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Training Complexity is not Decisive Factor for Improving Adaptation to Visual Sensory Conflict

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Abstract—**Ground-based preflight training utilizing unusual visual stimuli is useful for decreasing the susceptibility to space motion sickness (SMS). The effectiveness of the sensorimotor adaptation training is affected by the training tasks, but what kind of task is more effective remains unknown. Whether the complexity is the decisive factor to consider for designing the training and if other factors are more important need to be analyzed. The results from the analysis can help to optimize the preflight training tasks for astronauts. Twenty right-handed subjects were asked to draw the right path of 45° rotated maze before and after 30 min training. Subjects wore an up-down reversing prism spectacle in test and training sessions. Two training tasks were performed: drawing the right path of the horizontal maze (complex task but with different orientation feature) and drawing the L-shape lines (easy task with same orientation feature). The error rate and the executing time were measured during the test. Paired samples t test was used to compare the effects of the two training tasks. After each training, the error rate and the executing time were significantly decreased. However, the training effectiveness of the easy task was better as the test was finished more quickly and accurately. The complexity is not always the decisive factor for designing the adaptation training task, e.g. the orientation feature is more important in this study. In order to accelerate the adaptation and to counter SMS, the task for astronauts preflight adaptation training could be simple activities with the key features.**

I. Introduction

It is reported that 60 to 80% of astronauts experience space motion sickness (SMS) during the first 3 days at the beginning of space missions [1, 2]. Many etiological factors for elicitation of SMS have been proposed [2], and sensory conflict theory is currently the most accepted explanation [2, 3]. It suggests that SMS can be triggered by mismatches of the visual, vestibular and proprioceptive inputs, among which inversion illusions and visual reorientation illusions are often taken as the incentive of SMS for astronauts in weightlessness [4].

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As the recalibrated sensorimotor mapping [5] and the brain activities changes [6-9], both formed during sensory conflict adaptation training, can be generalized to new different situations [10-12], some studies suggest that the ground-based preflight training under conditions of unusual visual stimulation such as visual inversion (or reversal) [13, 14] or virtual microgravity environment [15, 16] may be useful for decreasing the susceptibility of SMS. Although some experiments have proved that certain training tasks could affect the process of adaptation [17-21], what kind of training task is more effective and suitable for sensory conflict adaption remains unknown.

Complex task training is often considered to be more effective [17]. However, the training may fail if it is too complex to be finished. The degrees of complexity should be considered carefully during the design of training task. Current studies even demonstrate that the complex task is not the most effective one. For instance, Zhang et al. confirm that training programs should be designed based on both the complexity of tasks and the cognitive characteristics of astronauts [22].

Previous studies have indicated that each hemisphere contributes to goal-directed activities in a particular method [23]. The left (dominant) hemisphere responds to task complexity [24, 25], while the other one clearly involves in the visual-spatial regulation [26, 27]. More activities of the right hemisphere should be designed in the training to determine a new visual-spatial regulation, and then a correct sensorimotor under sensor conflicts can be established. It may suggest that the task complexity is not the decisive factor to consider when designing the adaptation training to sensory conflict induced by visual illusion, which also means that the training task can be simplified. For example, visually guided hand movements play an important role in operational activities of astronauts in space, and these hand movements vary a lot in complexities. If the complexity of a training task is not the main issue to be considered, the training task for improving the sensorimotor adaptation to sensory conflicts can be simple activities with location and orientation features.

In this study, we compared the effectiveness of the complexity training and the orientation feature training on the visuomotor adaptation to the sensory conflict induced by the up-down reversing prism spectacle. In our experiment, the 45° rotated maze was taken as a test task performed before and after the training. Subjects were trained with the horizontal maze task (which had different orientation information but same complexity as the test task) and the L-shape lines task (which had the same orientation feature as the test task but simpler). The former was taken as a complex task, while the latter the easy one. The error rate and the executing time of the test task would be recorded and analyzed to explore which training task was more effective.

II. Methods

A. Subjects

Ten male and ten female healthy volunteers (mean age 18.40 years ± S.E.M. 0.13, range 18-20) participated in the experiment with informed consent, which was approved by the local ethics committee. They were all right-handed and none of them had a history of neural diseases, visual or motional disability.

B. Apparatus

Up-down reversing prism spectacle was used to distort the visual field, achieving the up-down reversed vision. It resulted in a conflict between vision and proprioception which provide the afferent information for motor control. The viewing angles extended 100° vertically and 40° horizontally for the up-down reversing prism.

C. Test Session

Fig. 1 shows a schematic representation of the experimental setup. Subjects sat on a chair wearing the reversing prism. Considering that the visually guided hand movement is the major operational activity in space, drawing the path of a maze was selected as the test mission to evaluate the capacity of identifying the location and orientation.

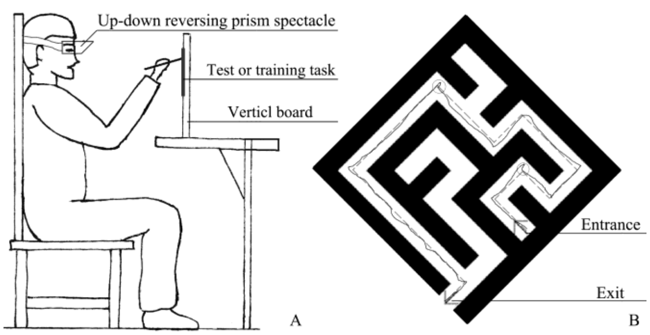

Figure 1. Schematic diagram of experimental setup (A) and one of six 45° rotated maze tests (B). The maze has 9 corner points, and is fixed on the vertical board. The gray dashed line indicates the standard path of the maze and cannot be seen during the test; the black solid line indicates the typical path drown by one subject before the training. The circle indicates where an error happens. In this test, the subject makes 2 mistakes, so the error rate is 22.2%.

All paper-pencil mazes were rotated by 45° to the horizontal plane and fixed on the vertical board which was placed at a suitable distance. The mazes almost occupied the view of subjects in order to facilitate drawing the path and to avoid the visual effects brought by the ceiling and floor. For each subject, the test consisted of 6 trials with 6 different mazes with a break between each two trials. According to the preliminary experiments, all test mazes were designed to be 9 corner points which reflected the task's complexity. At each corner point, subjects would judge both the hand location and orientation.

At the beginning of each trial, subjects closed their eyes and held the pencil, and were assisted to place the pencil at the entrance of maze. Once hearing the "start" signal, subjects immediately opened their eyes and drew the path continuously from the entrance to the exit of the maze as quickly and precisely as possible. The executing time of finishing task was recorded by a stopwatch including the time of movement and the time spent on thinking and judging the location and orientation. An error was considered to take place if the directional change at the corner point was not consistent with that of the maze standard path (see Fig. 1B). The directional errors could be easily distinguished and the error rate was calculated as the error number divided by the number of the corner points. Executing time and error rate of each trial were averaged in each condition respectively.

D. Training Sessions

Two tasks for training subjects' adaptation to sensory conflict were designed. One was complex task which required subjects to draw the right path of the horizontally placed maze, but the orientation of each path was different from that in test. The other was easy task which required subjects to draw L-shape lines with 16 orientations according to the indication of the arrowheads (see Fig. 2). The experiment settings in training sessions were the same as that in the test session.

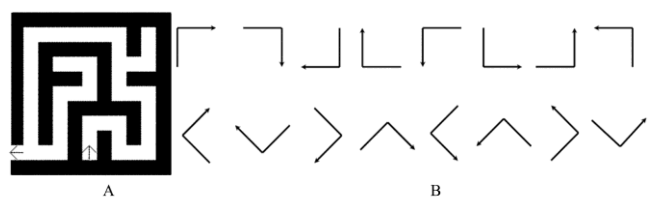

Figure 2. Schematic diagram of the two training tasks (see Fig. 1A). A: Horizontal maze training: The complexity training has 9 corner points in the path of maze. Those mazes will be rotated 45° for testing task. B: L-shape lines training: The orientation feature training has 16 types of the L-shape lines, and those in second row would appear in the 45° rotated maze test.

One of two training tasks was allocated to the subjects at random. The training lasted 30 minutes for each task, and then subjects were tested with the 45° rotated maze again. There was an interval of 3 or 4 days before subjects performed the second training task in order to minimize the effects of prior learning on performance of the second test.

The complexity of the 45° rotated maze test was regarded as the same as that of the horizontal maze training, as the only difference lied in the 45° rotating angle.

The orientation features of the 45° rotated maze test and the L-shape lines training were considered to be similar , since the path of the 45° rotated maze was actually the combination of several L-shape lines listed in the second row of Fig. 2B.

E. Data Analysis

All data were presented as mean ± standard error of the mean (S.E.M.). Statistical analysis was done via paired samples t test between the values of pre- and post-training tests and between the values of two post-training tests. The significance level was set at 0.05.

III. RESULTS

All subjects showed difficulties in performing the 45° rotated maze test, especially before training. There were significant differences between pre- and post-training in both the error rate and the executing time ($P<0.05$) of finishing 45° rotated mazes, as shown in Fig. 3. Before training, the error rate and the executing time were 15.9±3.0% and 18.8±1.9s respectively, which were decreased to 1.4±0.4% and 9.2±0.6s after the horizontal maze training and to 0.4±0.2% and 7.0±0.3s after the L-shape lines training. The results demonstrated that both training could improve the accuracy and speed of finishing maze tasks. This also meant the adaptation to sensory conflicts can be accelerated by training.

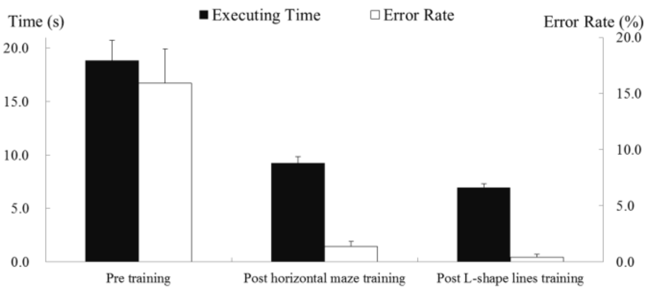

Figure 3. The results of the 45° rotated maze test pre training, post horizontal maze training and post L-shape lines training. Filled bars indicate the executing time, and open bars indicate the error rate. Error bars are standard errors of the mean.

Comparing the test results after two trainings, there were also significant differences ($P<0.05$). After the L-shape lines training, both the error rate and the executing time were decreased much more than those after the horizontal maze training. Furthermore, during the L-shape lines training, subjects often showed great difficulties when tracing the oblique L-shape lines, because both their segments were affected by the prism. It suggested that the orientation feature training was more effective than the complexity training for the task of 45° rotated maze under the up-down reversed vision condition, although the former was a very simple training task.

IV. DISCUSSION

The results of the present study demonstrated the training task could improve the adaptation to sensory conflicts. Both the L-shape lines training and the horizontal maze training reduced the error rate and the executing time of finishing the 45° rotated maze test task under up-down reversed vision, and the effectiveness of the L-shape lines training were much more remarkable, which presented as the test finished more quickly and accurately.

In this study, the horizontal maze training was defined as the complex task training, while the L-shape lines training was defined as the easy task training. Here, the complexity was based on the topological nature which was expressed as the number of corner points in the tasks [28]. The horizontal maze training had the same complexity as the 45° rotated maze test, because in both the 45° rotated maze test and the horizontal maze training, the number of corner points was 9 in contrast to only 1 in the L-shape lines training.

Previous research proposed that three kinds of adaptive processes were evoked by prism exposure, including postural adjustments, spatial realignment and strategic control [20]. Postural adjustments in goal-directed movement were the muscle potentiation which caused that the proprioception should be considered more. Spatial realignment was required to adjust to the new sensorimotor coordinate, when the spatial representations were changed [19]. Strategic control, including skill learning and recalibration, was to establish a new movement plan between visual input and position coordinates of the targets [18]. Furthermore, strategic control was task specific, and the generalization of recalibration was associated with the feature of the task, while the other two adaptive processes were not [19, 29].

In this study, subjects were asked to wear the up-down reversing prism to achieve the reversed vision and maintain the same posture all the time during the test and trainings, thus the two adaptive processes, the postural adjustments and spatial realignment, were exercised for each training task. As the result, both training significantly reduced the error rate and the executing time comparing with the test before trainings. It was also in agreement with the previous studies that the adaptation could be generalized to a novel task [11, 12].

In order to finish the 45° rotated maze test task, the main problem of strategic control was to select correct turning direction at each corner point. Although the complexity was the same for testing maze and training maze (containing 9 L-shape lines), the turning directions at the corner points were different (see Fig. 2B, as 8 types of L-shape lines in the first row appearing in the horizontal training maze, while the other 8 types of L-shape lines in the second row appearing in the 45° rotated test maze), thus the strategic control (recalibration) for test had been not practiced correctly in the horizontal maze training task. On the contrary, the L-shape training task was of low complexity, but the turning directions at the corner points were the same as those in test task, thus the strategic control (recalibration) had been practiced correctly. This may explain why the effectiveness of L-shape lines training was significantly better than those of the horizontal maze training, although the latter is similar to test task in complexity.

Based on these results, we could conclude that the effectiveness of training task depended mainly on its proper features according to specific situation, instead of the complexity. In order to improve the task performance and to accelerate the adaptation to sensory conflicts, the main purpose of the training was to recalibrate a new visuomotor rather than only complete the highly complexity task.

V. CONCLUSION

The present study demonstrates that although both trainings are effective on the adaptation to a novel untrained task under sensory conflict condition induced by up-down reversed vision, the effectiveness of the easy task training with key orientation feature are more remarkable than that of the complex task training without key orientation feature. The complexity is not the decisive factor to consider for designing the adaptation training task, while the orientation feature is more important in this study. It also suggests that the task for astronauts preflight adaptation training should be designed according to the key features, including but not limited to the complexity of tasks. The training task for improving the sensorimotor adaptation to sensory conflicts can be simple activities with location and orientation features in order to accelerate the adaptation process and to counter SMS.

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REFERENCES

[1] M. Heer and W.H. Paloski, Space motion sickness: incidence, etiology, and countermeasures, *Auton Neurosci*, vol. 129, (no. 1-2), pp. 77-9, 2006-10-30 2006.

[2] J.R. Lackner and P. Dizio, Space motion sickness, *Exp Brain Res*, vol. 175, (no. 3), pp. 377-99, 2006-11-01 2006.

[3] C.M. Oman, Motion sickness: a synthesis and evaluation of the sensory conflict theory, *Can J Physiol Pharmacol*, vol. 68, (no. 2), pp. 294-303, 1990-02-01 1990.

[4] C.M. Oman, I.P. Howard, T. Smith, A.C. Beall, A. Natapoff, J.E. Zacher, and H.L. Jenkin, The role of visual cues in microgravity spatial orientation, in Proc. J. C. Buckey Jr. and J. L. Homick (Eds) The Neurolab Spacelab Mission: Neuroscience Research in Space, 2003, pp. 69-81.

[5] H.A. Cunningham and R.B. Welch, Multiple concurrent visual-motor mappings: implications for models of adaptation, *J Exp Psychol Hum Percept Perform*, vol. 20, (no. 5), pp. 987-99, 1994-10-01 1994.

[6] S. Miyauchi, H. Egusa, M. Amagase, K. Sekiyama, T. Imaruoka, and T. Tashiro, Adaptation to left-right reversed vision rapidly activates ipsilateral visual cortex in humans, *J Physiol Paris*, vol. 98, (no. 1-3), pp. 207-19, 2004-01-01 2004.

[7] K. Sekiyama, S. Miyauchi, T. Imaruoka, H. Egusa, and T. Tashiro, Body image as a visuomotor transformation device revealed in adaptation to reversed vision, *Nature*, vol. 407, (no. 6802), pp. 374-7, 2000-09-21 2000.

[8] I. Berndt, V.H. Franz, H.H. Bulthoff, K.G. Gotz, and E. Wascher, Effects of rearranged vision on event-related lateralizations of the EEG during pointing, *Biol Psychol*, vol. 68, (no. 1), pp. 15-39, 2005-01-01 2005.

[9] D.M. Clower, J.M. Hoffman, J.R. Votaw, T.L. Faber, R.P. Woods, and G.E. Alexander, Role of posterior parietal cortex in the recalibration of visually guided reaching, *Nature*, vol. 383, (no. 6601), pp. 618-21, 1996-10-17 1996.

[10] R.B. Welch, B. Bridgeman, S. Anand, and K.E. Browman, Alternating prism exposure causes dual adaptation and generalization to a novel displacement, *Percept Psychophys*, vol. 54, (no. 2), pp. 195-204, 1993-08-01 1993.

[11] O. Bock, Adaptation of aimed arm movements to sensorimotor discordance: evidence for direction-independent gain control, *Behav Brain Res*, vol. 51, (no. 1), pp. 41-50, 1992-10-31 1992.

[12] O. Bock and M. Burghoff, Visuo-motor adaptation: evidence for a distributed amplitude control system, *Behav Brain Res*, vol. 89, (no. 1-2), pp. 267-73, 1997-12-01 1997.

[13] J.R. Lackner and P. DiZio, Decreased susceptibility to motion sickness during exposure to visual inversion in microgravity, *Aviat Space Environ Med*, vol. 62, (no. 3), pp. 206-11, 1991-03-01 1991.

[14] F. Pu, Y. Yang, D.Y. Li, S.Y. Li, H.J. Niu, and Y.B. Fan, Effects of location training and orientation training on the visual-motor coordination under up-down reversed vision, *Yiyong Shengwu Lixue/Journal of Medical Biomechanics*, vol. 25, (no. 4), pp. 249-252+256, 2010.

[15] K.J. Stroud, D.L. Harm and D.M. Klaus, Preflight virtual reality training as a countermeasure for space motion sickness and disorientation, *Aviat Space Environ Med*, vol. 76, (no. 4), pp. 352-6, 2005-04-01 2005.

[16] D.L. Harm and D.E. Parker, Preflight adaptation training for spatial orientation and space motion sickness, *J Clin Pharmacol*, vol. 34, (no. 6), pp. 618-27, 1994-06-01 1994.

[17] R.M. Rine, M.C. Schubert and T.J. Balkany, Visual-vestibular habituation and balance training for motion sickness, *Phys Ther*, vol. 79, (no. 10), pp. 949-57, 1999-10-01 1999.

[18] G.M. Redding and B. Wallace, Strategic calibration and spatial alignment: a model from prism adaptation, *J Mot Behav*, vol. 34, (no. 2), pp. 126-38, 2002-06-01 2002.

[19] G.M. Redding and B. Wallace, Dual prism adaptation: calibration or alignment? *J Mot Behav*, vol. 35, (no. 4), pp. 399-408, 2003-12-01 2003.

[20] G.M. Redding, Y. Rossetti and B. Wallace, Applications of prism adaptation: a tutorial in theory and method, *Neurosci Biobehav Rev*, vol. 29, (no. 3), pp. 431-44, 2005-05-01 2005.

[21] J.J. Marotta, G.P. Keith and J.D. Crawford, Task-specific sensorimotor adaptation to reversing prisms, *J Neurophysiol*, vol. 93, (no. 2), pp. 1104-10, 2005-02-01 2005.

[22] Y. Zhang, B. Wu, X. Zhang, W. Quanpeng, and M. Liu, Task complexity related training effects on operation error of spaceflight emergency task, in Book Task complexity related training effects on operation error of spaceflight emergency task, *Series* Task complexity related training effects on operation error of spaceflight emergency task, Orlando, FL: Springer-Verlag, 2011, pp.*436-445.

[23] K.E. Stephan, G.R. Fink and J.C. Marshall, Mechanisms of hemispheric specialization: insights from analyses of connectivity, *Neuropsychologia*, vol. 45, (no. 2), pp. 209-28, 2007-01-28 2007.

[24] K.Y. Haaland, C.L. Elsinger, A.R. Mayer, S. Durgerian, and S.M. Rao, Motor sequence complexity and performing hand produce differential patterns of hemispheric lateralization, *J Cogn Neurosci*, vol. 16, (no. 4), pp. 621-36, 2004-05-01 2004.

[25] T. Verstynen, J. Diedrichsen, N. Albert, P. Aparicio, and R.B. Ivry, Ipsilateral motor cortex activity during unimanual hand movements relates to task complexity, *J Neurophysiol*, vol. 93, (no. 3), pp. 1209-22, 2005-03-01 2005.

[26] G.R. Fink, J.C. Marshall, P.W. Halligan, C.D. Frith, J. Driver, R.S. Frackowiak, and R.J. Dolan, The neural consequences of conflict between intention and the senses, *Brain*, vol. 122 (Pt 3), pp. 497-512, 1999-03-01 1999.

[27] P.W. Halligan, G.R. Fink, J.C. Marshall, and G. Vallar, Spatial cognition: evidence from visual neglect, *Trends Cogn Sci*, vol. 7, (no. 3), pp. 125-133, 2003-03-01 2003.

[28] R.C. Miall and J. Cole, Evidence for stronger visuo-motor than visuo-proprioceptive conflict during mirror drawing performed by a deafferented subject and control subjects, *Exp Brain Res*, vol. 176, (no. 3), pp. 432-9, 2007-01-01 2007.

[29] G.M. Redding and B. Wallace, Calibration and alignment are separable: evidence from prism adaptation, *J Mot Behav*, vol. 33, (no. 4), pp. 401-12, 2001-12-01 2001.