANAM4^{R} cognitive assessment tests are mainly used to determine the cognitive changes of individuals using the elements such as speed and accuracy of memory, attention, reaction time, concentration with millisecond sensitivity especially in clinical and military domains [12]. ANAM4^{R} consists of 30 cognitive tests which enable to collect data for assessing the cognitive status and neuropsychological functions of individuals in a given time. Users can create special batteries (subtests) which are a compilation of two or more ANAM4^{R} tests for specific purposes. Each ANAM4^{R} battery consists of a collection of pre-selected tests including demographics module, sleepiness scale and symptoms checklist that are administered in a sequential manner. These pre-selected tests allow optional entry of a wide variety of information including participant's age, gender, ethnicity, medical diagnosis, medications, current level of sleepiness and frequency and severity of subjective symptoms that the researchers find useful. Performance results of the participants are presented in ANAM4^{R} Performance Report which is designed to provide a summary snapshot of a single ANAM4^{R} test session. ANAM4^{R} Performance Validity Report is also another tool to identify participants who may not have properly understood the test instructions necessitating and confirm that participant scores by calculating the ANAM4^{R} Performance Validity Index and highlighting other validity indicators [12 and 13].

During the study, a particular cognitive test module consists of 2-choice reaction time, code substitution–learning, code substitution-delayed, spatial processing, mathematical processing, running memory-continuous performance task and stroop tests were applied to participants by the same trained moderator each lasting approximately five minutes. These cognitive tests were administered to the participants in a convenient laboratory environment enable to concentrate solely on the tests while seated at a wide-screen desktop

computer, using the handheld mouse. A practice test was applied to the participants before each actual test to ensure that test characteristics properly understood. An ANAM4^{R} battery selected from the following tests were applied to the participants in the current study:

- **2-Choice reaction time:** This test results are used to measure an individual's processing speed and alternating attention with a motor speed component. The test presents the users a series of (*) and (o) stimulus on the screen. The user is directed to respond by pressing the designated button for each stimulus as soon as the symbols appear on the screen.
- **Code substitution–learning:** This test assesses visual scanning and perception, attention, information processing speed and associative learning. During the test, a set of digit-symbol pairs (the key pairs) presented at the top of the screen. Participants must compare a displayed digit-symbol pair with given digit-symbol pairs and press the assigned buttons to indicate whether the pair is correct or incorrect as fast as possible. The number of correct symbols and response times are recorded by the test.
- **Code substitution–delayed:** This neurocognitive test is applied to evaluate learning and delayed visual recognition memory immediately after the code substitution–learning test. The key digit-symbol pairs in the code substitution–learning test are removed and a series of digit-symbol pairs are given in succession at the bottom of the screen. Individuals are asked to decide whether given digit-symbol pairs match with the key digit-symbol pairs from their memories. Users press the designed buttons if the pair match or not as quickly as possible.
- **Spatial processing:** This test relies heavily on visual spatial skills, selective attention and mental rotation. During the test, two four-bar histograms are presented on the screen, one is displayed upright and another is displayed after a 90-degree rotation either clockwise or counter-clockwise. Individuals must press designated buttons to state if the two histograms are the same or different, regardless of the orientation.
- **Mathematical processing:** The results of this test are used to evaluate basic computational skills, concentration and working memory of the individuals. During the task, user is instructed to solve three single-digit arithmetic equations that include subtraction and/or addition (e.g. "6-2+3=?). The test is completed by clicking right or left button of the mouse whether the answer is greater or less than 5, respectively.
- **Running memory-continuous performance task:** This test is used to evaluate concentration, attention, and working memory skills of the individuals. During "Running Memory-CPT" test, single characters appear in the center of the screen in a randomized sequence. The user completes the test by pressing designated buttons, in the shortest time possible, to indicate whether the displayed character matches or does not match the preceding character.
- **Stroop tests:** "Stroop Color and Word Interference" is one of the most widely used test to evaluate processing speed, selective attention, and executive functioning. There are three blocks of trials for this test. In the first one, the words RED, GREEN, and BLUE are presented randomly in black type in the center of the screen. The participant is directed to read each word and to press a related key for each word (1 for RED, 2 for GREEN, 3 for

BLUE). In the second block, a series of XXXX's is demonstrated on the screen in one of three colors. The participant is instructed to indicate the color of the XXXX and to press the related key based on color. In the last block, a series of individual words (RED, GREEN, BLUE) are presented in a color that does not match the name of the color depicted by the word (e.g. the word "BLUE" appears in either red or green). The participant is instructed to press the response key allocated to that color. The test presents three separate scores based on the number of items completed on each of the three blocks. And it also provides an inter-score obtained from special calculation of these three scores (number correct on Lvl 3 (Color/Word trials) minus the predicted color/word score (predicted Color/Word score=[NumCorr Lvl1xNumCorr Lvl2]/[NumCorr Lvl1+NumCorr Lvl2]).

3.3. Statistical Analyses

In this study; means, standard deviations and frequency tables were used to define the sample including oceangoing masters, oceangoing chief officers and oceangoing watchkeeping officers. After that, analysis of variance (ANOVA) test was performed in order to determine the differences among these groups. The data were examined to ensure the assumptions of the one-way ANOVA test. No violations of the assumption of homogeneity of variance were present (Levene's test of homogeneity of variances significance value:$p>.05$) and data were approximately normally distributed (kurtosis [-1, +1] and skewness [-1, +1]) for each test. The confidence level is cited as 95 percent ($\alpha=.05$) for all analyses. Finally, The Tukey post hoc test was conducted to detect the groups that are significantly different from each other.

4. RESULTS

In order to assess the cognitive status of the seafarers who belongs the different experience levels (oceangoing masters, oceangoing chief officers and oceangoing watchkeeping officers) and age groups (range:22-54 years), a particular ANAM4^{R} cognitive test battery including 2-choice reaction time, code substitution–learning, code substitution–delayed, spatial processing, mathematical processing, running memory-continuous performance task and stroop color and word interference test. Test results were examined separately for each test using descriptive tables, one-way (ANOVA) test and The Tukey post hoc test.

4.1. "2-Choice Reaction Time" Test Results

2-choice reaction time test, which is conducted to evaluate processing speed and alternating attention skills, presents 40 stimuli that the participants must give reaction. Descriptive statistics of the test including the mean, standard deviation, standard error based on the response accuracy for each separate group are presented below.

Table 1. Descriptive statistics - 2-choice reaction time test

Explain	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Min.	Max.
					Lower Bound	Upper Bound		
Oceangoing Wacthkeeping Officer	55	38.9091	1.11010	.14969	38.6090	39.2092	36.00	40.00
Oceangoing Chief Officer	46	37.3913	.93043	.13718	37.1150	37.6676	36.00	40.00
Oceangoing Master	35	35.7143	.92582	.15649	35.3963	36.0323	34.00	38.00
Total	136	37.5735	1.62222	.13910	37.2984	37.8486	34.00	40.00

According the Table 1, oceangoing watchkeeping officers own the highest mean accuracy score (mean:38.9, SD:1.11) than the other groups. A linear decrease from oceangoing watchkeeping officers to oceangoing masters is observed in the mean accuracy value. ANOVA test results show that, there is a significant difference in terms of processing speed and alternating attention abilities among our group means ($F_{2,133}$:108.962, $p<.05$, η^2:0.62). The Tukey post hoc test also points out all groups are separated from each other statistically ($p<.05$ for each group). In this regard, oceangoing masters represent the highest risk group for the possibility of human induced errors occurrence due to cognitive impairment.

4.2. "Code Substitution-Learning" Test Results

Throughout the code substitution-learning test, which is administered to assess visual scanning and perception, attention, information processing speed and associative learning abilities, 72 digit-symbol pairs are submitted to participants that they must response. Descriptive statistics of the test are presented below for each separate group.

Table 2. Descriptive statistics - code substitution – learning test

Explain	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Min.	Max.
					Lower Bound	Upper Bound		
Oceangoing Wacthkeeping Officer	55	70.1091	1.30061	.17537	69.7575	70.4607	68.00	72.00
Oceangoing Chief Officer	46	68.6739	1.68726	.24877	68.1729	69.1750	66.00	72.00
Oceangoing Master	35	65.7714	1.71646	.29013	65.1818	66.3611	63.00	70.00
Total	136	68.5074	2.31580	.19858	68.1146	68.9001	63.00	72.00

As shown in Table 2, oceangoing masters have an observable decrease in the number of correct (mean:65.77, SD:1.71) compared to oceangoing watchkeeping officers and oceangoing chief officers. According to ANOVA test results, difference in terms of visual scanning and perception, attention, information processing speed and associative learning is identified among our group means ($F_{2,133}$:84.131, $p<.05$, η^2:0.55). The Tukey post hoc test shows that all groups differed from each other statistically ($p<.05$ for each group). In this respect, oceangoing masters can pose a risk in maritime operations that necessitate cognitive abilities represented by the test.

4.3. "Code Substitution – Delayed" Test Results

Code substitution-delayed test, which is applied to monitor learning and delayed visual recognition memory, presents 36 digit-symbol pairs to the participants immediately after the code substitution-learning test. Descriptive statistics including the mean, standard deviation, standard error, minimum and maximum values for each separate group are shown in Table 3.

Table 3. Descriptive statistics - code substitution – delayed test

Explain	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Min.	Max.
					Lower Bound	Upper Bound		
Oceangoing Wacthkeeping Officer	55	32.4545	1.86407	.25135	31.9506	32.9585	29.00	36.00
Oceangoing Chief Officer	46	30.8696	2.02878	.29913	30.2671	31.4720	27.00	35.00
Oceangoing Master	35	27.3429	1.69676	.28680	26.7600	27.9257	24.00	30.00
Total	136	30.6029	2.76828	.23738	30.1335	31.0724	24.00	36.00

When the mean number of correct responses are evaluated oceangoing watchkeeping officers get (mean:32.45, SD:1.86), oceangoing chief officers (mean:30.86, SD:2.02) and oceangoing masters (mean:27.34, SD:1.69) test scores. Age-related cognitive decline can be observed for the seafarers nearly in a linear manner. The mean scores of the groups have significant difference in points of monitor learning and delayed visual recognition memory according to ANOVA test results ($F_{2,133}$:79.649, $p<.05$, η^2:0.54). The Tukey post hoc test also indicates that all groups are separated from each other statistically ($p<.05$ for each group).

4.4. "Spatial Processing" Test Results

During the spatial processing test, which is used to evaluate visual spatial skills, selective attention and mental rotation, presents 20 pairs of four-bar histogram that the participants must give reaction. Descriptive statistics of the test including the mean, standard deviation, standard error based on the response accuracy for each separate group are presented below.

Table 4. Descriptive statistics - spatial processing test

Explain	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Min.	Max.
					Lower Bound	Upper Bound		
Oceangoing Wacthkeeping Officer	55	19.1273	.86184	.11621	18.8943	19.3603	17.00	20.00
Oceangoing Chief Officer	46	18.2391	1.09919	.16207	17.9127	18.5655	16.00	20.00
Oceangoing Master	35	17.1714	1.15008	.19440	16.7764	17.5665	15.00	20.00
Total	136	18.3235	1.28168	.10990	18.1062	18.5409	15.00	20.00

As seen in Table 4, spatial processing test has the minimum difference among the groups in terms of the cognitive characteristics of this test. All groups reach the maximum accuracy score of the test (20), but mean accuracy scores vary across these groups. Although the mean test scores of the groups are close to each other, ANOVA test results show that, there is a significant difference in visual spatial

skills, selective attention and mental rotation among our group means ($F_{2,133}$:39.254, p<.05, η^2:0.37). The Tukey post hoc test also indicates that all groups differed from each other statistically (p<.05 for each group). In this regard, the possibility of human induced errors occurrence rises from oceangoing watchkeeping officers to oceangoing masters.

4.5. "Mathematical Processing" Test Results

Mathematical Processing test, which is conducted to evaluate basic computational skills, concentration and working memory, submits 20 arithmetic equations that the participants must solve as quickly as possible. Descriptive statistics of the test are presented below for each separate group.

Table 5. Descriptive statistics - mathematical processing test

Explain	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Min.	Max.
					Lower Bound	Upper Bound		
Oceangoing Wacthkeeping Officer	55	18.2545	1.18974	.16042	17.9329	18.5762	16.00	20.00
Oceangoing Chief Officer	46	17.0435	1.26415	.18639	16.6681	17.4189	15.00	20.00
Oceangoing Master	35	15.3714	1.39507	.23581	14.8922	15.8507	13.00	18.00
Total	136	17.1029	1.70524	.14622	16.8138	17.3921	13.00	20.00

According to Table.5, oceangoing watchkeeping officers have the highest mean accuracy score (mean:18.25, SD:1.18) than the oceangoing chief officers (mean:17.04, SD:1.26) and oceangoing masters (mean:15.37, SD:1.39). When the mean scores are examined, age-related cognitive impairment of the seafarers can be observed easily. Especially, test performance of the oceangoing masters shows a distinct decline compared to other test groups. The mean scores of the groups have significant difference in points of basic computational skills, concentration and working memory in accordance with ANOVA test ($F_{2,133}$:55.191, p<.05, η^2:0.45). The Tukey post hoc test also shows that all groups are separated from each other statistically (p<.05 for each group).

4.6. "Running Memory CPT" Test Results

"Running Memory- Continuous Performance Task" test which is administered to assess concentration, attention, and working memory skills of the individuals, presents 80 stimuli that the participants must give reaction. Descriptive statistics of the test for each separate group are shown in Table 6.

Table 6. Descriptive statistics - running memory-CPT test

Explain	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Min.	Max.
					Lower Bound	Upper Bound		
Oceangoing Wacthkeeping Officer	55	77.5818	1.59503	.21507	77.1506	78.0130	74.00	80.00
Oceangoing Chief Officer	46	75.3261	2.37631	.35037	74.6204	76.0318	71.00	80.00
Oceangoing Master	35	71.0571	2.46078	.41595	70.2118	71.9025	68.00	76.00
Total	136	75.1397	3.34481	.28681	74.5725	75.7069	68.00	80.00

As observed in other cognitive tests, oceangoing masters have dramatic decrease in mean accuracy score (mean:71.05, SD:2.46) compared to other groups. Especially, the difference between oceangoing masters and oceangoing watchkeeping officers is much more than the differences between oceangoing chief officers and oceangoing watchkeeping officers. This gradual decline in concentration, attention, and working memory skills of the seafarers is also approved by ANOVA test results ($F_{2,133}$:101.632, $p<.05$, η^2:0.60). The Tukey post hoc test also indicates that all groups differed from each other statistically ($p<.05$ for each group). Similar with the other tests, oceangoing masters once more represent the highest risk group for the possibility of human induced errors occurrence.

4.7. "Stroop" Test Results

"Stroop" is the most commonly used test in psychology to assess processing speed, selective attention, and executive functioning for all age groups. This test consists of three blocks and generates an inter-score derived from the each of these three blocks. According to inter-score of each separate group, descriptive statistics of the test are presented below in Table 7.

Table 7. Descriptive statistics – stroop test

Explain	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Min.	Max.
					Lower Bound	Upper Bound		
Oceangoing Wacthkeeping Officer	55	17.3636	1.33837	.18047	17.0018	17.7254	15.00	20.00
Oceangoing Chief Officer	46	16.0217	1.54185	.22733	15.5639	16.4796	13.00	19.00
Oceangoing Master	35	13.8571	1.57448	.26614	13.3163	14.3980	11.00	17.00
Total	136	16.0074	2.02025	.17324	15.6647	16.3500	11.00	20.00

When the mean number of correct responses are examined, gradual decrease of test scores from oceangoing watchkeeping officers (mean:17.36, SD:1.33) to oceangoing masters (mean:13.85, SD:1.57) can be detected clearly. ANOVA test results show that, there is a significant difference in terms of processing speed, selective attention, and executive functioning performances among our group means ($F_{2,133}$:60.730, $p<.05$, η^2:0.48). The Tukey post hoc test also shows that all groups are separated from each other statistically ($p<.05$ for each group).

5. CONCLUSION

In this study, seven ANAM4^R cognitive tests including 2-choice reaction time, code substitution-learning, code substitution-delayed, spatial processing, mathematical processing, running memory-CPT and stroop were applied to measure cognitive performances of the seafarers who belongs the different experience levels and age groups. Based on the mean number of correct responses, a gradual decrease of test scores from oceangoing watchkeeping officers to oceangoing masters can be observed in all cognitive abilities such as memory, attention, reaction time. This fact can be consisted with the literature that advocates direct relationship between declines in cognitive abilities and age [9]. Statistical analyses also show that all groups differed from each other in all cognitive tests and most radical decreases are observed in processing speed, alternating attention, concentration and working memory skills of the seafarers. It is obvious that performing

a safe and effective task is in direct relation with cognitive competence required for the task. And deficient cognitive competence can increase the possibility of human induced errors occurrence.

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