DOI: 10.22122/jrrs.v14i4.3123 Published by Vesnu Publications

Making Increase in Bimanual Coordination Task Accuracy under Limitation of Peripheral Vision

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Original Article

Abstract

Introduction: The effect of central vision occlusion on two-hand coordination tasks is assessed in previous studies. However, the effect of peripheral vision on these tasks is not clearly identified; therefore, the purpose of this study was to investigate the effect of limitation of peripheral vision on two-hand coordination tasks.

Materials and Methods: Seven right-handed and right eye-dominant girl students with a mean age of 24.00 ± 3.46 years participated in this study. Subjects tested under four experimental conditions including peripheral vision limitation of the position of right hand, left hand, and both hands, and no peripheral limitations of hand position in the two-handed Vienna coordination task with four tries for each condition. The data were analyzed using 1 × 4 repeated measures ANOVA.

Results: All three conditions of visual peripheral limitation showed less errors than the conditions without visual limitation ($P < 0.05$). However, no significant difference was observed in the variable of total time between four experimental conditions ($P \geq 0.05$).

Conclusion: It seems that the visual peripheral limitation, as an environmental constraint, may increase the focus of individuals in the two-hand coordination task.

Keywords: Visual occlusion, Environmental constraint, Attention

Citation: Doosti M, Tahmasebi Boroujeni S. **Making Increase in Bimanual Coordination Task Accuracy under Limitation of Peripheral Vision.** J Res Rehabil Sci 2018; 14(4): 199-205.

Received: 26.06.2018 Accepted: 16.09.2018 Published: 07.10.2018

Introduction

Bimanual coordination task (BCT) is an issue favored by many motor behavior researchers. Bimanual coordination involves the skillful inter-organ coordination of two hands in bimanual activities that requires inter-organ coordination and the integration and sequencing of inter-organ actions (1). An important feature of BCTs is the tendency of hands to pair to perform a single movement (2). Dependence on the available peripheral information poses numerous constraints on performing the coordination tasks. Afferent information can lead to reduced inter-limb reflections whose function is to reducing coordination instabilities, while afferent visual information in particular is one of the most important sources of information and can be effective in pairing organs in discrete and continuous tasks (3).

Most studies examining the role of vision in coordination tasks have used central vision manipulation. In this regard, investigation of the effect of sensory intervention (auditory, visual, proprioception) and cognitive load on the relative phase transition of the BCT of the old women showed that cognitive load reduced the relative phase transition time (3). In addition, central vision occlusion and proprioception interventions have a negative effect on the accuracy of coordination tasks in both in-phase and anti-phase stages, however, the proprioception interventions have a more negative effect on the accuracy of these tasks (4). Moreover, in the study conducted by Cortis et al., the effect of visual and age constraints on the foot and hand flexion and extension coordination tasks was investigated. Given the findings in this study, the

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elderlies showed greater variability in both open-eye and closed-eye conditions compared to the younger two groups in the in-phase task, but in the anti-phase task and in both open and closed-eye conditions, the elderlies showed less variability compared to the other two groups. On the other hand, less variability in the open-eye condition than in the closed-eye condition in the 12-year-old anti-phase coordination task revealed that younger people were more dependent on visual information. In general, they stated that visual perception plays a different role in the stability of coordination tasks with age (5). In this regard, the results of a study suggested that central vision orientation toward the active limb decreased the BCT performance and this decrease was greater in the elderly compared to the young individuals, however the central vision orientation to the inactive member led to the performance improvement, which was found to be less frequent in the elderly (6). Given the literature on the coordination tasks, most of the investigations have been carried out on central vision and its occlusion.

The results of a study performed aiming at investigating the effect of central and peripheral visual occlusion on coordination tasks in healthy individuals indicated that central vision, like the effect that aging has on macular degeneration- which blurs central vision- affects all aspects of grasping task (grip, access, placement, and return), but peripheral vision only affects the grip phase. In fact, the difference between the effect of central and peripheral vision depends on the complexity of the coordination task. Given the above-mentioned issues, the role of the peripheral vision in BCTs is not clear, needing further studies. For example, peripheral visual occlusion can establish conditions that restrict the individual's vision access to the position of the effector organ. The results of a study suggested that directing visual attention to the active member in the bimanual coordination tracking reduces performance even in the visionless conditions (6).

Additionally, in BCTs, the peripheral visual information due to the dominant and non-dominant hands may have different effects on the BCTs. There are various theoretical foundations for the control of the BCT. From a motor program perspective, a joint motor program for two hands guides the whole BCT (2). Furthermore, according to the interactive interference model, the distinct motor program guides each hand individually, but in the theoretical model of dynamic systems, the coordinated structures act in the form of muscles that all gather as a single functional unit and increase the efficiency of movement with a reduction in the number of degrees of freedom (7). The results of a study conducted aiming to examine these three perspectives (motor program, interactive interference model, theoretical dynamic system model) by asymmetric bimanual movement transfer supported the theory of motor program because the observation of positive inter-organ transfer confirmed the independence of the effector organ from the motor memory, showing that motor skill could be attributed to different effector organs (2). In view of this, the issue of the independence of the effector organ from the motor memory has been questioned and it has been found that the independence of the effector organ depends on the specific features of the bimanual movement (7). Apart from the differences in the tasks of the right-hand dominant and left-hand dominant individuals, it seems important to know to what extent the dominant and non-dominant hand control the BCT. It has been found in a study that regardless of the dominant hand side, those who could use their non-dominant hand in some specific tasks are superior in planning and organizing BCTs (8). Therefore, this study was conducted with the objective to determine the effect of peripheral visual constraint on dominant and non-dominant hands on the performance of BCT.

Materials and Methods

This was a quasi-experimental study carried out in the within group design. The study population consisted of young girls aged 20-30 years and the sample size was estimated to be 5 people using G*Power software with statistical power of 0.7, effect size of 0.8, and confidence interval of 0.95 as well as using the repeated measures analysis of variance (ANOVA) 4*1. However, taking into account drops, 11 subjects were studied, of whom 4 were excluded from the statistical analysis due to asymmetric eye and hand dominance (right hand and left eye dominance). Therefore, the final number of participants consisted of 7 right-handed and right-eyed girl students with informed consent and no prior knowledge of the task. The study ethics approval was obtained from the Sport Sciences Research Institute of Iran with the code IR.SSRI.REC.1397.368.

The Vienna Test System (SCHUHFRIED Company, Australia) was utilized to perform BCT. The instrument consists of a software test section, a display, and a keyboard containing two metal knobs and 16 circular keys. The right knob moves forward and backward, and the left knob moves left and right. The participants had to use these knobs to guide a circle in a specified direction. Getting out of the path was considered to be an error that was accompanied by a sound warning the intensity of which was adjustable in the software, and the subjects were informed of their error. The total time and percentage of error time were also recorded in each trial by the Vienna software. To apply a peripheral vision constraint, a cardboard plate with a thin foam coating was applied that was put on the face. This cardboard plate prevented the participants from viewing the position of the right hand, left hand, and both hands in three modes, but did not limit their vision on the screen.

The Edinburgh Handedness Inventory was exploited to determine the dominant hand. The questionnaire was comprised of 10 items used to evaluate the hand dominance. This scale consisted of some general activities including writing, drawing, throwing, sweeping, using scissors, brushing, using a knife (without a fork), getting a spoon, lighting a match, and opening a box. On the basis of the Edinburgh Handedness Inventory guidelines, the peripheral benefit has a score ranging from -100 to +100, with scores of less than -40, -40 to +40, and higher than +40 indicating left-handedness, double-handedness, and right-handedness, respectively. This tool has been validated among the Iranian male and female communities with age ranges of 7 to 65 years and its Cronbach's alpha coefficient, split-half correlation, and construct validity have been respectively reported to be 0.97, 0.94, and 81.09 (9).

The Ocular dominance testing card was employed to determine the eye dominance. This card was a 25-cm square with a 0.5-cm hole in the center through which the participants observed a target at a distance of 2 m by closing one of their eyes once and seeing the target with the other eye and vice versa, and in this way, their dominant eyes were identified. The eye closing wherein the target was not observed was considered as the dominant eye of the individual (10).

Initially, the informed consent forms were completed by the subjects for participation in the study and the Edinburgh Handedness Inventory. The perforated card test was then performed to determine the individuals' eye dominance.

At the beginning of the test, the subjects were seated on a chair the height of which was adjustable to place the line of sight in the center of the screen. The instructions associated with the implementation of the BCT were presented to the participants with maximum speed and accuracy by two levers, and they made two trials to get acquainted with the task. Four test conditions, including "visual occlusion of the right hand position, left hand position, of both hands, and no visual occlusion of the two hands" were considered for the BCT (Figure 1). Four trials were made in each condition. Total trials (16 trials) were performed in 2-trial random categories, in such a way that to prevent the effects of learning order, the test conditions were changed randomly after each trial. Because the pre-designed 4-trial test was used in Vienna software, the coincidence of the trial number and test conditions were manually recorded, and at the end, 4 trials related to a condition were considered to calculate the mean values.

The central tendency measures were reported as mean and standard deviation (SD). The Shapiro-Wilk and Levene tests were utilized to evaluate the normal distribution of data and to determine homogeneity of variances, respectively. In the inferential statistics section, the repeated measures ANOVA with 4 test replications (visual occlusion conditions) was used. The mean trial for each individual and test condition was analyzed in Excel software 2013 and data were analyzed in SPSS software (version 24, IBM Corporation, Armonk, NY, USA). Besides, $P \leq 0.05$ was considered as the significant level.

(a) **(b)** **(c)**

Figure 1. Visually restricted conditions: (a) Right hand visual limitation, (b) Both hands visual limitation, (c) Left hand visual limitation

Table 1. Descriptive information in different visual occlusion conditions

Visual conditions / Variable	Right hand visual occlusion	Left hand visual occlusion	Both hands visual occlusion	No visual occlusion
Total time (s)	26.21 ± 4.68	26.78 ± 4.50	29.84 ± 9.70	31.10 ± 11.49
Error time (%)	5.16 ± 4.15	5.46 ± 4.33	5.88 ± 4.30	*6.68 ± 4.24

* P ≤ 0.050 significant decrease in performance compared to other visual conditions; data were reported as mean ± SD.

Results

7 undergraduate girl students with right-hand and right-eye dominance with a mean age of 24.00 ± 3.46 years and the mean height of 165.17 ± 32.30 cm participated in the study.

The mean total time and percentage of error time of BCT in different test conditions are represented in table 1.

Given the results of the Shapiro-Wilk test, the data followed a normal distribution (P = 0.310). In addition, the results of the repeated measures ANOVA on total time variable revealed that the effect of visual constraint was not significant and there was no significant difference among the 4 test conditions ($F_{(3,18)} = 1.80$, $P = 0.182$, $\eta^2 = 0.231$), however regarding the error time percentage variable, there was a significant difference among different test conditions ($F_{(3,18)} = 4.24$, $P = 0.020$, $\eta^2 = 0.414$). The results of the least significant difference (LSD) post-hoc test suggested that the error time percentage in the conditions without visual constraint was significantly higher compared to the right hand visual constraint conditions (P = 0.040), left hand visual constraint conditions (P = 0.030), and both hands visual limitations (P = 0.019), however no difference was observed among the three conditions with peripheral visual constraint (P > 0.050). Thus, all the conditions with visual limitations improved the BCT accuracy compared to the conditions without visual limitation (Figure 2).

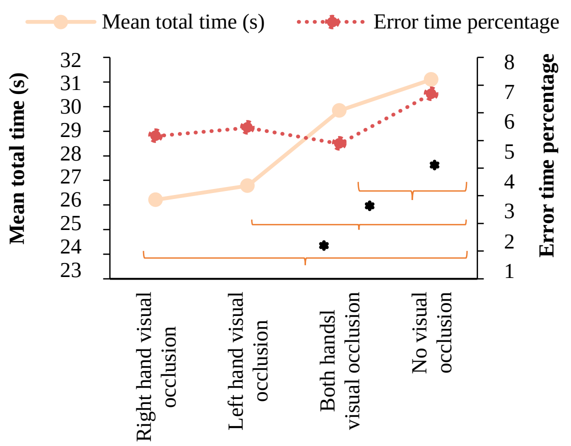

Figure 2. Mean total time and error time percentage under different conditions of vision occlusion

* Significant difference in the error time variable percentage.

Discussion

The study was accomplished with the aim to investigate the effect of peripheral vision occlusion on BCT. The results of total movement time did not show any significant difference in the four test conditions. In other words, the peripheral visual limitation had no effect on the BCT speed. These results were in line with the findings of the studies by Farsi et al. (3) and Norouzi et al. (4). In these studies, visual occlusion had no effect on the coordination task phase transfer time. However, both studies used central vision occlusion (3,4). The findings of a study showed that central and peripheral vision activate different cortex parts (11). According to the mean values, the motion time was also higher in conditions without visual constraint in comparison to the visual constraint conditions. Therefore, the difference in the motion time may be due to the fact that BCT is more affected by the proprioception intervention and less affected by the presence of vision, especially peripheral vision and the position of the effector organ (3). Additionally, Boisgontier et al. concluded that attention deviation took place easily due to less sharpness and accuracy in the peripheral vision, and it is inefficient for attentional processes (6).

Concerning the accuracy of coordination, the results of the study were in contrast with the expectations. The BCT accuracy in the peripheral visual limitation was significantly better than the conditions without visual limitation. This result contradicts the findings of Norouzi et al. (4). They examined the effect of complete visual occlusion and proprioception interference of the in-phase and anti-phase tasks at three different speeds. Visual occlusion in their study led to an increase in the relative phase error in the in-phase and anti-phase tasks. However, performance was more dependent on proprioception (4). The results of this study were inconsistent with the findings of the study by Baker et al. who reported the detrimental effect of peripheral visual occlusion on the grip phase (12). Moreover, the findings of the study by Cortis et al., which examined the effect of age and visual constraint on the inter-organ in-phase and anti-phase coordination task (5), were not consistent with the findings of this study. Complete visual occlusion in their study resulted in greater variability in the in-phase and anti-phase movements (5). The peripheral vision constraint in this study not only did not decrease performance, but also increased accuracy. Among the reasons of inconsistency in the findings, one can point out that in the previous studies, the relative phase scheduling accuracy was investigated in the in-phase and anti-phase tasks (3-5) and was different from the spatial accuracy used in this study. In other words, the difference is related to the type of coordination task and its requirements. In this regard, Basevitch et al. reported that the visual and performance relationship was affected by the task type. Discrete tasks are less dependent on visual information compared to the tasks with variable environments (such as open and tracking tasks) (13). Furthermore, increasing accuracy in this study contradicted the findings of the study by Boisgontier et al. They observed a decrease in the performance of the BCT tracking task in directing the peripheral visual attention (6).

Comparing the findings, it sounds that the role of peripheral vision in the two states of attention direction and occlusion is different. Besides, the increase in the accuracy took place in the visual limitation conditions while the speed-accuracy trade off did not occur. In other words, the lack of difference in total motion time in the four test conditions indicates that the participants increased their accuracy by maintaining the movement time. This is confirmed by the discrepancy between the total time and the error time percentage under different conditions present in the statistical analyses. The peripheral constraint created by the peripheral vision constraint seems to have mentally affected the participants' attention and concentration during the task implementation. However, the oral feedback received from the participants showed that they did not need to see their hands even in the absence of a visual constraint. Additionally, it seems that the Vienna BCT is conducted under the conditions of external attention focus. Thus, according to the results of the study by Land et al., in the visual occlusion, the external attention focus reduces variability and improves performance (14).

The lack of difference in the accuracy and speed of the three visual constraint conditions could be due to the relatively equal involvement of the hands in the whole BCT path. The results of the study by Franz et al. revealed that the dominant hand does not necessarily lead the coordination task (15). The findings of this study, obtained from circles drawn in clockwise and counterclockwise directions in the two right-handed and left-handed groups, indicated that the right hand and the left hand always guided the clockwise and counterclockwise task directions, respectively. Indeed, the task direction and coordination were important factors in this regard (15). Although the path in the Vienna tool is generally redirected to the left, the angles in the path and the need for full involvement of both hands in most part of the path offset the advantage of the left-handed direction of the task. Moreover, participants may be able to use the non-dominant hand in specific situations and tasks, which represents greater neural communication in the brain that is an advantage for the BCTs and is independent of the dominant hand side (9). These results contradict the findings in the studies reporting that directing visual attention to the dominant hand improves performance (16). Finally, the results of this study appear to be closer to the movement program view to control the coordinated movement, since the visual limitation of the position of each hand did not interfere with the coordination task implementation.

Limitations

One of the limitations of this study was the lack of consideration of the long-term impact of peripheral vision constraint on the learning of BCTs.

Recommendations

Investigating more objective variables such as electromyography (EMG) or electroencephalography (EEG) recording in research projects with interventions on each hand individually, can be helpful in confirming or rejecting the existing bimanual coordination theories. Moreover, investigations on different ages allow for specifying the interaction of perceptual needs arising from peripheral vision and the existence of age-related limitations. Finally, the permanent effects of peripheral vision constraint on retention and transfer tests should be evaluated.

Conclusion

The results of this study showed that peripheral visual limitation increases the accuracy of BCT. Peripheral vision occlusion appears to cause ignorance of its associated feedback - which may not even be related to the task. It is evident that studies on the field of peripheral vision in coordination tasks are very limited and further investigation is required. Some peripheral constraints may be used as hidden in order to increase attention and, hence, enhance performance of coordination tasks.

Acknowledgments

This study was approved by the Sport Sciences Research Institute of Iran and was conducted in the Laboratory of Motor Behavior, School of Physical Education and Sport Sciences, University of Tehran, Tehran, Iran. The authors would like to appreciate all the students who contributed to this study, as well as the staff of the Laboratory of Motor Behavior, School of Physical Education and Sport Sciences.

Authors' Contribution

Masoumeh Doosti: Study design and ideation, attracting funding for the study, providing study equipment and subjects, data collection, analyzing and interpreting results, manuscript arrangement, Shahzad Tahmasebi Boroujeni: Study design and ideation, attracting funding for the study, supporting and executional and scientific services of the study, expert evaluation of the manuscript in scientific terms, final verification of the manuscript for submission to the journal office, responsibility for preserving the integrity of the study process from beginning to publication, and responding to referees.

Funding

This study, with the code IR.SSRI.REC.1397.368, was registered in the ethics committee of Sport Sciences Research Institute of Iran and performed in the Laboratory of Motor Behavior, School of Physical Education and Sport Sciences, University of Tehran, without the financial support of the center or any other institution, at the personal expense of the authors. The data were collected using the tools available in the Motor Behavior, School of Physical Education and Sport Sciences, University of Tehran. The University of Tehran did not apply any comments on the manuscript for publication.

Conflict of Interests

The authors declare no conflict of interest. Dr. Shahzad Tahmasebi Boroujeni has been working as a faculty member at the School of Physical Education and Sport Sciences, University of Tehran since 2008. Masoumeh Doosti is a PhD student in motor behavior at the School of Physical Education and Sport Sciences, University of Tehran since 2017.

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