Int. J. Engng Ed. Vol. 9, No. 5, pp. 377–385, 1993
Printed in Great Britain.

0742-0269/91 $3.00+0.00

A Study of the Deviation in Performance Rating of Engineering Students

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Investigations were carried out to study the deviation in performance rating of more than 300 undergraduate engineering students, using the walking and card-dealing techniques. It was found that the average deviation was 24% and 13% respectively for walking and card-dealing for students who had no prior practice training prior to the assessment. The performance rating ability of students improved as more time was spent in practice training. The practice training times required to achieve a deviation of 5% were estimated to be 8 hours for walking and 4 hours for card-dealing respectively.

1. INTRODUCTION

AS time study (work measurement) is an important tool to improve productivity in industries [1, 2], all students doing a third-year course in Mechanical and Production Engineering at Nanyang Technological University have been introduced to the subject since the academic year 1992/1993. The objective is to give them some basic knowledge to undertake time-study tasks during their six months industrial attachment in industries, immediately after completing their third-year course.

Stop-watch time study is commonly used in industries. During the recording of the elemental readings in the course of a time study, it is necessary to rate the performance the operator is displaying. This is because a time study that is truly representative of the output of a group of several operators employed on the same job is seldom recorded. Hence rating is used to adjust the observed time values to correspond more closely to the time which is deemed to be reasonable and fair for doing the work in question.

The following are some of the definitions of rating [3]:

- Rating is that process during which the time study engineer compares the performance of the operator under observation with the observer's own concept of proper performance.
- Rating is the gauging of the operator's pace during the time study in terms of a normal pace.
- In order that the time standard established from a time study for any degree of skill or effort may be a standard representing average performance, it is necessary to use some method of adjustment of the recorded elemental times if the operator studied gave other than an average performance.

Each of these statements recognizes that the particular operator under observation may work at a performance level which does not coincide exactly with what is expected of an operator on the job. Hence the reliability of the standard developed cannot be assured unless the time-study analyst has done a precise job of rating during the entire course of time study. It is therefore obvious that time-study analysts must be trained in rating.

There are many rating systems used in the manufacturing industries [3, 4]. Some of these are: the Westinghouse system rating, performance (speed) rating, objective rating and synthetic rating. The Westinghouse system rating is the most comprehensive. The characteristics and attributes it considers are classified under dexterity, effectiveness and physical application. Nine attributes are evaluated under this system: three are related to dexterity, four to effectiveness, and two to physical application. A training course involving 30 hours of intensive effort is the minimum that is required of time-study analysts who intend to use the Westinghouse system rating.

On the other hand, performance rating is probably the most widely used rating system. Under this method the time-study analyst considers only the rate of accomplishment per unit of time, i.e. rating only the operator's speed, pace or tempo. He or she compares the performance being demonstrated with his or her concept of normal performance for the operation being studied. The rating system may be expressed as a percentage, with normal performance equal to 100%.

The training programme recommended for performance rating for the analysts would involve about 25 hours of rating videotapes of films and live operators and then discussing the results with

* Paper accepted 5 September 1993.

professional time-study engineers who conduct the course. The key to good time standards is regular training in performance rating by all practising engineers. The time-study analyst is expected to regularly establish standards within ±5% of the correct standard. Training in performance rating should normally be provided by the Industrial Engineering Department of an established organization wherever possible. However, since not all companies have an industrial engineering department, some basic training should be given to students before they graduate from the university.

As only a limited time span is available to cover the time study topic it is not possible to give elaborate training on performance rating. Some research work was therefore done to find a solution to the problem. An attempt was made to introduce simple exercises like walking and card-dealing to students who were later assessed on their ability to rate the performances in both these areas in a tutorial class. Walking on the level at 3 miles per hour is frequently used to represent normal tempo. A person dealing a deck of 52 cards into 4 equal piles in 0.5 min is often considered to be exhibiting normal pace [1, 2]. Hence it was hoped that at the end of the exercises, the students would have gained a better concept about these normal performances and a better knowledge about their own rating abilities.

2. METHODOLOGY

This study was carried out in two stages. The first stage was done in September 1992, involving 309 third-year students from the School of Mechanical and Production Engineering. The second stage was carried out in April 1993, involving 10 second-year students, again from the same school, who were doing their in-house practical training under a project module supervised by the author.

Stage 1

There were 12 groups of students involved in the Stage 1 study. Each group consisted of about 30 students who were subdivided into smaller groups of 3 people in each subgroup to facilitate practice. In their practices, the first student was required to perform, either in walking or in card-dealing, while the second one was doing the timing and the third one doing the rating. The students were supposed to practise on 80%, 100% and 120% performances before coming to the tutorial sessions for their assessments. However, it was found later through a survey that the majority of them did not practise at all, due presumably to the lack of time and other commitments.

At each of the 12 assessment sessions, students first gathered at an open space where they could do some performance rating in walking. Two students were appointed as official time keepers. Six students were selected by the group to do the walking. The distance to be covered was about 60 feet or about 20 metres. However, this distance was unknown to the students until the end of the exercise. The first time keeper stood near the starting point while the second one stood at the end point. Each of the six students was required to walk at a different pace. The time keeper raised one of his or her hands when the performing student crossed both the starting and end points to facilitate timing by both of them. The rest of the students were required to rate the performance of each of these six students and record this on a form. At the end of the exercise, the distance between the starting and end points was measured by the two time keepers with a measuring tape.

The students then proceeded to a tutorial room where they performed the card-dealing exercises and did the rating. Similarly two official time keepers and six students, to perform card-dealing with six different paces, were chosen. The performance of each student was rated and recorded on a form by all the other students. The number of cards used by each performing student was different each time to create a new situation for the observing students who knew the exact number of cards used only after the end of the rating exercises. The centre-to-centre distance between two opposite piles of cards was 25 inches.

After the students had finished the rating exercises, they also completed some questionnaires on the same recording form indicating the duration of their previous experiences on time study and the amount of time spent on group practice prior to the assessments. They then exchanged the completed forms with one another to compute the rating deviations. The official time keepers first presented the average time taken by each performer, in both walking and card-dealing exercises. The actual performances of these performers, in terms of percentages, were then worked out. The standard pace of 100% for walking was based on covering a distance of 3 miles in an hour (i.e. 264 feet in 1.0 minute) and the standard pace of 100% for card-dealing was based on dealing 52 cards in 0.5 min. The deviations between the observed ratings and the actual performances were then calculated by subtraction and taking only the absolute values. The average of the absolute deviations was then computed for both the walking and card-dealing exercises. The completed forms were then shown to the original students who did the ratings before they were finally collected for analyses. Table 1 shows the number of students with different experience participated in Stage 1 of this investigation.

Stage 2

The ten students were divided into three subgroups, three students each in the first two subgroups and four students in the third subgroup. Besides doing some design and fabrication work for pin assembly boards, they were required to do some practices in performance ratings for walking and card-dealing. The practising time for each group ranged from 4 to 12 hours. In both the

Table 1. Number of students with different experience participated in the walking and card-dealing exercises in Stage 1

S/N	Previous experience in time study (months)	Prior practice before exercises (h)	No. of students
1	none	none	200
2	none	0.5	66
3	none	1.0	15
4	3	none	8
5	3	0.5	5
6	6	none	5
7	6	0.5	3
8	12	none	4
9	12	0.5	3
10	Total no. of students		309

practice and assessment sessions, the performers were required to repeat a particular performance, at a pace to be specified by the author individually, 15 times. This would allow more meaningful average deviations to be determined later. The nominal performances expected ranged from 80% to 150%.

The three subgroups were assessed separately after their practices. During the assessment session, the students took turns to perform, one at a time, with the remaining two or three students doing the performance ratings. Each performer was given three different nominal performances to do, with 15 repetitions for each performance. The timing was done by the author. Each performer was required to raise one of his or her hands when crossing both the starting point and the end point to facilitate timing in walking. However, the conditions used in both walking and card-dealing exercises were identical to those used in Stage 1. After the assessments, the average deviations and standard deviations were calculated. A survey was also made on some personal particulars of each participating students and the time each had spent in group practising before the assessment. Table 2 shows some of their particulars.

3. RESULTS

3.1 Walking exercise

Walking without having any prior practice. There were a total of 200 students, from 12 groups, who participated in this exercise. Table 3 shows the number of students from each group, the average rating deviation and the standard deviation for each group in the walking exercise. Hence for students without having any prior practice, the average rating deviation for all the groups is 23.71%.

Walking after having more than 0.5 hour of prior practice. There were a total of 66 students who had 0.5 h prior practice before they participated in this exercise. Table 4 shows the number of students from each group, the average rating deviation and the average standard deviation of each group in the walking exercise. Hence after having 0.5 h of prior practice, the average deviation of all the groups is now 24.22%. This figure is similar to 23.71% indicated in Table 3. It seems that the beneficial effect of prior practice on performance rating is not apparent.

Table 5 shows the rating deviations and standard deviations of other groups of students not listed in Tables 3 and 4. They had either spent one hour in

Table 2. Particulars of students participated in performance rating exercises in walking and card-dealing in Stage 2

Group no.	Student	Age	Weight (kg)	Height (m)	Practice (h)	
					Walking	Card dealing
1	A	27	60	1.59	12	6
	B	23	60	1.76	12	6
	C	27	58	1.72	12	6
2	D	29	62	1.63	6.5	6.5
	E	25	71	1.73	6.5	6.5
	F	22	85	1.72	6.5	6.5
3	G	25	71	1.75	4.5	4.5
	H	22	52	1.70	4.5	4.5
	I	22	70	1.75	4.5	4.5
	J	23	72	1.75	4.5	4.5

Table 3. The average rating deviations and standard deviations from 12 groups of students who participated in walking exercises without having any prior practice

Group no.	No. of students	Av. dev.	Std. dev.
1	25	48.52	6.60
2	23	18.83	8.30
3	18	21.28	6.98
4	11	19.90	15.53
5	11	28.82	7.52
6	10	14.80	7.77
7	20	26.35	8.87
8	17	12.53	4.73
9	19	33.89	13.95
10	17	25.94	11.02
11	18	15.61	5.40
12	11	18.09	5.09
Total	200		
Average		23.71	8.48

Table 4. The average rating deviations and standard deviations from 12 groups of students who had 0.5 h practice before they participated in the walking exercises

Group no.	No. of students	Av. dev.	Std. dev.
1	4	42.50	3.04
2	4	37.25	10.35
3	2	22.50	3.50
4	8	21.50	15.38
5	2	26.50	6.50
6	9	17.33	7.07
7	3	21.00	1.63
8	4	17.00	8.75
9	3	24.33	10.40
10	11	29.27	9.77
11	3	25.67	10.33
12	13	19.30	8.33
Total	66		
Average		24.22	11.80

practice prior to assessment or had some previous experience in time study before taking up the present course. It can be seen from Table 5 that with a one hour prior practice, the average deviation was now reduced to 20.53%. It can be seen from the same table, as well as from Section 4.5, that generally, the rating deviation also reduces as the length of previous experience in time study is increased.

Walking after having more practices. Table 6 shows the rating deviations and standard deviations obtained in Stage 2 from walking exercises for students who had 4.5 to 12 h of practice prior to their assessments. The average deviation has now reduced to 6.36%.

3.2 Card-dealing exercise

Card-dealing without any previous practice. There were a total of 200 students, from 12 groups, who participated in this exercise. Table 7 shows the number of students from each group, their average rating deviations and standard deviations in the card-dealing exercise. It can be seen from Table 7 that the average deviation for all the students is 13.02%.

Card-dealing after more than 0.5 hour of prior practice. There were a total of 66 students who had 0.5 h prior practice before they participated in this exercise. Table 8 shows the number of students from each group, their average rating deviations and standard deviations in the card dealing exercise. The average deviation for all the students is 16.35%. This figure is slightly higher than the 13.02% obtained from Table 7, indicating that too little practice may not be able to improve their abilities in performance rating.

Table 9 shows the rating deviations and standard deviations of other groups of students not listed in Tables 7 and 8. They had either spent one hour in practice prior to the assessment or had some previous experience in time study before taking up the present course. It can be seen from Table 9 that, for students who had 1.0 h of prior practice before the assessment, the deviation has now reduced to 9.07%. The effect of prior practice on improving performance rating is therefore obvious. Table 9 also shows that, for students without any prior practice, previous experience in time study may not be helpful in improving their abilities in performance rating. However, with 0.5 h of prior practice, it is also obvious that the rating deviation reduces as the length of previous experience in time study is increased. In fact, for the students who had 12 months previous experience and 0.5 h prior prac-

Table 5. Rating deviations and standard deviations from walking exercises for students who either spent one hour in practice prior to their assessments or had some previous experience in time study

S/N	Previous experience (months)	Prior practice (h)	No. of students	Deviation (%)	Std. dev.
1	None	1.0	15	20.53	14.60
2	3	none	8	22.88	7.34
3	3	0.5	5	32.60	13.84
4	6	none	5	20.20	9.62
5	6	0.5	3	22.33	3.30
6	12	none	4	14.75	4.66
7	12	0.5	3	14.33	1.25

tice, the average deviation is 8.33%, which is better than the 9.07% obtained by students who had no previous experience but spent 1.0 h on prior practice.

Card-dealing after more practices. Table 10 shows the rating deviations and standard deviations obtained in Stage 2 from card-dealing exercises for students who had 4.5 to 6.0 h of practice prior to the assessment. It will be seen from Section 4.2 that the rating deviation reduces as the practice time is increased.

Table 6. Rating deviations and standard deviations for walking exercises obtained from Stage 2 students

Student	Practice (h)	Av. dev.	Std. dev.
A	12	3.00	1.15
B	12	2.67	1.10
C	12	1.50	1.26
Group Av		2.40	1.17
D	6.5	8.17	4.63
E	6.5	5.33	2.05
F	6.5	6.00	4.80
Group Av		6.50	3.83
G	4.5	6.80	2.62
H	4.5	9.00	3.97
I	4.5	8.67	4.52
J	4.5	8.67	5.23
Group Av		8.30	4.09
Overall Av		6.36	4.45

4. DISCUSSIONS

4.1 Frequency distribution of the deviations

Figure 1 shows the frequency distribution chart for the deviations obtained from the walking exercises for the 200 students assessed without prior practice, for the 66 students who had spent 0.5 h in practice prior to their assessments and for Stage 2 students who had more than 4.5 h of prior practice before their assessments.

Figure 2 shows the frequency distribution chart for the deviations obtained from the card-dealing exercises for the 200 students assessed without prior practice, for the 66 students who had spent 0.5 h in practice prior to the assessment and for Stage 2 students who had more than 4.0 h of prior practice before their assessments.

It can bs seen from these figures that the shape of Figs 1(a, b) and 2(a, b) are closer to the normal distribution curve while Figs 1(c) and 2(c) are not, obviously due to the smaller sample size used in Stage 2 of the study.

Table 7. The average rating deviations and standard deviations from 12 groups of students participated in card-dealing exercises without any prior practice

Group no.	No. of students	Av. dev.	Std. dev.
1	25	8.44	3.07
2	23	15.35	10.15
3	18	17.06	6.65
4	11	17.00	7.26
5	11	12.73	3.86
6	10	10.10	5.86
7	20	9.55	3.65
8	17	11.41	4.97
9	19	14.10	8.87
10	17	12.59	4.07
11	18	16.67	6.86
12	11	11.20	7.63
Total	200		
Average		13.02	6.08

Table 8. The average rating deviations and standard deviations from 12 groups of students who had 0.5 h practice before they participated in the card-dealing exercise

Group no.	No. of students	Av. dev.	Std. dev.
1	4	13.00	8.77
2	4	33.00	11.38
3	2	12.00	1.00
4	8	22.25	11.64
5	2	10.00	6.00
6	9	13.67	5.31
7	3	8.67	1.25
8	4	17.5	7.30
9	3	16.00	12.96
10	11	16.18	7.53
11	3	25.00	2.94
12	13	11.77	5.42
Total	66		
Average		16.35	9.76

Table 9. Rating deviations and standard deviations from card-dealing exercises for students who either spent one hour in practice prior to their assessments or had previous experience in time study

S/N	Previous experience (months)	Prior practice (h)	No. of students	Deviation (%)	Std. dev.
1	None	1.0	15	9.07	4.77
2	3	none	8	9.38	5.74
3	3	0.5	5	14.20	3.87
4	6	none	5	10.60	4.59
5	6	0.5	3	12.67	6.60
6	12	none	4	17.50	9.60
7	12	0.5	3	8.33	1.25

Table 10. Rating deviations and standard deviations from card-dealing exercises obtained from Stage 2 students

Student	Practice (h)	Av. dev.	Std. dev.
A	6	2.50	1.38
B	6	4.00	3.37
C	6	1.38	0.90
Group av.		2.80	1.88
D	6.5	8.0	6.08
E	6.5	4.17	3.18
F	6.5	4.83	3.80
Group av.		5.70	4.35
G	4.5	2.44	1.71
H	4.5	5.00	4.97
I	4.5	4.22	3.05
J	4.5	5.22	4.98
Group av.		4.20	3.68
Overall av.		4.22	4.07

4.2 The effect of practising time on the deviation

Figure 3 shows the effect of practising time on the deviations, for both walking and card dealing. The data for Fig. 3(a) are taken from Tables 3, 4, 5, 7, 8 and 9; and those for Fig. 3(b) are taken from Tables 6 and 10. It can be seen from these figures that the deviation decreases as more practising time is given. The curves are of the exponential type

$$Y = ae^{bX} \quad (1)$$

where Y is the deviation, x is the practising time (h), and a and b are coefficients.

The square of each of the correlation coefficients together with the coefficients a and b for curves, A, B, C and D in Fig. 3 are listed in Table 11.

It can be seen from Table 11 that the square of the correlation coefficients for curves C and D are better than those for curves A and B; and the correlation coefficient for curve C is extremely high. This is an indication that the data set obtained from Stage 2 is more representative. Hence it can be estimated from C and D that a practising time of 8 and 4 hours are required to achieve a rating deviation of 5% in walking and card-dealing respectively.

It should be noted that learning curves are usually represented by the power equation of the form [5]

$$Y = aX^b \quad (2)$$

where Y is the time per cycle, X is the number of cycles, a is a coefficient and b is a constant.

However, in the present case, the square of the correlation coefficients obtained for curves C and D, by assuming them to conform to this format, are 0.963 and 0.016 respectively. These figures are lower than those obtained from eqn (1) earlier.

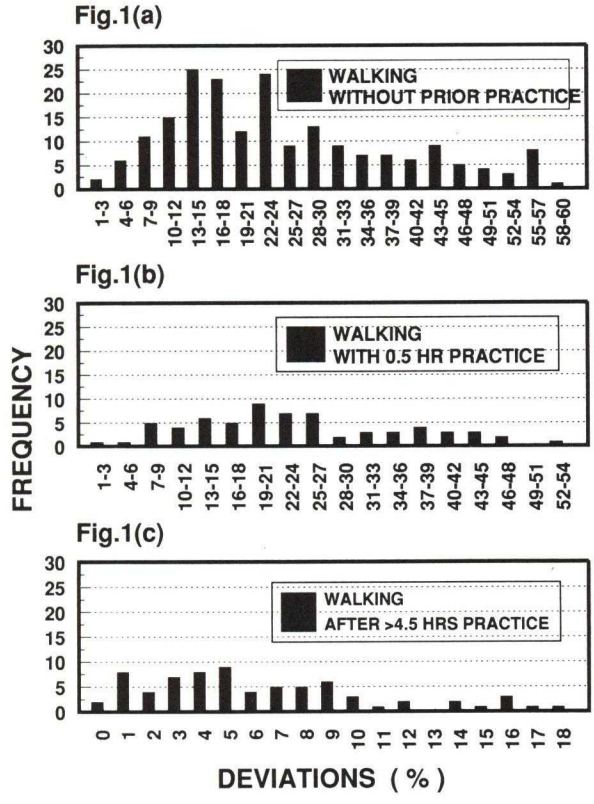

Fig. 1. Frequency distribution chart for the deviations obtained from the walking exercises: (a) without prior practice; (b) 0.5 h prior practice; (c) more than 4.5 h of prior practice before their assessments

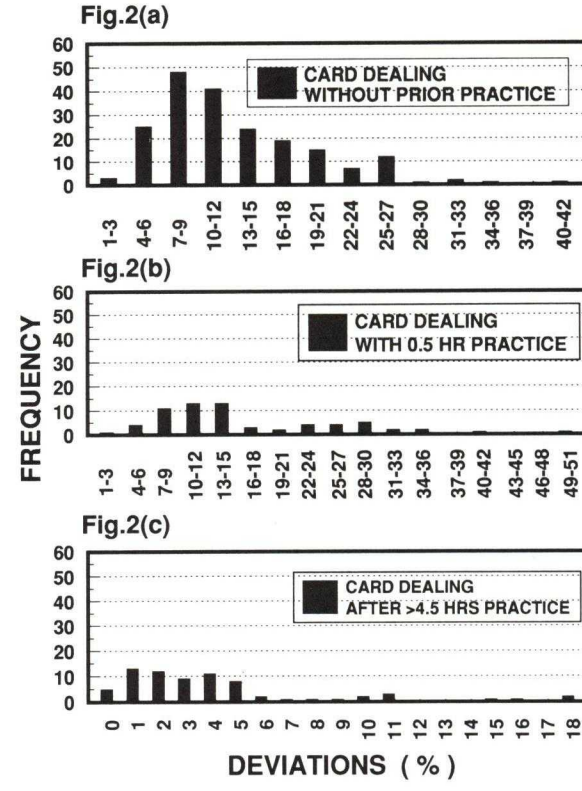

Fig. 2. Frequency distribution chart for the deviations obtained from the card-dealing exercises: (a) without prior practice; (b) 0.5 h prior practice; (c) more than 4.5 h of prior practice before their assessments

Table 11. Square of correlation coefficients, and coefficients for curves A, B, C and D

S/N		Curve	Sq. corr. coeff. (R^2)	Coefficient (a)	Coefficient (b)
1	A	walking	0.644	24.449	−0.145
2	B	card dealing	0.361	14.907	−0.357
3	C	walking	0.997	19.590	−0.175
4	D	card dealing	0.523	7.965	−0.115

Hence the exponential equation used earlier is more suitable for the present work.

4.3 The variations of rating abilities between subgroups

Figure 4 shows the variations in rating abilities between subgroups obtained in Stage 1 of this study for the walking and card dealing exercises respectively. It can be seen from Fig. 4(a) that in walking, the average deviation of Group 1 is nearly twice that of the average of all the groups. In card dealing, it can again be seen from Fig. 4(b) that there are still variations; although the variations are smaller.

Figure 5 shows the variations in rating abilities between participants in walking and in card dealing respectively obtained in Stage 2 of this study. Again there are variations between each individual in rating ability in both walking and card dealing. However, it should be noted that participants from the same group (participants A, B and C in one group, D, E and F in the next group; G, H, I and J in another group) tend to have similar rating abilities.

4.4 The difference in rating abilities in walking and card dealing

Results obtained from both Stage 1 and Stage 2 of the present studies indicate that, for a similar amount of time spent in practising, walking is more difficult to rate as compared with card dealing. It is therefore obvious that more rating practices need to be spent in walking than in card dealing in order to achieve the same rating deviation. It can be seen from Section 4.2 that a practising time of 8 and 4 hours are required to achieve a rating deviation of 5% in walking and card dealing respectively.

4.5 The effect of previous working experience

Tables 5 and 9 show the rating deviations in walking and card dealing respectively for students

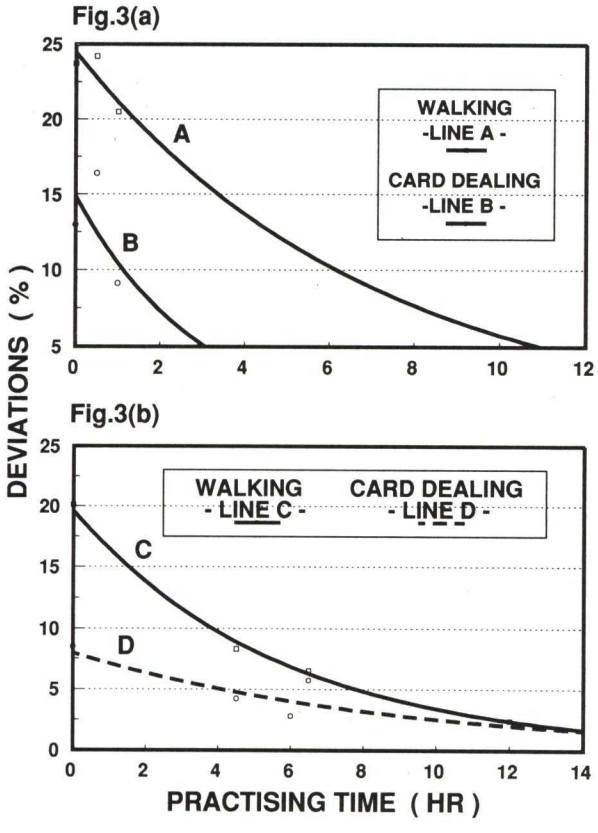

Fig. 3. The effect of practising time on the deviations, for both walking and card-dealing:(a) data taken from Tables 3, 4, 5,7, 8 and 9; (b) data from Tables 6 and 10.

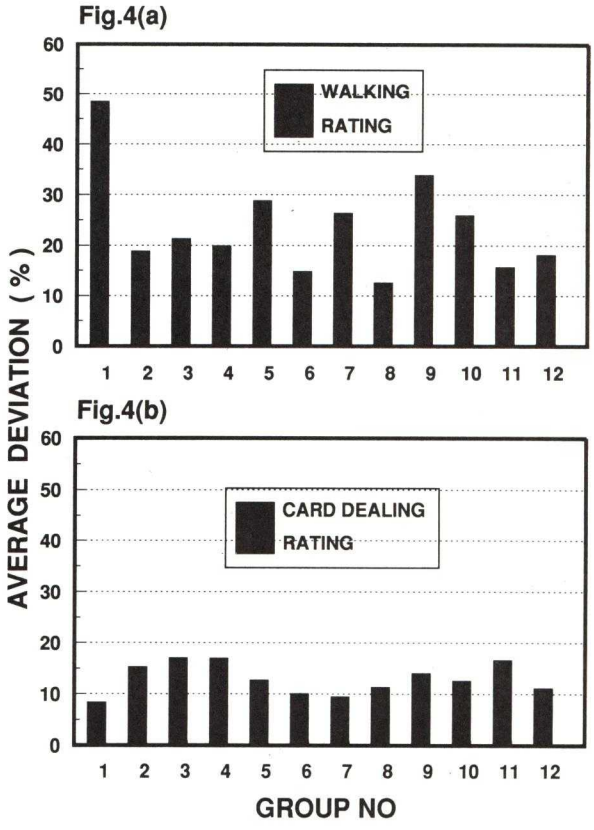

Fig. 4. Variations in rating abilities between sub-groups obtained in Stage 1 of this study: (a) walking; (b) card-dealing.

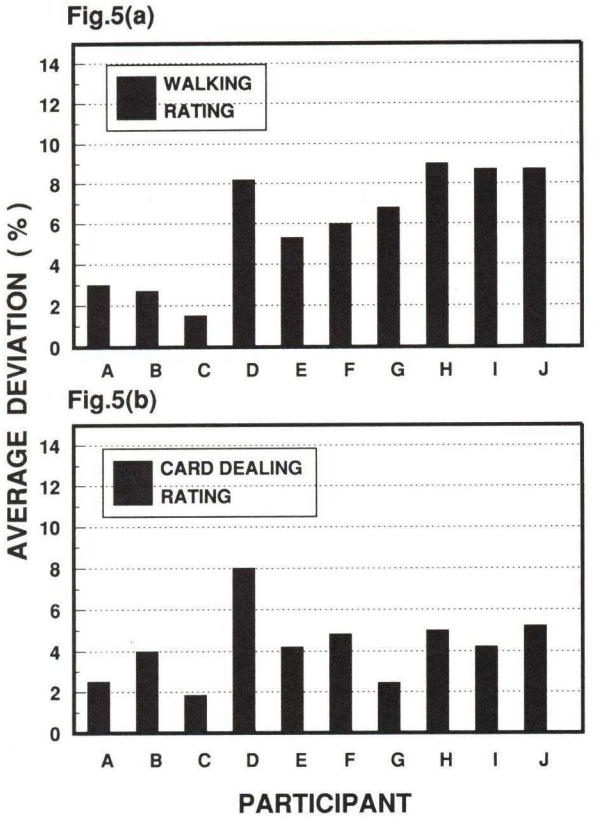

Fig. 5. Variations in rating abilities between individuals obtained in Stage 2 of this study: (a) walking; (b) card-dealing.

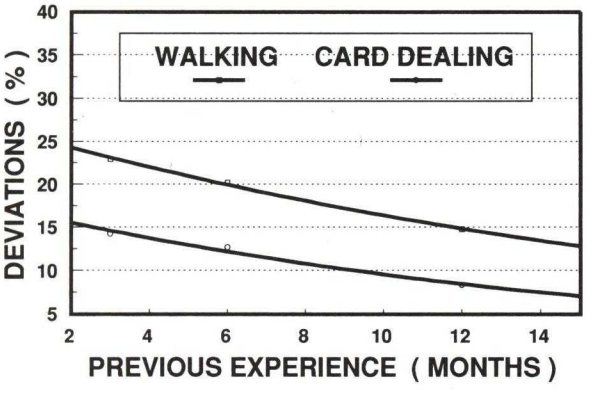

Fig. 6. The effect of previous experience in time study on rating deviation.

with some previous experience in time study. Some of these figures are plotted in Fig. 6, which shows that the rating deviation depends on the previous experience in time study. The rating deviation decreases as the previous experience in time study is increased, for both walking and card dealing, for students who had spent about 0.5 h prior practice before the assessment. The data obtained from students who did not practise prior to the assessment are inconsistent. This is due to probably some extreme cases and the small sample size, i.e. small number of students participated.

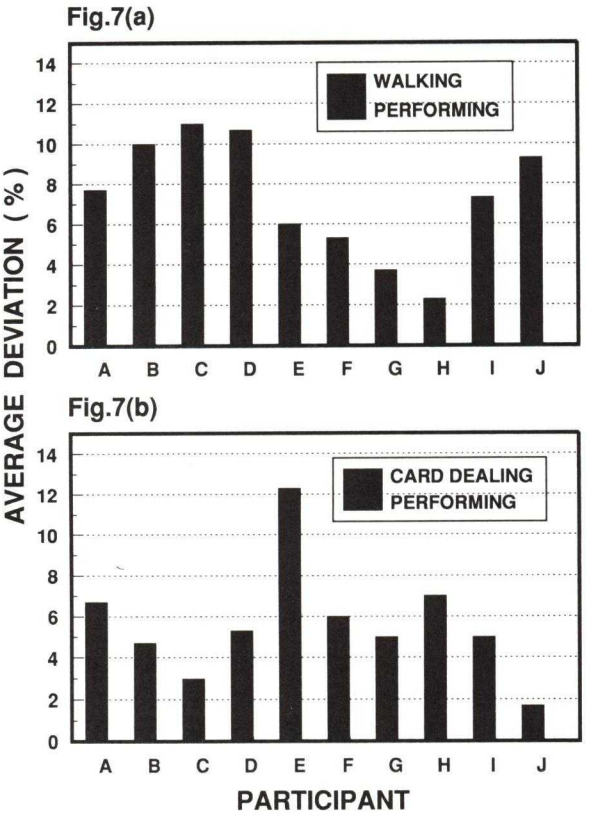

Fig. 7. The deviations in performing: (a) walking; (b) card-dealing

4.6 The performing abilities of students

Figure 7 shows the deviations in performing in walking and card dealing. These are based on data collected during Stage 2 of the present study. By comparing Fig. 7(a) with Fig. 5(a), and Fig. 7(b) with Fig. 5(b), it can be seen that the deviations in performing are greater than those in rating. Hence more practising time needs to be given to the students or operators if they are expected to perform with the same degree of consistency.

5. CONCLUSION

Investigations carried out to study the deviation in performance rating of more than 300 undergraduate engineering students, using the walking and card-dealing techniques, has found that:

- the average deviation was 24% and 13% respectively for walking and card dealing for students who had no prior practice training prior to the assessment;
- previous industrial experience in work study was beneficial;
- generally, the performance-rating abilities of students improved as more time was spent in practice training;
- the practice training times required to achieve a deviation of 5% were 8 hours for walking and 4 hours for card dealing respectively. Therefore

more time needed to be spent to achieve the same consistency;
- it was more difficult to perform a nominal standard than doing performance rating;
- variations in performing and rating existed between individuals and between groups.

Acknowledgements—The author would like to thank all the students who participated in the above-mentioned exercises.

REFERENCES

1. R. M. Barnes, *Motion and Time Study Design And Measurement of Work*, 7th edn, Wiley, New York (1980).
2. F. E. Meyers, *Motion & Time Study—Improving Work Methods and Management*. Prentice Hall, Englewood Cliffs, N.J. (1992).
3. C. A. Anderson, Performance rating, in *Industrial Engineering Handbook* (Editor-in-Chief: H. B. Maynard) Chapter 3. McGraw-Hill, New York (1971).
4. B. W. Niebel, Time study, in *Handboook of Industrial Engineering* (ed. G. Salvendy), 2nd edn. Wiley, New York (1992).
5. W. M. Hancock and F. H. Bayha, The learning curve, in *Handbook of Industrial Engineering* (ed. G. Salvendy) 2nd edn. Wiley, New York (1992).

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