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The Effect of Physical Factors Towards the Worker Performance in Automotive Machining Shop

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Abstract

There are many factors (ie age, noise level, shift, temperature) surrounding a person while working, causing difficulty in evaluating their productivity. This research aims to develop the relation between age, shift as well as noise level and worker productivity rate in an automotive machining shop and give company improvement suggestions on how to improve the worker productivity. Consequently, this research will help the company to maximize the productivity of their production line. Method used for this project was 2 x 3 factorial experimental design. The scope for the research was CNC Machining Shop, Mass-pro design with U shape conveyor, manual loading and unloading work type, cycle time at 2.0 min with constant temperature of 32.2 °C, Humidity at 56% and 300 Lux. The research found that, among all three factors, only age was significant to productivity. Based on this research, younger workers were more productive by 3.1% as compared to older workers. The 3.1% acted as reference for employers in the production line to rotate their men, by putting older manpower at lower demands production line and younger manpower at higher demands production line.

Keywords

Physical Factors, Productivity, Automotive, Machining Shop, Design of Experiment

1. Introduction

Productivity is an important yet complex issue which can help in cost reduction and increase efficient resource usage (Nestor et al. 2019). But the definition of productivity is simple, which is the ratio between output and input (Puspita Andriyanti 2007). Widespread opinion assumes older workers are less productive, but research showed that older workers experience often compensates for any physical disadvantages Viviani (2019). Getting older also brings in wisdom and knowledge to people, which can make him better at his job in other ways Axel Börsch-Supan And Matthias Weiss (2013) . The production department often needs strong, fast, and flexible workers, yet those things usually get weaker with age.

In addition, a better work environment will lead to better productivity and performance (Arminas, Nurwahidah and Ahdan 2020). Loud distractions and high noises reduce productivity. Noise affects productivity. Moreover, workers will experience more fatigue during night shift which reduces productivity (Iwan M Ramdan, 2007). Planning, conducting, and analyzing the results of experiments were done using the Design of Experiments (DOE) approach, in

which under this branch of applied statistics, systems, processes, or products are scientifically investigated with the changes in variables factors to see how they affect the measured responses (Benjamin 2017). DOE is a very powerful tool to analyze the impact of certain factors on the responses (Puertas and Luis 2003). The type of DOE used in this research was Factorial DOE. The reason behind using the Factorial DOE as it was used by Douglas C. Montgomery, in "Design and Analysis of Experiments" and was cited for more than 50,000 other research. Previous research on shift work and injuries concentrated on healthcare employees, with few studies on manufacturing industry (Ryu et al. 2017).
This research investigated physical factors that were affecting worker productivity in an Automotive Machining Shop in Rawang, Selangor, Malaysia. The research underwent eight runs and regression analysis method were used for data validation. All data were run through Minitab Software Analysis Version 21.4.10 by using Factorial DOE features. Development of the relation between factors; age, shift and noise level contributed to the production line in maximizing the productivity of production.

1.1 Objectives
The aim for this research was to develop the relation between age, shift and noise level and the worker productivity rate in an automotive machining shop and give company improvement suggestions on how to improve worker productivity.

2. Literature Review
Productivity is difficult to measure because it is influenced by many factors, including physical abilities, experience, and social skills. Physical abilities decline with age, while experience and social skills increase. The latter are difficult to measure, and thus studies that rely on direct measures may underestimate the productivity of older workers. A research that studied the relation between worker age and worker productivity in an assembly plant of a truck manufacturer found that there was no evidence to confirm the common belief that older workers are less productive than younger workers.

Moreover, noise is one of the key factors that influence productivity compared to other factors. Shift work is related to a higher risk of illness however, research on the level of presenteeism, or diminished work performance, caused by shift work is scarce (Seong-Sik, Dong-Wook and Mo-Yeol 2020). The automobile industry is an example of a 24-hour society, in which enterprises are open 24 hours a day, seven days a week. Job performance does not always decrease with age, but there is some evidence that it can decline for certain tasks. Studies showed that older employees were just as capable as younger employees and they may even have some advantages, such as being more organized. A research that studied the workers in the manufacturing area of a company found that age, job type and length of service did not have a significant impact on their efficiency. The worker productivity is affected by their experience. Meanwhile, age is also a factor to consider. Workers from the oldest age group, who have more experience in the factory, were praised by their colleagues for their effective and efficient work. Moreover, there is no evidence to support the common belief that older workers are less productive than younger workers. Noise is an auditory sensation that passes through the human ear caused by air pressure deviations. This deviation is usually caused by vibrating objects. Exposure to noise levels of 85 decibels (dB) for eight hours per day and 40 hours per week is considered safe, but it can still have negative health effects over time . The results from 12 respondents showed that noise was one of the reported factors affect work productivity. Furthermore, there is a difference in the level of perceived work fatigue at temperatures and noise levels below and above the threshold. Moreover, noise has significant effects on productivity. Noise contributed 79.23% to productivity. It was found that productivity was improved by controlling the noises.

The level of muscular pain and depression experienced by shift workers varied, depending on the shift they work . The levels of fatigue, depression, mental load and job demand did not vary across the two shifts. Moreover, the research found that shift work was associated with increased health-related productivity loss (HRPL). Workers who worked fixed night shifts had the largest productivity loss. Although shift work was originally introduced for economic reasons, it can have negative consequences for worker performance and worker productivity if it is not managed properly. Production workers who worked night shifts reported feelings of more tension, depression, fatigue and less vigor. Night shift workers experience more fatigue than day shift workers.

3. Methods

The method used for this research was a 2 x 3 Factorial Design. Table 1 shows the levels of all three factors. Both age groups are at the extreme end of the age range of workers in the company.

Table 1: Low and High Level of all three factors

Factor	-1	1
Age	20-25 years old	40-45 years old
Shift	Day	Night
Noise	Below 82dB	95dB and more

4. Data Collection

Table 2 shows results for all eight runs and three repetitions for each run. The data shown were then processed through Minitab Software for analysis.

Table 2: Table of Result

Run	Factors			Productivity (%)		
	Noise	Age	Shift	Rep 1	Rep 2	Rep 3
1	-1	-1	-1	97.8	97.5	96.8
2	1	-1	-1	99.3	97.9	98.9
3	-1	1	-1	95.2	96.3	94.6
4	1	1	-1	93.6	95.5	93.1
5	-1	-1	1	99.3	100	98.7
6	1	-1	1	99.3	98.7	99.5
7	-1	1	1	100	90	96.7
8	1	1	1	97.6	96.3	97

5. Results and Discussion

Table 2 shows that the productivity response varied over all runs and repetitions, ranging from a minimum of 90% to a maximum of 100%. The Minitab analysis of the effects of noise, age, and shift towards productivity produced the following results.

5.1 Minitab Analysis

Table 3 displays the analysis of variance (ANOVA) of gathered data, which was produced by Minitab software. The F-value of 15.82 in the ANOVA was greater than the F-table of critical values at α 0.05, which was 4.49, indicating that age was the primary significant factor which influenced productivity. This proves Hypothesis 1 (H11), which claimed that at least one factor is significant to at least one response; hence rejected the null hypothesis (H01) which claimed that all factors are not significant to all responses. The ANOVA also rejected H12 which asserted that at least one factor interacts with another factor, and affirmed H02, which states that there are no interactions between any of the factors, based on the F-value of interactions.

Table 3: Analysis of Variance (ANOVA) generated by Minitab for Productivity

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Noise	1	0.602	0.6017	0.16	0.695
Age	1	59.535	59.5350	15.82	0.001
Shift	1	11.482	11.4817	3.05	0.100
Noise*Age	1	0.427	0.4267	0.11	0.741
Noise*Shift	1	0.540	0.5400	0.14	0.710
Age*Shift	1	0.167	0.1667	0.04	0.836
Noise*Age*Shift	1	6.615	6.6150	1.76	0.204
Error	16	60.227	3.7642		
Total	23	139.593			

The Minitab-generated Pareto chart of variables which influenced productivity response is displayed in Figure 1. The graph indicates that the only significant factor which influenced productivity was age. The ANOVA result in Table 3, where age factor was significant factor to productivity, was confirmed by the Pareto in Figure 1. The Minitab-generated Main Effects Plot for Productivity vs Age, Shift, and Noise is displayed in Figure 2. Looking at Figure 1, the only significant factor was age. Furthermore, it can be inferred from Figure 2, that productivity was higher at younger age than it was at older age. Figure 2 concludes that, as age increases from -1 to +1, productivity decreases.

An equation for regression can be made based on the value of coefficient. The predicted value or outcome of factor will be represented by the regression equation. The coefficient for the constant and significant factor in this equation—age, in this case—are values that matter. Therefore, the regression equation is:

$$\hat{y}=97.067+(-1.575\ (\text{Age}))$$

Referring to Figure 2, to maximize productivity, Age needs to be at -1. Therefore, the value -1 can be put in the equation and the predicted value was $\hat{y}=98.642\%$.

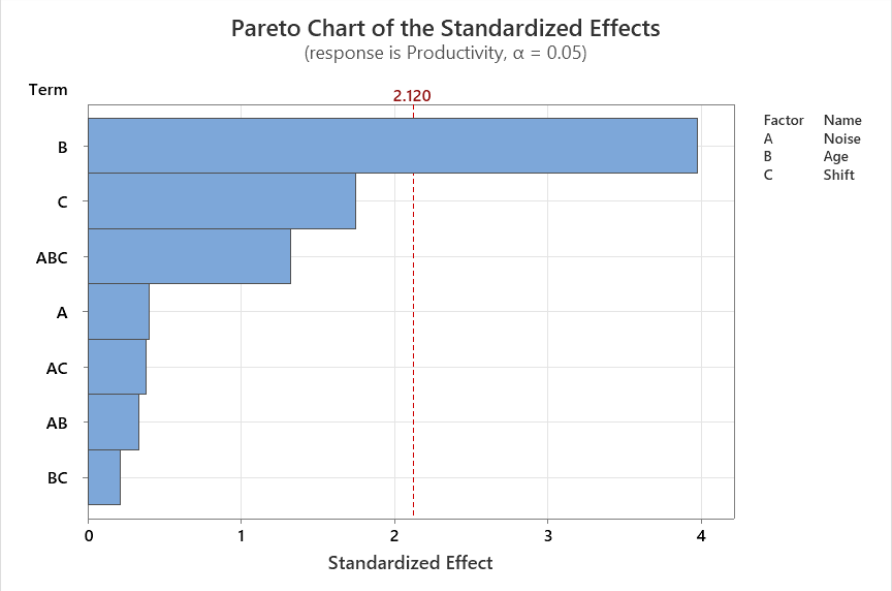

Figure 1: Minitab Pareto results of which factors are significant to the Productivity response.

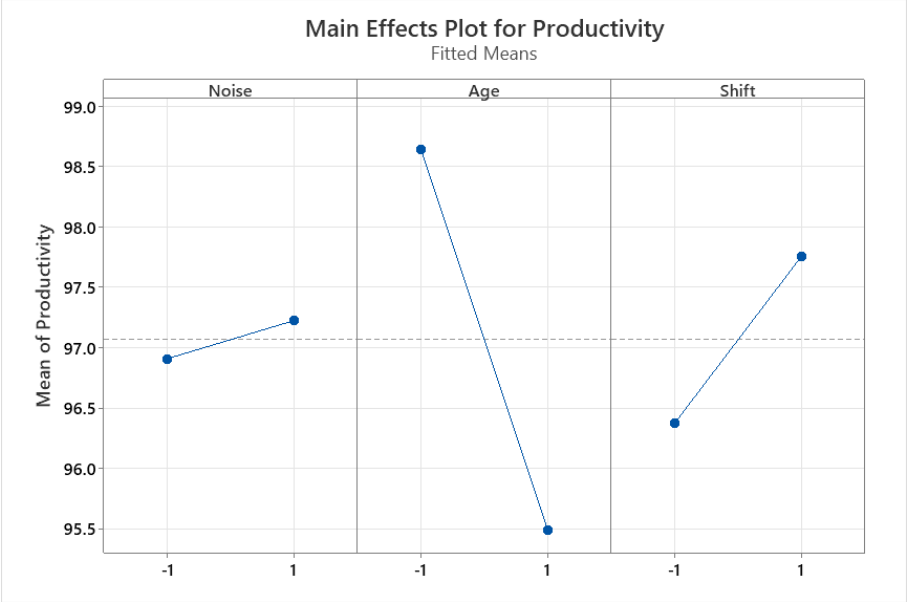

Figure 2: Minitab Main Effects Plot for Productivity vs all three factors.

5.2 Data Validation

Another set of data was collected for validation by using configurations that were determined based on the Minitab results. Since productivity should always be maximized, the settings recommended that Age be -1. Table 4 shows the result of Productivity with Age at -1. The average of the 3 repetitions was 97.23%, while from the regression, the predicted value showed that with age at -1, the productivity was at 98.642% and the percentage difference was 1.43%. The data was validated.

Table 4: Result of Productivity with Age at -1

Age	Productivity (%)			
	Rep 1	Rep 2	Rep 3	Average
-1	97.4	96.2	98.1	97.23333

5.3 Discussion

Age is the primary factor which had the greatest impact on worker productivity, as evident by Figure 1. Table 2 indicates that, across all eight runs and three repetitions, the average productivity of older workers was 95.5%, with 90% representing the lowest and 100% representing the highest. When it comes to younger workers, the mean productivity was 98.6%, with a minimum of 96.8% and a maximum of 100. The result was not aligned to the reviewed literature, which stated that age had no effects on productivity. Even though the difference in productivity was only 3.1%, it is still important to note because it will affect productivity of the production line. The results showed that only younger workers can meet the 97% productivity target set by the production line under research for this literature. The mean productivity of younger workers was 98.6%, while that of older workers was 95.5%. Furthermore, the outcome was inconsistent with another literature, which found that employees with greater experience were more likely to be evaluated based on their effectiveness and productivity at work. In the meantime, the author discovered that even though older workers have more experience than younger workers, they were not more productive. The author believed that issues with durability and stamina accounted for the productivity gap between older and younger workers. Moving from machine to machine while carrying a load is a physical aspect of the work (product). Referring to Table 4, the percentage difference of 1.43% between the second data set and predicted value generated validated the findings regarding the impact of age on productivity, with younger workers being more productive.

According to Table 2, the average productivity at lower noise was 96.5%, with a minimum of 90% and max of 100%. Meanwhile, at higher noise level, the mean productivity was 97.2%, with a minimum of 93.1% and a maximum of 99.5%. Based on Figure 1 and the ANOVA at Table 3, noise did not have any significant effect on productivity. This is aligned with who found that noise is insignificant to productivity rate, but this did not align with the literature that

reducing noise can increase productivity. In regard to the author's experience working in the production line, neither the current management nor the previous one conducted any research on the connection between noise levels and output. The impact of noise on workers' health was the only thing that was known, not how it affected their productivity. Therefore, further research can be conducted to comprehend the connection between noise and productivity, particularly in a mass-production automotive machining shop.

According to Figure 1 and the ANOVA at Table 3, shift had no significant impact on productivity. According to Table 2, the mean productivity during day shift was 96.4% with 93.1% at minimum and 99.3% at maximum while the mean productivity at night shift was 97.8% with 90% at minimum and 100% at maximum. The literature that was reviewed did not support this. Based on literature, night shift workers are less productive. The author had never before investigated the effects of shift work on productivity but based on his experience working in the production line, some validity can be found in the findings of the reviewed literature because weariness and drowsiness, quality problems, mistakes, and defects typically increase during the night shift. The lower productivity during the night shift can be attributed to these quality issues, errors, and defects. Therefore, more research can be conducted to comprehend the relation between productivity and shift, particularly in an automotive machining shop with mass production settings.

For shift factor, the result found was not aligned with the reviewed literature could be due to the short period of this research. If this research was done for longer period, the result could be different.

5.4 Suggestion to Company

Based on the author's experience in production line, here are the suggestions that the author would like to recommend to the company to improve their productivity,

1. Re do their time study for the line, but using the average of multiple age group as the standard.
2. Use automation improvement to help in reducing the workload.
3. Rotate their men. Put old workers at low volume lines and young workers at high volume line.

6. Conclusion

Age is significant towards productivity while the other two factors, Shift and Noise Level, are not significant. Younger workers are 3.1% more productive than older workers. Based on the author's experience in managing production shifts, it is evident that older workers get tired easily than younger workers when their jobs involve a lot of physical labor. Regression analysis of the data demonstrated the validity of this result. Suggestions were also given to the company to improve their productivity.

The author would like to suggest a few improvements to improve the research outcomes.

1. Control more factors. Despite being the same in both work areas, the environment in this research is uncontrollable. Tiny changes in the variables under control may have an impact on the outcomes.
2. Apply a multiple level factor. The author's coded approach for this research has two levels for the factors, denoted by the codes +1 and -1. If the factors—noise at 70, 75, 82, 90, and 100 dB and age at 20, 25, 30, 35, and 40 years old, the outcome may not be as clear-cut as "younger workers are more productive." Better worker selection will be possible because of increased precision.
3. Include responses that specifically address the worker's health, such as oxygen saturation and heart rate. These data allow for a more thorough analysis of the relation between the environment, health and physical factors.

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