The Influence of Age on Mental Workload in High Difficulty Assembling Plant: A Case Study at PT Surya Toto Indonesia

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Abstract

This research is a case study at PT Surya Toto Indonesia, a company engaged in the production of sanitary goods. Lot of activities in this company are done manually. The ages of the workers in assembling section range from 19 to 48 years old. The purpose of this study is to determine the relationship between the age of workers and the mental workload of workers in assembling difficult type products. This cross-sectional study was conducted in 2019 on 73 workers who participated in this study by filling out a NASA-TLX mental workload questionnaire. The results showed that assembling difficult type products had a high mental workload and mental workload of the middle age group is 7.5% higher than the young group. An analysis of the 6 NASA-TLX dimensions showed that effort was the mental load that most affected in both age groups due to monotonous work, high concentration levels, and musculoskeletal symptoms as a result of repetitive work. ANOVA showed that there was no effect of age on the 6 dimensions of mental workload of the assembling workers. The main source of mental burden for workers in assembling products is the behavior characteristic.

Keywords
Mental, workload, high difficulty assembling, NASA-TLX.

1. Introduction

Mental workload is a condition that could have a negative impact on the overall health of workers. Mental load is usually higher in jobs that involve cognitive processing, information processing and affective aspects such as tasks requiring high mental concentration, attention, memory, coordination, decision making or self-control. Mental load depends on the quantity and quality of information, and will increase with the complexity of the information. On the other hand, mental load can also increase in repetitive, monotonous and very alert work, where these workers can result in a state of saturation, drowsiness and decreased reaction capacity. Repetitive, monotonous and very vigilant work conditions are encountered in assembly work, especially in assembled products with various components and assembled components consisting of various types of products.

PT Surya Toto Indonesia is an Indonesian company engaged in the production of sanitary goods, toilets, plumbing, washbasins, showers, accessories and so on. This company still uses a lot of human labors, especially in assembling. The actual assembly process is highly influenced by human factors and removing the human aspect of assembly planning can lead to inefficient operations. Disregarding human aspect in assembly planning could result in incorrect or inefficient operations (Wei Gao, 2016). Assembling plant in PT. Surya Toto Indonesia is divided into 3 groups. Group 1 assembling the product with the easy type, where a maximum of 20 parts are assembled. Group 2 assembling products with medium type, where the parts assembled are 21-60 pieces. While group 3 assembled products with difficult types, where the parts assembled were 61-100 components. Products included in group 3 among others are bath spout, mixing valve, flush valve, thermostat, lavatory, floor standing, and global faucet products. For each product to be assembled, workers must memorize each part to be assembled according to the type of products to be produced. Group 3 workload is certainly higher than groups either 1 or 2, where a higher mental workload in this case is associated with more information processed per unit time (Klemmer, 1969). Therefore, the level of information processed per unit time during assembling process affects mental workload of the assembling worker. In addition, the components assembled in group 3 are prone to defects and require a longer inspection time. Workers in difficult type assembly consist of young and adult ages. Although the current literature shows that the brain's compensatory mechanism can fight cognitive decline due to aging at least to a certain level of task load, some symptoms of fatigue felt by adult assembling workers indicate workers experiencing mental workload.

Mental workload is a term that describes the amount of mental effort required to carry out work to meet specified requirements (Hart & Wickens, 1990; Wickens, 1992). Mental workload is very important factor in the work system because overloading mental work can result in decreased performance, increased errors (Johnson & Widyanti, 2011), and can even lead to health problems such as stress (Greenglass, 2003; Cinaz et al., 2013). Excessive mental workload can also lead to memory impairments and irritability (Young G, 2008). Therefore, it is necessary to conduct an assessment and evaluation of mental workload (Jo, Myung, & Yoon, 2012), especially in monotonous and boring work, because mental load is correlated with boredom (Johnson & Widyanti, 2011). Measuring mental load is very important in order to prevent individuals from experiencing overload while working, which aims to ensure workers have safety, health, comfort while working (Rubio S, 2004).

Mental workload assessment can be carried out based on performance, either objective or subjective methods (Widyanti et. al, 2019). Performance-based assessments can be measured by accuracy and reaction time. An objective assessment method can be carried out through a physiological index, but this method requires special skills and operational experience. On the other hand, subjective methods are cheaper and easier to manage, although they cannot provide accurate reports and require large numbers of samples (Lean & Shan, 2012). The most widely used subjective assessment methods are the subjective workload assessment technique (SWAT) and National Aeronautics and Space Administration Task Load Index (NASA-TLX) (Dey & Mann, 2010). In this research, the NASA-TLX method was used due to its practicality and the suitability of mental workload measurements for assembling workers.

Various studies to measure mental workload have been conducted using the NASA-TLX questionnaire, including to see the effect of age on mental workload. Workers who are over 30 years of age are at risk of experiencing a higher mental workload (López-López, 2018). Research on textile workers shows that the most important factor affecting work ability is age, where the decline in work ability drops sharply after the age of 40 (Safari, 2013). Research conducted on university employees in the Netherlands shows that the effect of age is evident in the actions and reactions of employees (Bos, Judith T, 2013). Although various studies to see the effect of age on mental workload have been carried out, research on the effect of age on mental workload of workers in assembling difficult type products is still very limited. In fact, many assembling parts are found on the production floor. That is why this research was conducted. This study aims to determine the mental workload workers in assembling difficult type of products associated with age.

2. Literature Review

The NASA-TLX method is a method used to analyze the mental workload faced by workers who have to perform various activities in their work. NASA-TLX is a multi-dimensional, subjective workload assessment tool (Hart SG, Staveland LE, 1988), which assigns a total workload score based on a weighted average of six subscales: mental demand, physical demand, temporal demand, performance, effort, and frustration (Stanton NA, 2004). Measurement of the NASA-TLX method is divided into two stages, namely the comparison of each scale (paired comparison) and assigning a value to the job (event scoring).

This study measures the mental workload of workers in difficult assembling type using the NASA-TLX questionnaire. The description of the NASA-TLX dimensions used in this study is shown in Table 1.

Table 1. Description of NASA-TLX dimension (Christopher, 2019)

Characteristics	Scale	Description
Task	Mental demands (MD)	How much mental activity and perception are needed to see, remember and seek at work? Does the job require accuracy or not?
	Physical demands (PD)	In doing a job, whether the task requires fast or slow motion, tiring or not.
	Temporal demands (TD)	How much time pressure is felt during working? Whether the work can be done in a relaxed manner or should be done fast and tiring

Behavior	Own performance (OP)	What is the success rate they have in carrying out their work and how satisfied are they with the results of their work?
	Effort (EF)	How much effort it takes to get the job done
Individual	Frustation (FR)	What is the level of security, feelings of annoyance compared to feelings of security and relaxation while working.

The six subscales of the NASA-TLX questionnaire can be divided into three groups, namely: 1) task characteristics, consisting of: mental, physical, and time demands; 2) behavior characteristics, consisting of: performance and effort; and 3) individual characteristics: frustration.

3. Methods

Data collection was carried out by distributing questionnaires to operators working in assembling. Assembling workers work each day in rolling according to work schedules. Respondents consisted of 32 young employees (m = 24.3 ± 0.7 years) and 41 employees aged adults (m = 31.0 ± 5.5 years). All of the respondents were male. The conditions of the assembling workers can be seen in Figure 1.

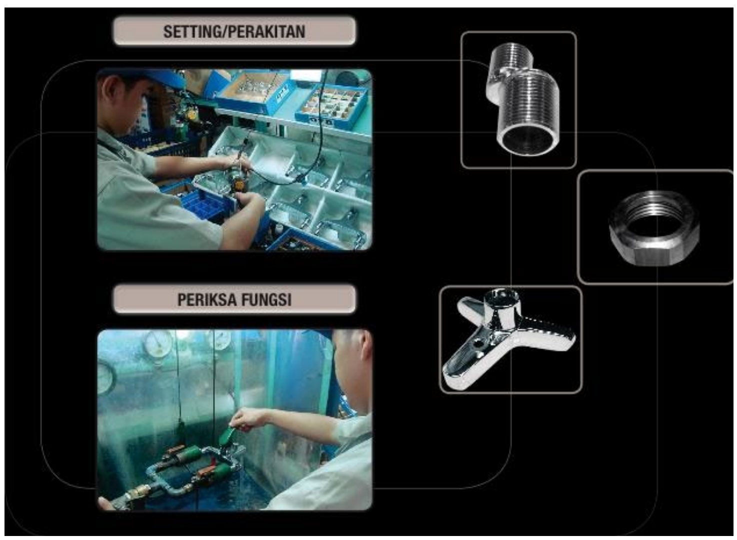

Figure 1. Assembling

Respondents were grouped based on age, referring to research conducted by Mickaël Caussel (2019), but adjusted to the conditions of workers in Indonesia. Workers are divided into 3 age groups, namely: young (19-25 years), adults (26–48), and old (49–64) as in Table 2. Respondents were randomly selected as many as 75 out of 90 workers. There are 73 valid questionnaires.

Table 2. Age group of the respondents

No.	Age Group	No. of Respondents	Percentage
1	Young (19-25 years)	32	43.8%
2	Middle Aged (26-48 years)	41	56.2%
3	Older (49-64 years)	0	0
	Total	73	100%

In the first stage, respondents are asked to choose one of the two indicators they felt more dominant in causing mental workload to the job. The questionnaire consisted of 15 pairwise comparisons. From this questionnaire, the number of tallies from the most influential indicator was calculated. Then, the number of tally will the weight for each indicator of mental workload. The next stage is grading, where the assembling workers are asked to rate the workload they felt with a value from 1 to 100 for each workload according to the age group. The value of the workload is obtained from the multiplication of weight and rating in the two age groups. Furthermore, the Weighted Workload (WWL) calculation and the final score from NASA-TLX are carried out, namely multiplying the rating value by the weight according to the contents of the questionnaire that has been filled in by the assembling worker.

4. Data Collection and Processing

4.1. Data Collection

The results of the NASA-TLX questionnaire from 73 respondents can be seen in Figure 2.

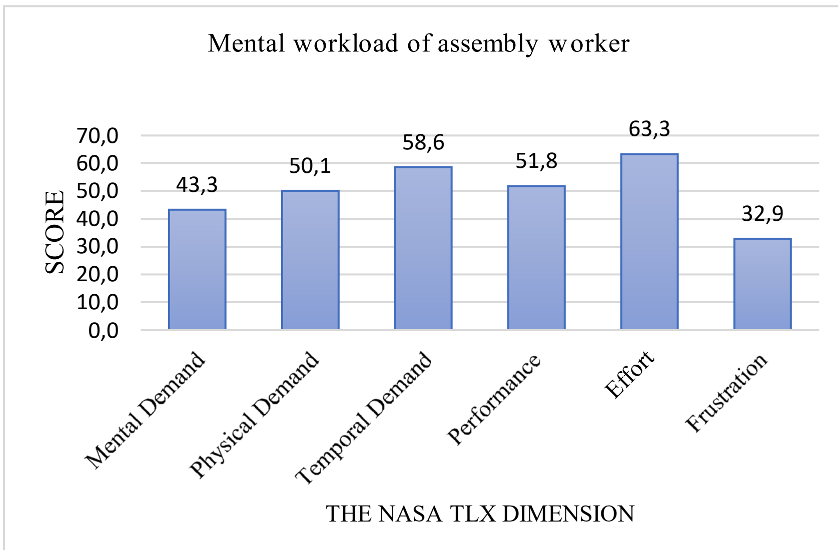

Figure 2. Mental workload of assembly workers

The mean and standard deviation of mental workload of assembly workers measured using NASATLX is 76.08 (SD = 12.66) out of 100. Figure 1 shows the dimension that most influences the amount of mental workload on assembling workers, is effort with a score of 63.3 (21.10%), followed by temporal demand with a score of 58.6 (19.54%).

4.2. Determine the Value

The next stage is to determine the value from multiplication of weight and rating in the two age groups. The comparison of NASA TLX dimension values by age group is as shown below.

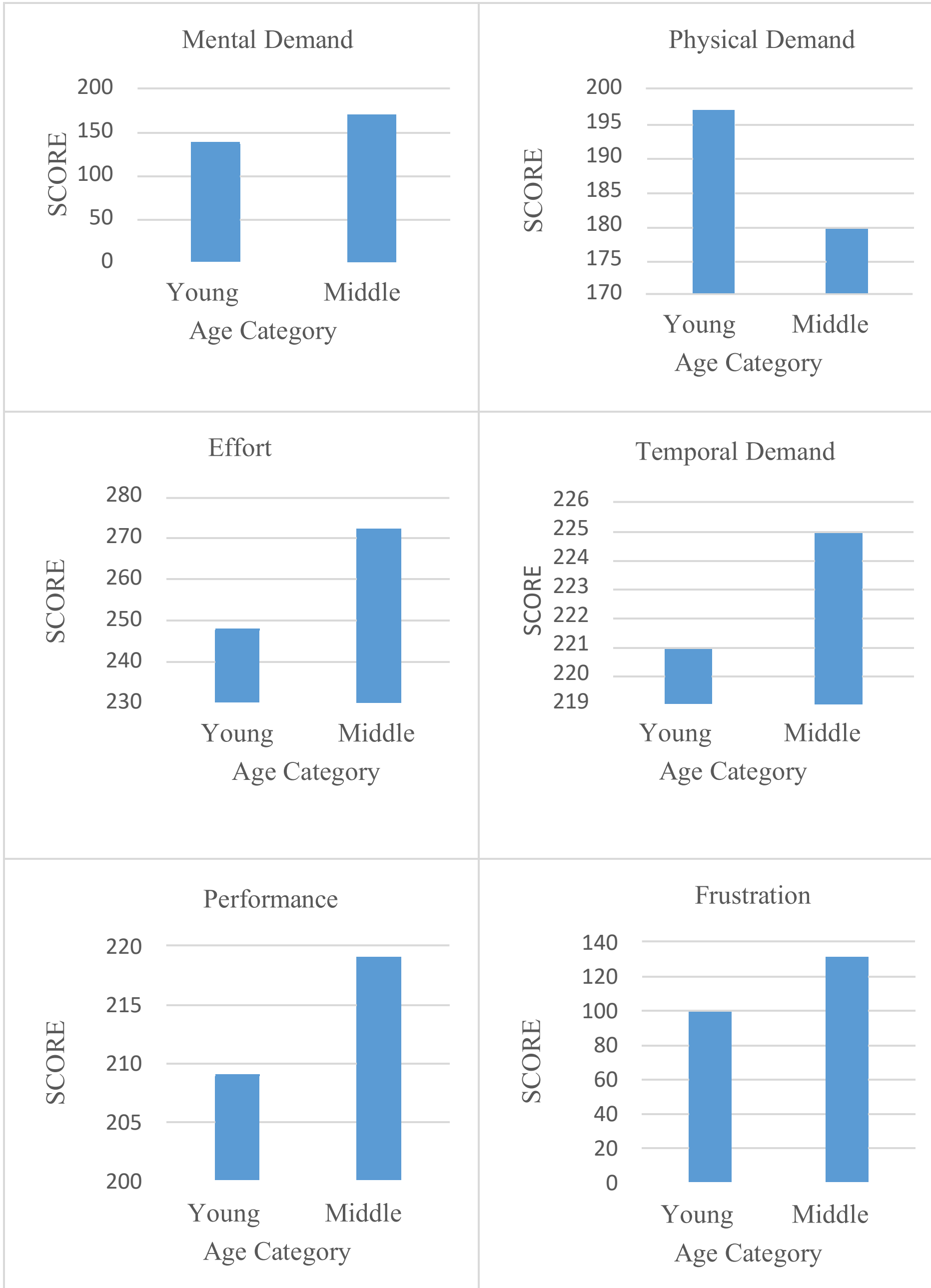

Figure 3. Comparison the value between age groups in NASA TLX dimension

Figure 3 shows how NASA-TLX represents a dimension of mental workload across different age groups. The results are as follows:

a. The value of mental demand (MD) in middle age was 23% higher than that of young people.
b. The value of the physical demand (PD) dimension at a young age is 10% higher than that of adults.
c. The value of the temporal demand (TD) dimension in middle age was 1.8% higher than that of young people
d. The value of the performance dimension (OP) in middle age was 4.7% higher than that of young people
e. The value of the effort dimension (EF) in middle age was 9.7% higher than that of adults.
f. The value of the frustration level (FR) dimension in middle age was 32.3% higher than that of young people.

In general, it can be stated that the highest NASA-TLX scores in both age groups are: effort dimension and temporal demand. Middle age group workers have an average mental workload dimensions of physical demand, mental demand, temporal demand, effort, frustration level is 7.5% higher than those of younger age group. From the comparison of the mental workload for both age groups, it can be seen that the frustration dimension has the highest percentage difference between the two groups, which is 32.3%. This shows that the frustration in middle age is 32.3% higher than that of young people. However, although the adult frustration rate was higher, the adult performance dimension was also 4.7% higher than the younger age. From all dimensions, only the physical demand of young people is higher than adults.

4. 3. Weighted Workload (WWL) Calculations

The WWL calculation and the final score from NASA-TLX are obtained by multiplying the rating value by the weight according to the contents of the questionnaire that has been filled in by the assembling worker. The mean and standard deviation of mental workload for young employees was 74.3 (SD = 18.0). The mean and standard deviation of mental workload for middle age employees was 79.9 (SD = 14.7). The values for WWL can be seen in Figure 4.

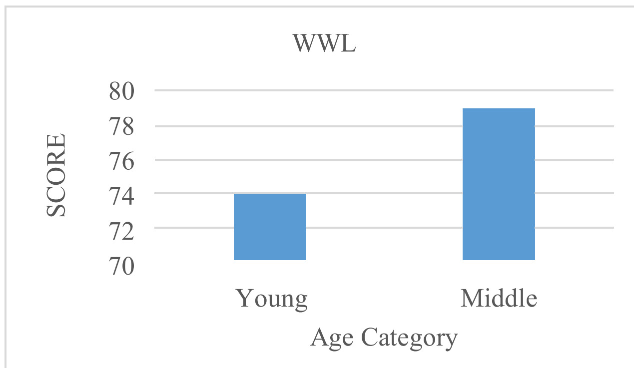

Figure 4. Weighted workload

In Figure 4, it is known that the average WWL of the adult age group is 7.5% higher than that of the young age group. The workload assessment category consists of five levels, namely: low mental workload on a scale of 0-9, moderate mental workload on a scale of 10-29, mental workload is rather high 30-49, mental workload is high 50-79 and mental workload. very high on the 80-100 scale. Thus, it can be seen that the average workload of assembling workers lies in the high category of workload.

ANOVA analysis was then performed to identify whether there are significant differences in mental workload based on age group, and also there are significant differences in all NASA-TLX dimensions. ANOVA results show the sig. 0.795 is greater than 0.05 and calculated F which is 0.475 is less than F Table which is 2.236. Thus it can be stated that there is no influence of age on the 6 dimensions of mental workload of workers who work to assemble components with a high level of difficulty. ANOVA also revealed that there was no influence of the age of the workers on all dimensions of the NASA-TLX dimensions. This can be seen from all the ANOVA test results which show a significance value is greater than 0.05, where mental demand (F = 2.885, ρ 0.094> 0.05, MSE = 5206,646), physical demand (PD) (F = 0.627, ρ 0.431> 0.05, MSE = MSE 8903,160), temporal demand (TD) (F = 0.17, ρ 0.898> 0.05, MSE = 12724,956), frustration Level (FR) (F = 0.893, ρ 0.348> 0.05, MSE = 20018,815), effort (EF) (F = 0.644, ρ 0.425> 0.05, MSE = 16565,131), and performance (OP) (F = 0.095, ρ 0.759> 0.05, MSE = 19537,538).

5. Results and Discussion

From the research it is difficult to associate mental workload with age in assembling process even for difficult type of products. The results showed that the average mental workload measured using NASA-TLX was 76.08 (SD = 12.66) with a scale of 100. This score indicates that the mental workload of workers in assembling process for difficult type of products is high. This result is not surprising, because it is in line with Klemmer's research, Muller (1969) who stated that mental work is higher when more information is processed per unit time.

The results also showed that there was no significant difference in mental workload based on worker age, as well as no significant differences across all NASA-TLX dimensions. This suggests that age does not affect the mental workload of workers assembling difficult type products. Mental workload involves three characteristics, namely task, behavior and individual, where in this study it shows that the source of mental workload for workers in assembling difficult type products is mainly behavioral characteristics. Thus the demands for behavior play more important role in the mental workload of workers assembling difficult type products than the demands of tasks and individuals. This can be seen from the high dimension of effort required to complete the work, because the work is monotonous and tedious. This is in line with the research of Johnson & Widyanti (2011) which states that mental load correlates with boredom. When working conditions are better designed and less boring, there is less effort. This is in line with the research of Mathis & Jackson (2006), which states that employee effort at work is influenced, among other things, by job design.

This study has several limitations. First, because the sample of assembling workers is limited to one firm, the generalizability of the findings is limited. Second, the study participants were limited to difficult type of product assembling workers, regardless of working period and shift. Further research that pays attention to years of work and shifts can certainly enrich the results and analysis of the research. The results of this study are useful to provide an overview of the mental workload of difficult type assembling workers, which are commonly found on the production floor. By knowing the dimensions of mental workload that are the most influential at work, individual overload can be prevented while working (Rubio S, 2004). This aims to ensure workers have safety and comfort while working so that productivity increases.

6. Conclusion

The work of assembling a difficult type of product is classified as risky work because it includes a high mental workload and mental workload of the middle age group is 7.5% higher than the young group. The most influential dimensions of mental workload are effort, which is caused by monotonous work, high concentration levels, and musculoskeletal symptoms due to repetitive work. In order to reduce employee effort at work, it is necessary to design an ergonomic job. While the characteristics that affect the mental load of difficult type assembling workers are mainly behavior. High mental load will certainly affect the behavior of workers where there are demands for time at work, so that it has the opportunity to increase errors and cause stress (frustration). Increased frustration results in decreased assembling worker performance. This is in line with Zhang (2019) research which states that high mental workload can increase the likelihood of operational errors and accidents. Therefore, further research to explore this matter will be very useful, especially in the context of years of work and work shifts which of course affect mental workload and worker productivity. The results also showed that there was no significant difference in mental workload based on worker age, as well as no significant differences across all NASA-TLX dimensions. This suggests that age does not affect the mental workload of workers assembling difficult type products.

References

Ballard, T. J., et.al., Self-perceived health and mental health among women flight attendants. *Occupational Environment Medicine*, 63(1), 33–38, 2006.

Bos, Judith T et.sl., Perceptions of mental workload in Dutch university employees of different ages: a focus group study, *BMC Research Notes*; London, Vol. 6: 102, 2013. DOI:10.1186/1756-0500-6-102

Cinaz, B., Arnrich, B., La Marca, R., & Tröster, G. Monitoring of mental workload levels during an everyday life office-work scenario. *Personal and ubiquitous computing*, 17(2), 229–239, 2013. https://doi.org/10.1007/s00779-011-0466-1

Dey, A., & Mann, D. D, Sensitivity and diagnosticity of NASA-TLX and simplified swat to assess the mental workload associated with operating an agricultural sprayer. *Ergonomics*, 53(7), 848–857, 2010. https://doi.org/10.1080/00140139.2010.489960

Greenglass ER, Burke RJ, Moore KA. Reactions to increased workload: Effects on professional efficacy of nurses. *Appl Psychol*, 52:580-597, 2003.doi: 10.1111/1464- 0597.00152

Hart, S. G., & Wickens, C. D. Workload assessment and prediction (pp. 257–296), 1990. Manprint. Springer. https://doi.org/10.1007/978-94-009-0437-8_9

Jo, S., Myung, R. & Yoon, D. Quantitative prediction of mental workload with the ACT-R cognitive architecture. *International Journal of Industrial Ergonomics*, 42(4), 359–370, 2012. https://doi.org/10.1016/j.ergon.2012.03.004

Johnson, A., & Widyanti, A. Cultural influences on the measurement of mental workload. *Ergonomics,* 54(6), 509–518, 2011. https://doi.org/10.1080/00140139.2011.570459

Klemmer, E.T. and Muller, P.F. The rate of handling information, *J Motor Behav*, 1, (2), pp 135–147, 1969. doi: 10.1080/00222895.1969.10734841.

Lean, Y., & Shan, F, Brief review on physiological and biochemical evaluations of human mental Workload. *Human Factors and Ergonomics in Manufacturing & Service Industries*, 22(3), 177–187, 2012. https://doi.org/10.1002/hfm.20269

López-López, et.al., Risk factors for mental workload: influence of the working environment, cardiovascular health and lifestyle. A cross-sectional study, *BMJ Open*; London Vol. 8, Iss. 12, 2018. DOI:10.1136/bmjopen-2018-022255

Mickaël Causse1, Zarrin K. Chua1 & Florence Rémy, Infuences of age, mental workload, and fight experience on cognitive performance and prefrontal activity in private pilots: *a fNIRS study*, 2019

Mulder G. The heart of mental effort: studies in the cardiovascular psychophysiology of mental work. University of Groningen: Groningen, 1980

NASA Task Load Index (TLX): Paper and pencil version MF, CA: NASA-Ames Research Center, *Aerospace Human Factors Research Division*, 1986

Nikulin, Christopher et.al., NASA-TLX for predictability and measurability of instructional design models: case study in design methods. *Educational Technology, Research and Development*; New York Vol. 67, Iss. 2: 467-493, 2019. DOI:10.1007/s11423-019-09657-4

Rubio S, Díaz E, Martín J, Puente JM. Evaluation of subjective mental workload: A comparison of SWAT, NASA-TLX, and workload profile methods. *Appl Psychol*; 53:61-86, 2004.doi: 10.1111/j.1464-0597.2004.00161.x

S. G. Hart, L. E. Staveland, Development of NASA-TLX (Task Load Index): results of empirical and theoretical research, *Advances in Psychology*, vol. 52, pp. 139-183, 1988 doi:10.1016/S0166-4115(08)62386-9

Safari, Shahram et.al., Personnel's Health Surveillance at Work: Effect of Age, Body Mass Index, and Shift Work on Mental Workload and Work Ability Index. *Journal of Environmental and Public Health*; New York, 2013. 289498. DOI:10.1155/2013/289498

Stanton NA, Hedge A, Brookhuis K, Salas E, Hendrick HW, editors. Handbook of human factors and ergonomics methods. 1st ed. Boca Raton: CRC Press; 2004

Wei Gao1 & Xiao-Dong Shao1 & Huan-Ling Liu, Enhancing fidelity of virtual assembly by considering human factors, *Int J Adv Manuf Technol* 83:873–886, 2016. DOI 10.1007/s00170-015-7628-7

Widyanti et.al, Assessment of Mental Workload of Flight Attendants Based On Flight Duration: An Effort To Provide Safe Working Condition, *Aviation* ISSN: 1648-7788 / ISSN: 1822-4180 2019 Volume 23 Issue 3: 97–103, 2019. https://doi.org/10.3846/aviation.2019.11847

Young G, Zavelina L, Hooper V. Assessment of workload using NASA Task Load Index in perianesthesia nursing. *J Perianesth Nurs*, 23:102-110, 2008. doi: 10.1016/j.jopan.2008.01.008

Zhang, X; X Qu; Xue, H; Zhao, H; T Li; et al. Modeling pilot mental workload using information theory, *The Aeronautical Journal*; London, Vol. 123, Iss. 1264, pp 828-839, 2019. DOI:10.1017/aer.2019.13

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