Eötvös Loránd University

Doctoral School of Education

Head of the Doctoral School: Prof. Dr. habil. Gábor Halász, D.Sc.

Head of Special Education Programme: Dr. habil. Klára Marton, Ph.D.

Tibor Vámos

Practice variability in learning isometric hand grip

PhD Thesis booklet

Supervisors: **Dr. Lajos Kullmann, PhD, professor emeritus emeritus**

Dr. Zoltán Dénes, PhD

Budapest

2019

1. Introduction

Hand movements are inevitable parts of our lives. Those are necessary for motor and cognitive development, daily living activities, education, work and social participation. Hand movements consists of two main motor components: scaling of isometric hand grip and controlling independent finger movements (Xu et al., 2015). Isometric hand grip is a basis of stability when grasping and holding objects such as a pencil or a full teapot. This function assumes the adequate scaling of forces applied to the objects kept in the hand. It is heavily affected in upper motor neuron syndrome such us in cerebral palsy or following stroke (Edmans, 2010; Szél, 2010; Woodson, 2013; Raghavan, 2007; Xu et al., 2015). Other type of motor function of the hand are independent finger movements that play role in manipulation with objects but in part they also rely on the supporting role of hand grip function (Payne & Isaacs, 2012). While learning of independent finger movements gained lot of attention in the last decades (Jueptner et al., 1997; Yan, 2017) learning of isometric force production that is inevitable for hand function is a scarcely investigated field in comparison (Godde et al., 2018; Vieluf et al., 2013). In spite of its importance, there is a lack of both basic and applied research addressing the effect of different learning schedules on isometric force production of the hand up to date.

Motor learning or motor memory formation is defined as an improvement of a motor skill through practice or experience that is associated with long-lasting neuronal changes (Brem, Ran, & Pascual-Leone, 2013). The effect of variability of practice refers to a phenomenon whereby task variability during practice may reduce acquisition performance but facilitate learning as assessed either by the retention of the learned skill (retention test) or by transfer to a new task variation (transfer test). This effect of the variability in practice arised from Schmidt's schema theory (Schmidt, 1975). According to the schema theory, when an individual is practicing a movement, he or she develops motor response schemas, whereby new variations from the same general class of movement can be produced effectively. Many of the investigations which supported the above prediction of Schmidt's schema theory showed a common feature. That is, participants who practiced many variations of a motor task showed larger errors during acquisition as compared to those who practiced one variation only. On the other hand, practice variability led to comparable or superior performance level when the learned tasks were produced either with the same conditions or with novel parameters (Schmidt & Lee, 2011).

The effect of variability on the acquisition of motor skills has been examined in various tasks (Yao et al., 2012; Giuffrida et al., 2002; Shea & Kohl, 1990), but isometric hand grip that is essential for effective hand function in both everyday activities and in educational settings has not been examined up to date.

2. Aim and rationale of the thesis

2.1. Overall aim and rationale

The aim of the present thesis is to examine the characteristics and effect of variable practice schedule in contrast to constant practice schedule during learning hand movements. As isometric force production is a neglected but important area in the field, the focus of the present thesis is to reveal if specific traits of variable practice such as higher level of errors during practice, effective retention and superior transfer performance compared to constant practice are present when learning appropriate isometric hand grip. To map these characteristics six studies have been conducted in line both with healthy participants and with hemiparetic stroke survivors with upper motor neuron syndrome.

2.2. Experiments 1 and 2.

Experiments 1 and 2 were the adaptations and re-examinations of the variability of practice effects found by Shea and Kohl (1990, 1991) in an isometric force production task. My hypothesis was that specific features of variable practice conditions will be present in the case of learning an isometric hand grip force production task. First, variable practice schedule will result in decreased performance during acquisition session. Second, it will result in comparable level of skill retention and comparable or higher level of transfer performance when compared to constant practice schedule.

2.3. Experiment 3.

Experiment 3 aimed at characterizing discrimination threshold level for isometric force production task. My hypothesis was that discrimination threshold for isometric force production will be similar or higher than in isotonic force production tasks.

2.4. Experiment 4.

In Experiment 4, I planned to examine the effect of variability of practice using an isometric hand grip force production task with force level differences below the discrimination threshold gained in Experiment 3. My hypothesis was that increasing difficulty in the means of decreased inter-target difference but keeping the number of task variations invariable may result in improved performance in terms of retention and transfer in variable practice group.

2.5. Experiment 5.

In Experiment 5, the goal was to examine the effect of varying inter-target difference and range of parameters on acquisition performance, retention and transfer. My hypothesis was that if the schema theory holds, increased variability with a broader range of force production levels experienced in practice would be advantageous in subsequent retention and transfer tests.

2.6. Experiment 6.

The aim of the study was to determine the characteristics and the effects of variable vs. constant practice on the learning process of isometric hand grip force production by the hemiparetic hand following unilateral stroke. My hypothesis was that characteristics of variable practice as compared to constant practice e.g., higher error level during practice, but successful or more effective learning in terms of retention and transfer will be present after hemiparetic stroke.

3. Methods

3.1 Design

In motor learning experiments, participants were assigned into two groups. Constant group practiced only the target force to be measured in retention test. Variable group practiced the same amount as constant group but five force variations including the target force was applied. Force was applied relative to participants own maximum voluntary contraction (MVC).

3.2 Participants

In experiments 1-5, participants were healthy university students from the Tokyo Metropolitan University who received course credit for participation. In experiment 6, participants were hemiparetic stroke patients, all inpatients at the National Istitute for Medical Rehabilitation, Budapest.

3.3 Apparatus

An isometric hand-grip dynamometer (Experiments 1-5) or JR3 force sensors (multi-axis load cells) were connected to a personal computer. The computer ran the LabView systems engineering software that was programmed by the PhD candidate for data acquisition and processing, visualization of target forces and providing feedback for participants.

3.4 Dependent variables and data analysis

In motor learning experiments, absolute error (magnitude of error), constant error (magnitude and direction of deviation from the target), variable error (variability of errors) and total error (deviation from target and consistency) were calculated in acquisition phase, in retention test of the learned target force and in transfer test using the learned skill with novel parameters.

3.5 Statistical analysis

A Multivariate analysis of variance was applied with repeated measures on within group variables (acquisition blocks, retention and transfer). Post hoc was performed with Least Significant Difference (LSD) test. Significance level was set at $p < .05$ in all experiments.

In force discrimination threshold measurement, participants were not divided into groups and psychophysical method of constant stimuli was applied for measurement.

4. Results and discussion

Main results

The results of both Experiment 1 and Experiment 2 indicated that the groups which practiced several variations of the isometric hand grip force production task during the acquisition phase (variable group) did not provide a better performance on retention and transfer tests than the groups which practiced merely one variation of the task throughout the acquisition phase (constant group). This phenomenon was found in all aspects of performance examined in the present experiments. Although the variable group did not show superior performance to the constant group in either the retention or transfer tests, the experience of several variations during acquisition may have caused an effective retention of the performance level acquired at the end of the practice. In conclusion, the results of the present studies indicated that variable practice may be good for the retention for at least 24 hours of a constant performance level acquired at the end of a practice session, whereas constant practice may result in deterioration. **In answer to my first hypothesis, results provide partial support: while lower performance was characteristic during learning isometric force production, beneficial effect was present only in terms of retention of the skill but not in superior performance (Vámos & Imanaka, 2007).**

The results of Experiment 3 showed that the discrimination threshold for the isometric hand grip force production task was in the difference range of 1.75-2.25% MVC when a force level of 14% of MVC was used as a standard stimulus (which was compared by different stimuli). In other words, threshold was found between 12,5-16% of the constant stimuli. This is partially consistent with the variability of practice hypothesis, although the two groups did not significantly differ in the absolute performance level for retention and transfer.

Experiment 3 supported the second hypothesis that discrimination threshold for isometric force production is similar or higher than in isotonic force production tasks (Vámos, Berencsi, & Imanaka, 2015).

Main findings of Experiment 4 were that decreasing variability in terms of decreased inter-target difference below threshold and decreased range of target forces resulted in abolished difference between variable and constant groups in all aspects of motor task, such as overall error level and consistency. This phenomenon was found both during acquisition, retention and transfer. **These findings did not support my third hypothesis that increased task difficulty in terms of discrimination between target force levels results in improved retention and transfer performance (Vámos & Imanaka, 2007).**

Experiment 5 showed that the range of experienced force levels (variability) during practice generally determined the amount of errors during practice. Increasing the range size of target forces (from 2,5% to 10% MVC) performed in practice generally increased performance errors during acquisition, such that the highest variability group showed the largest amount of errors in all aspects of performance. Results indicated that the variability manipulated by differing the range of force levels during practice did not have a significant influence on recalling the criterion task since there was no significant difference between practice groups in retention test after one day. Furthermore, the group with the highest variability (variable 10% group) that performed with the largest errors during acquisition did not outperform other groups in the retention test. Regarding the transfer test, the groups practicing with the lowest variability (the constant and variable 2.5% groups) showed the poorest performance. Although the variable 5% group experienced a higher variability but resulted in a similar amount of errors to the constant and 2.5% groups during acquisition, this group showed the most superior performance in the transfer test. **These findings partially support my hypothesis based on the schema theory: increasing the range of parameters during learning led to superior performance when a novel variation of motor action had to be produced. On the other hand, increasing variability above a certain level did not give a further rise to transfer performance (Vámos & Imanaka, 2015).**

Following hemiparetic stroke, results showed that variable practice as well as constant practice results in learning during a four-day learning period. Moreover, variable group showed superior performance during retention and transfer tests, the latter indicating generalizability of the learned skill. These results are consistent with studies of healthy participants indicating comparable learning and increased benefits for adaptation of the learned skill (Shea & Kohl, 1991; Shea, Lai, Wright, Immink, & Black, 2001). On the other hand, we did not find the inherent detrimental effect of variable practice on acquisition performance. Therefore, **results partially support my hypothesis: detrimental effect of practice variability was not present but advantages in terms of superior performance on retention and transfer appeared in motor learning of hand grip following stroke (Vámos et al., 2018).**

Studies in the thesis have several limitations. Broader age span including both youngsters and elderly individuals is necessary for increasing the impact of the results.

Furthermore, design in Experiments 1, 2, 4 and 5 allowed the study of short term learning, that is the fast, initial phase of motor learning. Further studies need to clarify if similar learning pattern found after longer acquisition periods (e.g., days, weeks). Moreover, mapping motor learning capacity as a function of sensory and functional status could add to our understanding of sensorymotor recovery after stroke or in atypical development (Vámos, Földi & Berencsi, 2018).

5. Summary

The aim of the present thesis was to study the effect of practice variability on the acquisition of accurate isometric hand grip force production, a component that plays crucial role both in fine and gross motor functions of the hand. There are three main findings of the thesis regarding learning in young adults and adult stroke survivors.

1. Introducing variability to the learned parameters during acquisition led to higher level of errors during the learning phase compared to a group that practiced only the target force. This phenomenon was present both in overall accuracy and consistency of the performance. In the means of retention of the learned skill, the two type of practice

resulted in same skill levels in all aspects of performance 24 hours after acquisition. A marked difference between variable and constant schedule was that those who practiced under variable condition were able to retain the level of performance achieved by the end of the practice while those under constant practice declined.

2. A novel finding to the field was that the range of parameters applied in variable condition determined the error level in the learning phase and affected retention and transfer performance as well. Increasing range of parameters in terms of increasing inter-target difference resulted in higher level of errors during acquisition. Higher variability, however, was beneficial for learning only within a certain range of practiced parameters. Larger range does not promote better performance during acquisition and learning tests above a given level. It indicates the existence of an optimum range of parameters for a given target to be learned.

3. Variable practice schedule was advantageous for learning hand grip after stroke. In hemiparetic stroke survivors' learning showed a differential pattern from healthy adults. Here, variability did not lead to decreased performance during a long term learning phase but redounded to superior performance in retention and transfer of the learned skill showing a clear advantage compared to constant practice group.

Taken together, variable practice schedule was proven to be beneficial for learning isometric hand grip force production both in healthy population and after central nervous system damage in hemiparetic stroke patients.

6. REFERENCES

Brem, A. K., Ran, K., & Pascual-Leone, A. (2013). *Learning and memory*. Edinburgh ; New York: Elsevier.

Edmans, J. (2010). *Occupational therapy and stroke* (2nd ed.). Chichester, West Sussex, U.K.; Malden, MA: Wiley-Blackwell.

Giuffrida, C., Shea, J., & Fairbrother, J. T. (2002). Differential transfer benefits of increased practice for constant, blocked, and serial practice schedules. J Mot Behav, 34(4), 353-365. doi:10.1080/00222890209601953

Godde, B., Trautmann, M., Erhard, P., & Voelcker-Rehage, C. (2018). Motor practice in a force modulation task in young and middle-aged adults. *J Electromyogr Kinesiol, 38*, 224-231. doi:10.1016/j.jelekin.2017.12.005

Jueptner, M., Frith, C. D., Brooks, D. J., Frackowiak, R. S., & Passingham, R. E. (1997). Anatomy of motor learning. II. Subcortical structures and learning by trial and error. *J Neurophysiol, 77*(3), 1325-1337. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/9084600

Payne, V. G., & Isaacs, L. D. (2012). Fine motor development. In V. G. Payne & L. D. Isaacs (Eds.), *Human motor development : a lifespan approach* (8th ed. ed.): McGraw-Hill,.

Raghavan, P. (2007). The nature of hand motor impairment after stroke and its treatment. *Curr Treat Options Cardiovasc Med, 9*(3), 221-228. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/17601386

Schmidt, R. A. (1975). A schema theory of discrete motor skill learning. *Psychological Review, 82*, 225-260.

Schmidt, R. A., & Lee, T. D. (2011). *Motor control and learning : a behavioral emphasis* (5th ed.). Champaign, IL: Human Kinetics.

Shea, C. H., & Kohl, R. M. (1990). Specificity and variability of practice. *Res Q Exerc Sport, 61*(2), 169-177. doi:10.1080/02701367.1990.10608671

Shea, C. H., & Kohl, R. M. (1991). Composition of practice: influence on the retention of motor skills. *Res Q Exerc Sport, 62*(2), 187-195. doi:10.1080/02701367.1991.10608709

Shea, C. H., Lai, Q., Wright, D. L., Immink, M., & Black, C. (2001). Consistent and variable practice conditions: effects on relative and absolute timing. *J Mot Behav, 33*(2), 139-152. doi:10.1080/00222890109603146

Szél, I. (2010). Stroke-betegek rehabilitációja. In Z. Vekerdy-Nagy (Ed.), *Rehabilitációs orvoslás* (pp. 473-485). Budapest: Medicina.

Vieluf, S., Godde, B., Reuter, E. M., & Voelcker-Rehage, C. (2013). Age-related differences in finger force control are characterized by reduced force production. *Exp Brain Res, 224*(1), 107-117. doi:10.1007/s00221-012-3292-4

Woodson, A. M. (2013). Stroke. In M. V. Radomsky & C. A. Trombly (Eds.), *Occupational Therapy for Physical Dysfunction* (7th ed., pp. 1000-1029). Philadelphia: Lippincott, Williams&Wilkins.

Xu, J., Haith, A. M., & Krakauer, J. W. (2015). Motor Control of the Hand Before and After Stroke. In K. Kansaku, L. G. Cohen, & N. Birbaumer (Eds.), *Clinical systems neuroscience* (pp. 271-289). New York, NY: Springer Japan.

Yan, J. H. (2017). Children benefit differently from night- and day-time sleep in motor learning. *Hum Mov Sci, 54*, 297-307. doi:10.1016/j.humov.2017.05.015

Yao, W. X., Cordova, A., De Sola, W., Hart, C., & Yan, A. F. (2012). The effect of variable practice on wheelchair propulsive efficiency and propulsive timing. Eur J Phys Rehabil Med, 48(2), 209-216.

7. LIST OF PUBLICATIONS RELATED TO THE THESIS

Vámos, T., Berencsi, A., Fazekas, G., & Kullmann, L. (2018). Precise isometric hand grip learning of hemiparetic stroke patients. *International Journal of Rehabilitation Research*, 41(2), 180-182.

Vámos, T., Földi, J. & Berencsi, A. (2018) A mozgástanulás gyors szakasza a funkcionális állapot függvényében hemiparetikus betegek esetén. *Rehabilitáció: A Magyar Rehabilitációs Társaság Folyóirata,* 28, 2-3.

Vámos, T. (2017) A variábilis gyakorlás hatásának áttekintése tipikus és atipikus fejlődés valamint a központi idegrendszer sérülései után. In: Márkus, Eszter; Péntek, Dózsa Melinda (szerk.) "30 múlt..." A Komplex Szomatopedagógiai Rehabilitáció Lehetőségei és Feladatai. Budapest, Magyarország: ELTE Bárczi Gusztáv Gyógypedagógiai Kar, 27-32.

Vámos, T. & Kuniyasu, I. (2015) Does increased practice variability mean increased learning? In: Laczkó, József (szerk.) Progress in Motor Control X.: Program and Abstracts Budapest, Magyarország: *Hungarian Society of Sport Science*, 161.

Vámos, T., Berencsi, A., & Imanaka, K. (2015). Különbségi küszöb izometriás szorítóerő kifejtése esetén. *Gyógypedagógiai Szemle: A Magyar Gyógypedagógusok Egyesületének Folyóirata,* 2015 (3), 193-199.

Berencsi, A. & Vámos, T. (2015). Kézmozgások tanulását befolyásoló tényezők. *Gyógypedagógiai Szemle: A Magyar Gyógypedagógusok Egyesületének Folyóirata*, 2015 (2), 139-145.

Vámos, T., Berencsi, A., Fazekas, G., Imanaka, K., Horváth, M. & Stefanik, Gy. (2013). Innováció a szomatopedagógiában: Mozgástanulás stroke után variábilis gyakorlással. *In: MAGYE 41. Országos Szakmai Konferencia: Mozgásfogyatékosság-ügyi Szakosztály,* P 3.

Vámos, T., Berencsi, A., Fazekas, G., Imanaka, K., Horváth, M. & Trócsányi, M. (2011) Precise isometric hand grip learning of patients with hemiparetic stroke. *European Journal of Physical and Rehabilitation Medicine* (47) S1 p.17.

Vámos, T., Berencsi, A., Fazekas, G., Imanaka, K., Horváth, M. & Stefanik, Gy. (2009). Hemiparetikus stroke-betegek mozgástanulása variábilis gyakorlással. *Rehabilitáció: A Magyar Rehabilitációs Társaság Folyóirata,* 19 (3) p.159.

Vámos, T., Berencsi, A., Fazekas, G., Imanaka, K., Horváth, M. & Trócsányi, M. (2009) Learning Isometric Hand Grip after Stroke. *International Journal of Rehabilitation Research* (32) Suppl. 1, pp. S14-S15.

Vámos, T. & Imanaka, K. (2007) Is Variable Practice Effective In Acquiring Accurate Isometric Force Production? *International Journal of Rehabilitation Research* Volume 30: Suppl.1, p. 117.