□原著論文□

Effects of occupationally embedded exercise on motor sequence learning and psychological status

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Abstract

Objective: The purpose of this study was to compare an occupationally embedded exercise (OE) versus rote exercise (RE) in terms of their effects on motor sequence learning, specifically retention, transfer of learning, and certain psychological aspects.

Subjects: In total, 99 right-handed healthy university students were randomly assigned to 4 groups: OE with a natural condition (OEN group); OE with an impoverished condition (OEI group); RE group; or the control group.

Methods: Using computer software, reaction time and accuracy were assessed in all participants while performing sequential finger tapping. The OEN group practiced the tapping sequences by playing an electric piano to produce familiar songs. The OEI group practiced the same sequences using a piano but without producing sounds, thereby creating the impoverished condition. The RE group practiced the same tapping sequences on a tabletop, and the control group rested instead of practicing. Immediately after the practice session, the participants in all 3 experimental groups were asked to rate their happiness, interest, relaxation, and tiredness using the Likert scale.

Results: There were no significant differences between groups, except the participants in the OEN group showed significantly higher accuracy on the intermanual transfer test in comparison with the control group. The OEN and OEI groups also reported a statistically significant higher level of happiness than the RE group and OEN group showed significantly a lower level of tiredness than the RE group.

Conclusion: The additional feedback provided by OEs could enhance the psychological aspects that motivate persons to engage in occupational therapy.

Keywords：occupationally embedded exercise, meaningful occupation, psychological effect, motor learning

Ⅰ. Introduction

Occupational therapists use occupations (i.e., meaningful activities) not only as the end goal of interventions, but also as the means to reach those goals[1,2]. The use of a real and functional activity that is meaningful and purposeful—often termed an occupationally embedded exercise (OE)—facilitates the learning of efficient, smooth, and coordinated movements[2,3]. The occupationally embedded exercise serves as a kind of exercise that is a by-product of pursuing task-specific goals[4]. Natural context provides a rich source of information to facilitate perception and to guide movement[5]. Moreover, objects inherent to the occupation may facilitate better and more organized performance than objectless exercises[6]. Different object characteristics may result in different levels of performance in terms of functional specificity[7].

Several studies have compared the effects of OEs versus rote exercises (REs), reporting OEs enhance motor perfor-

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mance, motivate participants to engage in the exercise, and produce positive feelings among them. Ferguson et al.[8] revealed that, compared to RE, OE enhanced motor skill retention of tune production with electric keyboards among college students. Sietsema et al.[4] and Nelson et al.[9] reported superiority of OE which not only facilitated the motor performance, but also increased the number of repetition of exercise by providing feedback to motivate the participants with brain injury. Hoppe et al.[10] found that engaging in OE increases physical activity and elicits a positive psychosocial response in college-aged females.

From the point of view of motor learning, OEs may provide motivational feedback, task-specific and meaningful goals, and an enriched environment[1,11]. The previous studies introduced above have demonstrated OEs' superiority using kinematic parameters, such as range of motion, number of repetition in physical exercise, and retention and accuracy of motor sequence as outcome measures; however, there are still limitations in observing the effects of OEs on motor learning. They recruited relatively limited number of subjects, measured motor performance only within short period of time after practice session, and determined level of learning by counting number of errors in practiced sequence. In this study, we assessed motor learning after a short period of time and 24 h after practice in terms of reaction time and accuracy, which is common in motor learning research[12]. Also we tested the performance of non-dominant hand without practice in order to see intermanual transfer of motor learning.

The purpose of this research was to compare the effectiveness of OEs versus REs in terms of their effects on motor sequence learning, specifically retention, transfer of learning, and certain psychological aspects. In this research, we assigned participants to 3 experimental groups and 1 control group as follows: OE with the natural condition (OEN group), in which the participant played an electric piano with sound that, which provided a higher level of information about the objects and added meaning to the task to create a more natural condition; OE with impoverished condition (OEI group), in which the participant played an electric piano without sounds and thereby received a lower level of object information[3,7]; RE group, in which the participant practiced sequential finger tapping on a tabletop as an objectless condition; and the control group, in which the participants did not engage in a practice session. Thinking these three experimental groups in terms of occupational therapy practice, RE, OEI, and OEN correspond respectively with physical exercise without object, physical exercise with therapeutic object, and functional practice using meaningful activity.

Hypotheses

1. The OEN group will show better retention and transfer than the OEI, RE, and control groups, as shown by a shorter reaction time and higher accuracy.
2. The OEI group will show better motor learning than the RE group.
3. The OEN group will show more positive scores for the assessed psychological aspects (i.e., happiness, interest, relaxation, and tiredness) than the other groups.

Ⅱ. Participants and Methods

1. Participants

In total, 104 Japanese university students (40 men and 64 women) were recruited to participate in this study. The participants ranged in age from 21 to 27 years (mean [SD], 20.72 [0.63] years). The inclusion criteria were as follows: 1) right-handed; and 2) < 3 years of formal education in playing the piano. All participants voluntarily decided to participate in this research and filled in a handedness questionnaire, the short form of the Japanese version of the Edinburg Inventory[13]. Written informed consent was obtained from each participant. This study was approved by the ethical committee of the International University of Health and Welfare (IUHW) (approval number 14-Io-143).

2. Methods and instrumentations

The sequential finger tapping task was assessed by computer software (SuperLab version 4.5) with a response pad (Model RB-730, Cedrus Co.). The 2 experimental groups (OEN and OEI groups) used an electric piano to practice the tapping task. The 4-point Likert scale was used to measure the psychological aspects, which consisted of happiness, relaxation, interest, and tiredness. For the sequential finger tapping assessment tests and sequential finger tapping practice task, the sequences were made by combining 5 notes on the piano to play 2 familiar children's songs in Japan, "*Bun Bun Bun*" and "*Seija no Koushin* (When the Saints Go Marching In)".

3. Design

A simple randomized design with 4 independent groups was used. Each participant was randomly allocated to one of 4 groups: OEN, OEI, RE, or control group.

4. Procedure

The participants attended the experiment on 2 consecutive days. The first day consisted of pre-assessment, practice or rest, and immediate post-assessment; the second day consisted of the 24-hour delayed post-assessments. On day 1, the reaction time and accuracy during sequential finger tapping were measured in both hands of all participants in all 4 groups using computer software (SuperLab), and their results were recorded as pre-assessments. The participants pushed the response pad while looking at the numbers displayed on the computer screen. The stimulus consisted of numbers 1 to 5, which corresponded to the thumb and 4 fingers; i.e., number 1 indicated the thumb, number 2 indicated the index finger, number 3 indicated the middle finger, number 4 indicated the ring finger, and number 5 indicated the little finger. The participants were instructed to accurately perform the task as fast as possible.

All participants in the 3 experimental groups practiced sequential finger tapping. They practiced at their own speed with their dominant hand (right hand), and they were instructed to not make errors. They practiced the same sequence of numbers used in the assessment. The sequence consisted of 63 numbers, and each participant practiced it 10 times. This required about 7 to 10 min. They were told to take a rest whenever they felt tired.

The participants in the OEN group practiced sequential finger tapping by playing the electric piano while looking at a sheet of paper on the table, which showed the 63-number sequence. When they correctly struck the keyboard of the piano, they could produce 2 songs ("*Bun Bun Bun*" and "*Seija no Koushin* (When the Saints Go Marching In)"). While playing the piano, a researcher asked each participant to name the song in order to determine if the participant recognized the song. As the first 4 participants in the OEN group did not recognize the songs, the researcher decided to provide the name of song to the rest of the participants to make them feel the natural condition.

The participants in the OEI group practiced sequential finger tapping by striking the electric piano keyboard in the same manner as the OEN group, but to create the impoverished condition no sound was produced when the keyboard was played. In contrast to the OEN, they were not told that the sequences produced familiar tune. In the RE group, the participants practiced sequential finger tapping by tapping on the tabletop while looking at the 63-number sequence. The participants in the control group were instructed to rest for 7 min between the pre- and post-assessments.

Immediately after practice, each participant in the 3 experimental groups rated their scores for happiness, interest, relaxation, and tiredness while performing the practice task using the Likert scale, and then all groups conducted post assessments for motor skill learning. First, like the pre-assessment, immediate post-assessment was assessed by measuring the reaction time and accuracy of sequential finger tapping (immediate retention test). Then, to assess the transfer of skill learning, the performance of the non-dominant left hand was measured (immediate intermanual

transfer test).

On day 2, to observe the long-term effects of motor learning, all participants performed the same assessments, which consisted of reaction time and accuracy during sequential finger tapping as delayed post assessments (delayed retention test and delayed intermanual transfer test).

5. Statistical methods and analysis

One assessment consisted of 63 numbers, and a mean of the 63 reaction time was used as reaction time of each participant. Similarly, accuracy was determined as the number of correct responses out of 63 taps.

SPSS (version 21) was used to perform all statistical analyses. Two-way repeated measures analysis of variance (ANOVA) was used to test the main effect (motor learning) between groups and phases which mean between assessments (pre-, post and delayed post assessments). Bonferroni correction was used for post hoc multiple comparisons. The nonparametric Fisher exact test was used to assess the responses to the Likert scale. The level of significance was set to 0.05.

Ⅲ. Results

For this study, 104 participants were recruited, and the data from 5 participants were discarded because 1 participant showed unusual number of errors from control group (3 times larger than the average of the other participants). As mentioned in the procedure part, the first 4 participants from OEN group were decided to exclude from analysis because they could not tell and were not provided the name of song as the other participants did. As a result, participant number of each group for analysis was as follows: OEN (*n*=23), OEI (*n*=25), RE (*n*=26), Control (*n*=25). Table 1 shows the demographic data for all groups. There were no significant differences among groups in terms of participant characteristics.

1. Retention test

Based on the data analysis, there was a statistically significant difference among the participants in their reaction time in phase. However, there was no significant difference in accuracy. No statistically significant effect was found between groups and interaction of phase and groups (Tables 2 and 3).

2. Transfer of learning test

In the intermanual transfer test, only phase effect was found in reaction time, but there was no significant difference between groups. In accuracy, there was a significant difference between groups, and phase and group interaction was also significant (Tables 4 and 5). Multiple comparison tests to examine simple effects indicated that there were significant differences between control and OEN, only in accuracy (Figure 1).

Table 1　Demographic characteristics of study groups

Group	*n*	Sex		Age (yrs)		No. of participants with piano experience
		Male	Female	Mean	SD	(< 3 yrs)
OEN	23	7	16	20.65	0.63	3
OEI	25	11	14	20.74	0.66	7
RE	26	9	17	20.72	0.74	4
Control	25	11	14	20.80	0.58	6
Total	99	38	61	20.75	0.82	20

n=number of participants; OEN=occupationally embedded exercise with natural condition; OEI=occupationally embedded exercise with impoverished condition; RE=rote exercise; SD=standard deviation.

Table 2　Descriptive data for retention test

Variables	Group	Pre-assessment		Immediate Post-assessment		Delayed Post-assessment	
		M	SD	M	SD	M	SD
Reaction time (msec)	OEN	769.72	99.98	643.42	101.73	611.39	100.19
	OEI	777.79	111.51	654.73	68.05	638.67	71.71
	RE	796.40	144.22	673.95	121.86	652.76	124.56
	Control	782.30	107.29	687.96	99.07	663.09	89.88
Accuracy (Numbers*)	OEN	61.22	1.78	61.13	1.82	60.91	1.81
	OEI	60.52	2.18	60.88	2.67	61.08	1.78
	RE	60.35	3.60	61.04	1.68	61.12	1.53
	Control	60.84	1.97	60.44	2.06	60.76	1.91

msec= milliseconds; M=Mean; SD=Standard Deviation.

* Numbers of correct response out of 63 taps.

Table 3　Results of two-way ANOVA in retention test

Source	df	SS	MS	*F*	*p*
Reaction time					
Between					
Group	3	60961.214	20320.405	0.704	0.552
Error	95	2741876.987	28861.863		
Within					
Phase	1	969278.338	969278.338	338.074*	0.000
Phase x group	3	9447.323	3149.108	1.098	0.354
Error	95	272370.744	2867.060		
Accuracy					
Between					
Group	3	6.103	2.034	0.346	0.792
Error	95	558.712	5.881		
Within					
Phase	1	2.757	2.757	0.722	0.398
Phase x group	3	9.601	3.200	0.838	0.476
Error	95	362.742	3.818		

df=degree of freedom; SS=sum of square; MS=mean square.

* Indicates a statistically significant result ($p<0.05$).

3. Psychological aspects

Among the 4 psychological aspects, the OEN group showed a significantly more positive psychological status for happiness and tiredness in comparison with the RE group, but not for interest or relaxation. When comparing the OEI and RE groups, a significant difference was found only in terms of happiness. However, there were no significant differences between the OEN and OEI groups in terms of any psychological item (Table 6 and Figure 2).

Ⅳ. Discussion

1. Effects of OEs on motor learning

The findings presented in this study partially supported our first hypothesis but not second hypothesis: there were no significant differences between the groups in retention tests, but for intermanual transfer of learning, there was significant difference between the control and OEN group. A possible reason for the small differences between groups in the retention tests is that the number of practice attempts was sufficiently large to provide all groups sufficient time

Table 4　Descriptive data for intermanual transfer test

Variables	Group	Pre-assessment		Immediate Post-assessment		Delayed Post-assessment	
		M	SD	M	SD	M	SD
Reaction time (msec)	OEN	771.53	108.20	688.35	107.52	659.57	100.15
	OEI	760.51	73.71	697.51	86.95	663.07	90.80
	RE	769.20	103.68	709.33	113.05	689.86	105.97
	Control	766.85	104.23	718.38	119.76	695.01	90.55
Accuracy (Numbers*)	OEN	61.61	1.75	61.48	1.28	61.52	1.70
	OEI	60.72	1.67	61.08	1.35	61.84	1.55
	RE	61.04	1.43	60.73	2.51	61.54	1.68
	Control	61.00	5.16	60.52	1.90	60.08	2.58

M=Mean; SD=Standard Deviation.

* Numbers of correct response out of 63 taps.

Table 5　Results of two-way ANOVA in intermanual transfer test

Source	df	SS	MS	*F*	*p*
Reaction time					
Between					
Group	3	24551.135	8183.712	0.310	0.818
Error	95	2508751.319	26407.909		
Within					
Phase	1	401472.567	401472.567	204.660*	0.000
Phase x group	3	11825.824	3941.941	2.009	0.118
Error	95	186357.137	1961.654		
Accuracy					
Between					
Group	3	38.132	12.711	2.627*	0.055
Error	95	459.592	4.838		
Within					
Phase	1	1.160	1.160	0.493	0.484
Phase x group	3	28.304	9.435	4.012*	0.010
Error	95	223.403	2.352		

df=degree of freedom; SS=sum of square; MS=mean square.

* Indicates a statistically significant result (p<0.05).

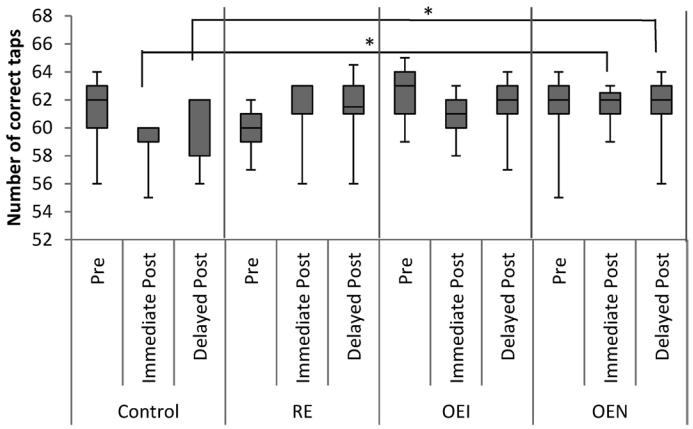

Figure 1　Accuracy of the intermanual transfer test (Bonferroni).
* Indicates a statistically significant result (p<0.05).

Table 6　Comparison of psychological aspects between the experimental groups

Psychological Aspect	OEN vs RE	OEI vs RE	OEN vs OEI
	F (*p*)	*F* (*p*)	*F* (*p*)
Happiness	13.511 (0.003)*	9.486 (0.030)*	1.927 (2.184)
Interest	4.243 (0.402)	3.040 (1.089)	1.803 (2.085)
Relaxation	4.052 (0.303)	6.961 (0.123)	1.198 (3.000)
Tiredness	17.365 (0.000)*	7.055 (0.096)	5.862 (0.297)

OEN=occupationally embedded exercise with natural condition; OEI=occupationally embedded exercise with impoverished condition; RE=rote exercise.
* Indicates a statistically significant result (p<0.05).

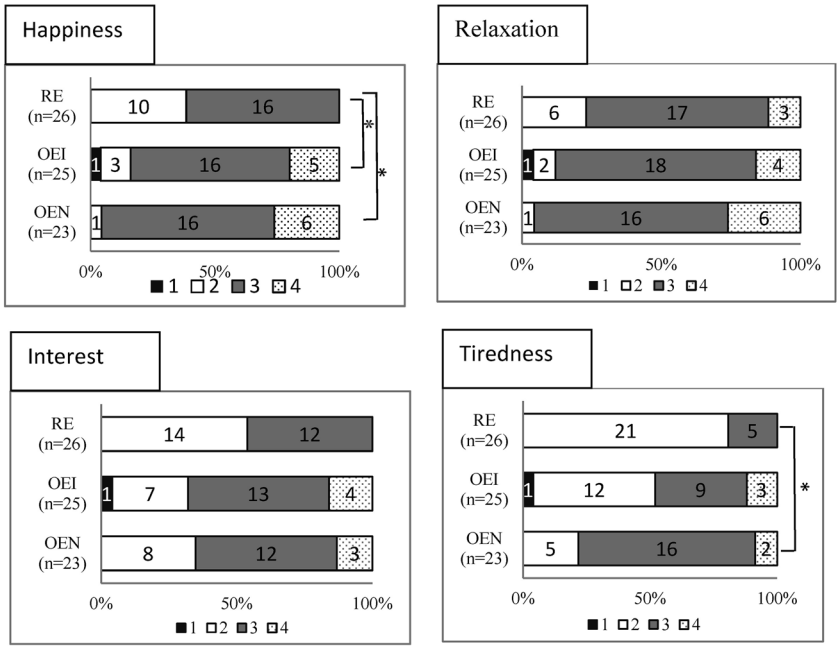

Figure 2　Results of the Likert scale (psychological aspects) in the experimental groups (n=74).
1=Negative meaning; 4=Positive meaning.
* Indicates a statistically significant result (p<0.05).

to learn the sequential finger tapping task, and this diminished the effect of practice in the experimental groups. It was not difficult for healthy adults to learn sequential finger tapping in this study, and even the control group had a chance to learn how to perform the 63-number sequence during the assessment sessions.

The results of intermanual transfer test differed from the results of the other tests, that is, the OEN group showed significantly greater accuracy than the control group, while there was no difference between the other groups. Therefore, OEN might be more effective than other experimental groups, as described by Urry et al.[14], indicating that accuracy-based measures provide a better measure of sequence learning than reaction time-based measures. These findings suggest that, even though the sequential finger tapping task could be easily improved in a short period of time, the intermanual transfer should have been too difficult to improve without practice. Also, it is suggested that practicing with meaningful activity in the natural settings is more effective than the other practice methods, and there is no difference between rote practice and practice with meaningless activity in terms of finger sequence learning.

The psychological results partially support the third hypothesis. The OEN group showed greater positive meaning than the other groups in terms of 2 items: happiness and tiredness. Psychological issues play an important role in rehabilitation by motivating and inspiring patients. The rehabilitation approach should consider psychological aspects because active patient participation is essential to improving performance. Hence, occupational therapists must choose and/or create the therapeutic environment and tasks that best facilitate learning by inducing patient motivation.

Regarding the level of meaning, the OEN group reported higher levels of happiness and interest but a lower level of tiredness than the other 2 experimental groups. The OEN group practiced familiar songs, and they might have felt as though they were performing rather than practicing. When they performed better, a rhythmic familiar song was produced as an outcome. Moreover, because familiar songs might provide some level of fun to the participants, they did not feel tired, as shown by the lower level of tiredness. This finding is similar to previously published studies that found a statistically significant higher number of repetitions and duration of OEs compared with REs[10]. Kircher[15] assumed that motivation is indicated by decreased perception of fatigue.

In addition, even the OEI group reported greater positive meaning than the RE group, though a significant difference was found only in the happiness score. It is likely that the participants in the OEI group also focused on playing the piano in a similar manner as the OEN group, even though they played under an impoverished condition. Therefore, the OEI group may have been happier than RE group, which focused on sequential finger tapping just as a repetitive exercise.

2. Clinical implications

Although the results of this research cannot be generalized, its implications can be applied to the field of occupational therapy. The results of this study indicate that, compared to RE, meaningful exercise may have some advantage in motor learning and eliciting positive psychological effects. Positive psychological effects can motivate active participation in a relearning program.

3. Limitations and future research

Sequential finger tapping may be too easy for healthy participants to perform, but it can be used to examine learning effects in participants with brain injuries. In this study, the participants rated their psychological aspects in front of the researcher. Hence, complete scales should be considered, which would allow the participant to provide correct and confident answers regarding their psychological aspects.

Ⅴ. Conclusion

The current study does not provide clear evidence for the advantage of OE in motor sequence learning because of issues in the study design, but the result of intermanual transfer test suggest a possible beneficial effect of OE compared to other exercise methods. Also, this study does provide experimental support for the occupational therapy's value. In other words, OEs can enhance psychological aspects, suggesting that a person may be happier and may not perceive tiredness as readily if he or she engages in a meaningful occupation. This study should be replicated and extended to allow generalization, and future studies should include clinical populations commonly seen by occupational therapists in order to determine direct clinical implications.

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There are no conflicts of interest that need to be disclosed.

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作業に基づいた練習の運動系列学習および心理状態への影響

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抄　録

目的：運動系列学習における保持，学習転移，心理的影響の観点から，作業に基づいた練習（OE）の効果を機械的訓練（RE）と比較し検証した．
対象：分析対象は 99 人の健康な大学生で，以下 4 群に無作為に割り付けた：自然状況下の OE（OEN）群，限定的状況下の OE（OEI）群，RE 群，対照群．
方法：ソフトウェアを使用し，運動系列指タップの速さと正確性を測定した．対照群は測定のみとした．OEN 群は電子ピアノでよく知る曲を演奏し，OEI 群は音の出ないピアノで，RE 群はテーブル上で同じ系列の指タップを練習した．これら 3 群では，練習直後の幸福感，興味，リラックス感，疲労感を，ライカートスケールで評価した．
結果：左手への学習転移では，OEN で対照群よりも有意に正確性が高かったが，他に運動学習における群間差はなかった．OE の 2 群は RE 群よりも幸福感が高く，OEN は RE よりも疲労感が低かった．
結論：OE から受けるフィードバックには，作業療法に取り組む動機を高める，心理的効果があることが示唆された．

キーワード：作業に基づいた練習，意味のある作業，心理的効果，運動学習