

Effects of Skill Differences of Adjacent Assemblers on Job Performance Based on fNIRS

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ABSTRACT

The LEGO model was used to simulate the actual assembly line assembly operation, and a repetitive assembly task experiment was designed, taking into account the differences in the skills of adjacent assembly personnel, and the behavior performance data of the personnel combination during the task was recorded. Simultaneously, the fNIRS near-infrared device was utilized to track changes in HBO2 concentration in the prefrontal lobe of the assembled brain, in order to investigate the impact of differences in adjacent assembly personnel's combined skills on job performance. The results of the experimental analysis show that the assembly error rate and task completion time do not show a relationship of first increasing and then decreasing with the difference in the skills of the personnel combination; however, within a certain range, the brain load of the personnel combination will increase as the skill difference increases. When the skill gap is too wide, it will play a part in reducing mental stress. As a result, when designing personnel arrangements to reduce worker load and improve production efficiency, manufacturing businesses should take into account the differences in skills between neighboring operators.

Keywords: fNIRS, personnel mix, prefrontal lobe, repetitive tasks, skill differences.

1. INTRODUCTION

Repetitive tasks involving the upper limbs of operators are nevertheless frequent in manufacturing organizations today [1]. In the case of manual assembly operations on a production line, it is frequently necessary for the operator and the operator at the neighboring station to collaborate in order to accomplish the processing task. However, there are certain disparities in the skills of the operators due to differences in their work experience, gender, age, and other factors. As a result, research into the impact of skill disparities in different staff combinations on work performance under repetitive assembly activities is required in order to provide recommendations to personnel organizations in this type of business.

Many academics are currently investigating the impact of skill differences on employee mix. In a panel study on perceived skill differences and complementarities within a portfolio, Aad Oosterhof discovered that self-rating behavior and perceived skill differences were unrelated to perceived complementarity

[3]. Fiona M Munro discovered that the skill difference within the personnel combination may be related to the operator's own personality in the prisoner's dilemma game [4]. In reasoning games, Brase Gary L et al. discovered that differences in reasoning abilities across operators were unrelated to how the task was presented [5].

At the same time, several researchers have looked into the brain activity of a group of people. Bbiloni et al., for example, discovered that in the prisoner's dilemma, the higher the consistency of the two sides' medial prefrontal activity, the better the team performance [6]. The job performance status of both subjects can be assessed by the changes in double EEG data, according to a study by De Vico Fallani et al. [7].

The previous studies focused on the impact of skill disparities on personnel portfolios' job performance and brain activity in various settings, whereas only a few scholars have integrated the work performance and brain activity of personnel portfolios for analysis. To find out how different skill sets affect job performance and brain activity in people's portfolios. This is extremely

important for the producing company's personnel setup. Because of its function of real-time monitoring of brain activity, as well as its portability and small size, fNIRS near-infrared technology has become widely employed in production management and other domains with the advent of neuroergonomics [7]. As a result, using the Lego vehicle model, this experiment duplicates the actual assembly line assembly procedure. Also, collect and monitor variations in HBO2 concentration in the prefrontal lobe area of different combinations of people using fNIRS near-infrared equipment. It then assesses the impact of various personnel combination skills on work performance in order to provide a theoretical foundation for production enterprises to arrange personnel combinations, as well as to guide production enterprises in carrying out production operations and achieving long-term enterprise development.

2. EXPERIMENTAL PROGRAM

2.1. subject

The total number of samples determined by G-Power is 64 [6] based on the features of repetitive activities and related experimental paradigms [5]. The study enlisted 70 college students (average age: 211.01), all of whom were right-handed and had no history of neurological or psychiatric illnesses, color blindness, or color weakness. The volunteers all agreed to take part in the experiment and signed the "Informed Consent Form for the Experiment." The subjects were paid a specified amount of money after the experiment was completed. The Experimental Ethics Committee of Jiangsu University of Science and Technology examined and approved this experiment.

2.2. Laboratory equipment

Two sets of Brite MKII near-infrared devices, two cameras, and a ThinkPad notebook were used in this study. From top to bottom and left to right, the LEGO model parts are placed in the storage box in the sequence of assembly. To meet ergonomic standards, the distance between the storage box and the front of both subjects was less than or equal to 600mm [11].

2.3. Experimental tasks and procedures

The task of this experiment is the assembly of 5 Lego car models. Due to the limited complexity of the LEGO model assembly task, the experimental subjects were able to independently and proficiently assemble the LEGO car model many times without relying on the manual after about 3 hours of training. By fitting the learning curve to the completion time of the tested Lego models, it was found that all reached the steady state level. When the model completion time is steady, it is still found that the experimental subjects show differences in the model

completion time, which can be understood as the differences in the skill levels of the experimental subjects. According to the different skill levels of the experimental subjects, they were randomly combined and divided according to the difference in the completion time of the tasks between the two subjects in the group. Those in the range of 60s-100s are divided into the combination of medium-skilled personnel, and those above 100s are divided into the combination of high-skilled personnel. There are 14 groups, 10 groups and 11 groups respectively. After the proficient subjects arrived in the laboratory, the process and specific tasks of the experiment were explained to the subjects on both sides, and the subjects were familiarized with the steps of assembling the Lego car model again. After both parties signed the "Informed Consent for Experiment", put on optical fiber caps for both parties to check the wearing status of the equipment, Before the start of the experiment, the 60s data in the resting state of both participants was collected as the baseline data, and then the experiment was officially started. During the experiment, the subjects on both sides needed to take out the parts of the Lego car model from the assembly box in front of them in a certain assembly order and assemble them until the assembly of the five Lego car models was completed, and the two subjects stopped the experiment.

3. RESULT

3.1. Assembly Error Rate

Statistical analysis of the assembly errors of different skill-differenced personnel combinations was carried out and converted into error rates. It is found that there are significant differences in the error rate of different personnel combinations. The error rate in the combination of medium difference personnel is 2.78%, which is 1.13 times and 1.45 times that of the combination of high and low difference personnel, respectively. After a pairwise comparison, it was found that there was no significant difference in the assembly error rate between the low-difference, medium-difference, and high-difference personnel ($P=0.294$, 0.652 , 0.138 , respectively).

3.2. Average task completion time

The paired t-test was conducted on the average task completion time of the two operators in the combination of personnel with different skill differences. There was a significant difference in the average completion time of tasks between the low-difference and medium-difference, and the medium-difference and high-difference personnel ($P=0.005$, 0.004 , respectively), but there was no significant difference between the low and high differences.

3.3. *fNIRS data analysis*

Paired-samples T-test and repeated ANOVA analysis were performed on the HBO₂ concentration data of both workers in the combination of personnel with different skill differences. From the analysis results, it can be found that the combination of low-difference people has significant activation in the lower frontal and medial prefrontal regions, the combination of medium-difference people has significant activation in the medial prefrontal region, and the combination of high-difference people is almost in the entire prefrontal lobe. area was significantly activated.

3.4. *Comprehensive analysis*

T-tests were performed on the average task completion time, assembly error rate and HBO₂ concentration data during the task period for different personnel combinations. The results of the analysis found that the HBO₂ concentration data of the combination of low-, medium-, and high-difference personnel had significant differences in the average task completion time and assembly error rate.

In addition, the relationship between the average task completion time and HBO₂ concentration for different combinations of skill differences was analyzed. It was found that in the medium-difference personnel combination, the HBO₂ concentration data has been on an upward trend during the mission, while in the other personnel combination, the HBO₂ concentration showed a trend of first decreasing and then increasing. The average task completion time of different personnel combinations shows a trend of first decreasing and then increasing.

4. DISCUSSION

The analysis results of the three types of indicators show that for the assembly error rate index, the skill difference of different personnel combinations will lead to obvious differences in the assembly error rate of repetitive tasks, and with the increase of the skill difference, the assembly error rate of the personnel combination will be significantly different. There will be a phenomenon of first increase and then decrease. When there is a difference within the group, the assembly error rate shows an upward trend, which may be related to the poor behavior of the operators on both sides and their own work ability [8], coupled with the fact that the operators deal with this simple, repetitive and monotonous for a long time. This leads to a certain degree of distraction, which leads to a significant increase in assembly error rates and a decrease in production performance [9]. Therefore, production enterprises should avoid excessive skill differences in the combination of adjacent workstations in order to improve the production efficiency of enterprises.

For the average task completion time index, the relationship between the skill differences within the group and the average task completion time showed a phenomenon of first increase and then decrease. The average task completion time shows an upward trend in the combination of medium difference personnel, while the average task completion time shows a downward trend in the combination of high variance personnel. This is largely due to skill differences within the workforce. When the skill difference within the group is in the middle difference, since the skill difference between the two workers is not too big, it will not greatly improve the work performance of the two workers, and the repetitive tasks are monotonous. In addition, the boring characteristics will easily cause the operator's attention to decrease [10], which will lead to an increase in the overall completion time of the personnel combination. Therefore, from the analysis of the assembly error rate and the average task completion time, when the production enterprise arranges the personnel combination, it should pay attention to the skill difference in the personnel combination and make adjustments in time to improve the work performance of the operator.

For the fNIRS indicator (that is, the HBO₂ concentration value), it can be known by analyzing the HBO₂ concentration data of different personnel combined in 12 measurement channels. The combination of low-difference people had significant activation in the lower frontal and medial prefrontal regions, the combination of medium-differenced people had significant activation in the medial prefrontal region, and the combination of high-difference people had significant activation in almost the entire prefrontal region. The above phenomenon is mainly caused by the difference in skill level within the group. In the low-difference personnel combination, because the skill levels of the operators on both sides are relatively close, this will bring greater psychological pressure to the personnel on both sides, and the operators on both sides will use more cognitive resources to adjust their emotions. It is also related to the emotion regulation and cognitive function of the lower frontal lobe and the medial prefrontal lobe in the prefrontal region [11], which in turn leads to an increase in the concentration of HBO₂ in this region. As a result, the lower frontal and medial prefrontal regions were significantly activated.

A comprehensive analysis of the behavioral performance indicators and fNIRS indicators found that in the combination of low-difference and high-difference personnel, task completion time and HBO₂ concentration first decreased and then increased. In the middle-differentiated personnel combination, the task completion time showed a phenomenon of first decrease and then increase, while the change of HBO₂ concentration has been showing an increasing trend. This phenomenon is mainly due to the different levels of skills within the personnel mix. With the increase of working

time, the learning effect will improve the skill level of the operator to a certain extent, and the brain activity of the operator will gradually decrease. It does not change much, and will gradually appear in the task completion time as the working time increases, which will lead to an increase in the operator's brain activity. Therefore, the task completion time and HBO₂ concentration of the personnel combination will first decrease and then increase. This finding is the same as that of previous studies [9]. At the same time, the HBO₂ concentration changes of different personnel combinations have significant differences in the average task completion time and the assembly error rate, which indicates that different personnel combinations are more sensitive to the size of the average task completion time and the number of assembly errors, and the HBO₂ concentration will vary with the It fluctuates with the size of the task completion time [11].

5. CONCLUSIONS

Using fNIRS near-infrared equipment, this paper analyzes and discusses the impact of different combination skills of different personnel on job performance under repetitive tasks, and draws the following conclusions, the assembly error rate and task completion time do not vary with the degree of personnel combination skills. , showing a relationship of first increase and then decrease; within a certain range, with the increase of skill difference, the brain load of personnel combination will increase, and when the skill difference is too large, it will play a certain role in improving the brain load.

In future research, factors such as location, gender, complexity, etc. can be considered in the experiment, and eye trackers, EEG and other instruments and equipment can be used to further study the change law of work performance and mental load in the combination of personnel, so as to provide information for the personnel of production enterprises. The allocation and personnel combination arrangement provide theoretical basis.

AUTHORS' CONTRIBUTIONS

Participated in the whole process of the experiment, analyzed the data, and finally wrote a document

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