MOTOR LEARNING WITHOUT EXTERNAL FEEDBACK WHEN TESTING MOTOR COORDINATION

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Abstract
The purpose of this study was to find out whether tests appropriate for assessment of motor response and speed of motor learning are those in which items differ in structure or those in which the same movement is repeated several times. A sample of 172 male students (mean age was 19 years; SD=2.11) performed coordination tasks, each consisting of three different movements. Data were interpreted as showing that motor learning contributed to maintaining consistency and accuracy of performance. This is due to the coordination of the whole body and the speed of motor learning. The results of tests were affected by the speed of motor learning and the development of motor programs that are closely linked to complex motor structures as well as to the familiarization with the test.

Key words*: motor learning, testing, motor coordination*

Introduction

Researchers of motor skills have long attempted to define the mechanism for structuring of movement called coordination which involves efficiency of performing complex motor movements and the speed with which some people adopt new movement structures of varying complexity. In other words, the speed of forming one's own motor programs is questioned. This is why Metikoš and Hošek (1972) assessed the factor structure of several coordination tests, but did not find a single general factor; however they did prove the existence of several factors of coordination. Fleischman (1964) divided motor abilities into perceptual motor abilities (Schmidt & Wrisberg, 2000) and physical implementation abilities (Schmidt & Wrisberg, 2000). Busch and Strauss (2005) stated that the concept of coordination is based on quantitative models such as the factor analysis which merely assumes that a person possesses the same number of capabilities as the number of dimensions to be analyzed. This has presented a substantial problem in research on motor learning. Keele and Hawkins (1982), Keele et al. (1987) found general factors of coordination such as the speed of movement (movement rate), motor timing, perceptual timing, and force control. Keele's most important contribution was identification of the constant level of solving an individual's task. He suggested a general factor, called time-keeping. Coordination is closely connected with the speed of motor learning, which refers to the use of concrete skills exercise (Schmidt, 1988), a series of internal processes associated with practice or experience that leads to a relatively permanent improvement in performance (Winstein, 1991; Lee et al., 1991), as well as the adoption of complex motion models suitable for performing various tasks and their use in various situations. (Wolpert et al., 2001). Research in the field of motor learning is mainly focused on providing feedback in terms of the knowledge of results or knowledge of performance. Winstein (1991) stated that the internal feedback includes visual kinaesthetic, cutaneous, vestibular, and auditory signals, while the external feedback is built on the internal one. The internal feedback motivates an individual to perform, while the external feedback informs about errors. Wolpert et al. (2001) warned that the internal sensory feedback from one action is not only necessary to evaluate that action but it also initiates a subsequent action. The authors De Oliveira et al. (2008) generally agree that, when learning a new motor movement, it is not desirable to provide a high frequency of knowledge of results. In a study of complex motor movements De Oliveira et al. (2008) found that participants given reduced knowledge of results were more actively involved in finding associated internal feedback to detect and correct errors. Sullivan et al. (2008) also examined knowledge of results frequency while training and retention of motor information. The information in a new motor task on a previously acquired and formed motor program has a significant role in improving performance. This phenomenon is especially pronounced in the practice of structurally similar tasks. Fleischman and Mumford (1989) researched how individual differences in abilities affect the adoption of motor skills at different levels using the causal model which assumes that performance on the first level causes the quality of performance on the second and the third level. The problem of contextual interference is dealt with by many authors. Thus Lee et al. (1991) state that it relates to engaging in a situation in which one activity results in a successful performance in other activities thus improving the learning process.

Resolving problems plays an important role in the development of skills. Brady (2008) explained that the phenomenon of contextual interference refers to the relatively consistent findings in the performance of several related tasks in random order. This results in poorer performance in the stage of adoption, but improves retention and transfer of information compared with the blocked or repeated practice. Many authors have also studied the impact of practice on the complex coordination ability. Busch et al. (2005) explored the qualitative differences in the performance of coordination tasks. Similar results were obtained by Entyre and Pointdexter (1995) on a specific task, balance being considered as coordination ability. They studied the performance after different intensity of practice, and the impact of the warm-up decrement and reminder reminiscence on the performance. Subjects learned the task during the first session of training, and showed improved performance from the 1st to the 5th or 10th trial. Vera et al. (2008) tried to analyze the difference between groups engaged in complex coordination tasks, with repeated practice, under high or low levels of contextual interference. The results at a later stage yielded better results than during the phase of acquisition. De Oliveira et al. (2009) used simple and complex motor tasks to investigate the hypothesis that the complex motor movements require high frequency of knowledge of results. The primary objective of this study was to find whether appropriate tests for the assessment of motor response and speed of motor learning are the tests in which the items are different in structure or the tests in which the same movement is repeated several times. The secondary aim of this study was to analyze the latent structure of some tests to assess the speed of motor learning. The reason is that larger tests with different item structure constantly face the subject with a new movement which reduces the impact of motor learning during the performance test. Some tests introduced by Momirović et al. (1975.) included a number of movement structures aiming to show the differences between people, because the same movements can be manifested in different ways. The participants were expected to quickly learn and perform movements in an optimal manner with minimal discrepancies. For the purpose of this study the Jumping while Squatting test was used for the first time. It is a very demanding test because it involves moving the entire body in space, i.e. the coordination of the whole body.

Methods

Participants
Respondents were 172 first-year male students of the Faculty of Kinesiology, University of Zagreb (mean age was 19 years; SD=2.11), who volunteered to participate in the study.

Measurements
The authors decided to use complex tests with different items, where every item is structurally more complex than the previous one. This is one way to reduce the effect of learning on the test results. The number of repetitions determined for the task adaptation is an indicator of the speed of motor learning. For this survey, three multiple-item tests were used in the area of coordination. Each task consisted of three logically related parts. These were: jumping over the stick (JUMSTI): 1 – jumping over the stick with both feet forward while holding the stick with both hands in front of the body, 2 – jumping backwards over the stick with both feet, while holding the stick behind the body, 3 – jumping over the stick with both feet forward and backward; jumping over the leg (JUMLEG): - 1 – jumping over the left leg with the right one while the participant holds his left foot with his right hand; after the jump the participant must return to the initial position to complete the task, 2 – jumping over the left leg four times in a row, while holding the left foot and without interrupting the rhythm, jumping over the left leg as in the first task, 3 – jumping over the left leg backwards, but from the final position in the second task: jumping while squatting (JUMSQU): JUMSQUA - three consecutive jumps forward while in the squatting position and holding the top of the feet; the hands must be in contact with the feet, JUMSQUB – jumping from the squatting position with both feet and making a full circle to the left; the number of jumps is not important, but the return to the original position in the proper way is, JUMSQUC - similar to the previous task, but this time turn is to the right (full round of jumps with both feet and in the squatting position.

Procedure
The tests presented three coordinating complex movements; each movement involved of simple to complex movement. The task required successful execution of a set of tests. For each test the participants had 10 trials to achieve successful performance, after which they then executed the next, more complex task. No external feedback as knowledge of results and knowledge of performance was given. Participants had a maximum of 10 trials for each task, and the score was the number of trials necessary to execute a task. If a participant failed to perform the task in 10 trials, the score was 0.

Statistical Analysis
Data processing was done with the statistical package SPSS, Version 11.5 for Microsoft Windows. The arithmetic mean, standard deviation, minimum and maximum score, and Pearson correlation coefficient were calculated. A factor analysis was applied to the component model, a significant number of factors was determined by the Kaiser criterion and diamond rotation, yielding the optimal factor structure.

Results

The test items were constructed in such a way that the first item had the simplest structure and every subsequent one a more complex structure.

Table 1 - Basic statistical parameters

Variables	Mean	Min	Max	SD
JUMSTI1	2.09	1.00	10.00	2.18
JUMSTI2	4.08	1.00	10.00	3.46
JUMSTI3	3.81	1.00	10.00	3.40
JUMLEG1	5.53	1.00	10.00	3.77
JUMLEG2	8.84	1.00	10.00	2.52
JUMLEG3	8.56	1.00	10.00	2.96
JUMSQUA	1.75	1.00	10.00	1.79
JUMSQUB	3.13	1.00	10.00	2.82
JUMSQUC	4.06	1.00	10.00	3.47

The participants mastered the items of the first and third tests with greatest ease (JUMSTI1; JUMSQUA, see Table 1), but they engaged in more trials when mastering the second and third test items (JUMLEG).

Table 2 - Correlation Matrix

Variables	jst1	jst2	jst3	jlg1	jlg2	jlg3	jsqa	jsqb	jsqc
JUMSTI1	1.0	.53	.59	.28	.16	.21	.33	.29	.11
JUMSTI2	.53	1.0	.71	.35	.15	.23	.25	.28	.20
JUMSTI3	.59	.71	1.0	.40	.12	.21	.21	.23	.20
JUMLEG1	.28	.35	.40	1.0	.33	.40	.11	.31	.23
JUMLEG2	.16	.15	.12	.33	1.0	.62	.09	.19	.04
JUMLEG3	.21	.23	.21	.40	.62	1.0	.12	.22	.12
JUMSQUA	.33	.25	.21	.11	.09	.12	1.0	.42	.23
JUMSQUB	.29	.28	.23	.31	.19	.22	.42	1.0	.46
JUMSQUC	.11	.20	.20	.23	.04	.12	.23	.46	1.0

The matrix in Table 2 shows correlations among the test items are statistically significant. It is also evident that the highest correlation is between the 2nd and 3rd items within each test, JUMSTI2 and JUMSTI3 r = .71, JUMLEG2 and JUMLEG3 r = .62 and JUMSQU2 and JUMSQU3 r = .46. Although the other obtained correlations are statistically significant, it is evident that the correlations between the items in a single test are higher than the correlations among items of different tests when assessing motor learning. Factor analysis yielded three factors (their eigenvalues being greater than 1) which explained 66.67% of the variance (Table 3).

Table 3 Eigenvalues

Eigenvalues	% total Variance	Cumulative Eigenvalues	Cumul. %
3.28	36.44	3.28	36.44
1.45	16.14	4.73	52.57
1.27	14.10	6.00	66.67

Table 4 Correlations of test items with the first principal component

Variables	Factor 1
JUMSTI1	.69
JUMSTI2	.74
JUMSTI3	.74
JUMLEG1	.64
JUMLEG2	.46
JUMLEG3	.55
JUMSQUA	.48
JUMSQUB	.61
JUMSQUC	.43

The position of variables in the first principal component (Table 4) shows a high correlation of test items with the main component despite the fact that the 2nd and 3rd items of the first test have the highest loadings (JUMSTI2 and JUMSTI3 r = .74) and the correlations decrease with the complexity of motion (JUMSQUA1 r = .48 and r = .43 JUMSQUA2). As is evident from Table 5, the first factor is mostly explained by the following items: JUMSTI3, JUMSTI2 and JUMSTI1. The second factor is also explained by the second test items in the same order: JUMLEG3, JUMLEG2 and JUMLEG1. The third factor is defined mostly by the second item (JUMSQUA), then the third (JUMSQUC) and in the end the first item test (JUMSQUA).

Table 5 The factors structure matrix

	Factor		
Variables	1	2	3
JUMSTI1	.61	.28	.42
JUMSTI2	.70	.31	.44
JUMSTI3	.73	.30	.43
JUMLEG1	.43	.45	.37
JUMLEG2	.21	.58	.21
JUMLEG3	.29	.61	.28
JUMSQUA	.30	.16	.42
JUMSQUB	.36	.30	.56
JUMSQUC	.25	.16	.44

Discussion

The larger correlations of items of each test, applied to assess coordination, rather than among items of different tests (Table 2) suggested the existence of the effect of motor learning. The results in the second item were affected by the motor experience from the first item, while the results in the last third item were affected by the motor experience of the previous two items. This effect aims at reducing the use of different items of the same test. Based on these correlation coefficients, it can be concluded that in order to estimate the speed of motor learning it is justified to repeat a complex motor task, but via a set of three different motor tasks. The correlations among items in reality are even greater because we defined the manner of carrying out tests in order to estimate the speed of motor learning, reduce the variance tests, and limit the number of repetitions available to test the performance of every item at the 10th repetition. The first factor was explained by the items of the first test, i.e. to the largest extent by the most complex item (JUMSTI3, r = .73), and then the less complex test items. The same situation occurred with the second factor that was explained by the items of the second test, where the most complex item had the most significant contribution (JUMLEG3, r = .62), followed by the less complex motions. A similar situation occurred with the third factor, although the second item (JUMSQUA, r = .56) had the highest loading, followed by the third and finally the first item, which was also the simplest. Most variance in explaining the space of coordination refers to the first test, which is the most familiar test to the study group: in addition to the participants' coordination, it demands explosive strength and flexibility. The second test proved to be the most demanding one, requiring intensive information processing besides coordination and strength. The third test was the simplest in the sense of coordination, but it also demanded motor learning for its quality performance. The results indicate that is represented by a factor that has a high correlation with three items of the same test composed of contextually similar movements. The obtained results thus indicate that the influence of motor learning contributes to maintaining the consistency and accuracy of task performance regardless of their complexity and diversity. Although the participants did not receive any external feedback, the results were highly correlated in each item. It is obvious that the internal feedback allows the participants more quality information on knowledge of results, allowing them to increase cognitive effort and process information from visual sources and proprioceptors. This helps them create a picture of their movement and allows error detection and performance improvement (Sullivan et al. 2008). Such information processing leads to an individual's perception of the quality of knowledge of performance and, accordingly, to the successful realization of the tasks mentioned. Patterson and Carter (2010) also established the improved performance in the transfer and retention phase in conditions when participants have estimated when they needed a knowlege of results. They also generalized learning strategy during the adoption of complex motor tasks. Contextual interference plays an important role in the task (Brady 2008, Vera et al. 2008). It is assumed that the participants in the learning process use the information from the previously formed motor program, although these tasks are not the same, and the next task builds upon the previously acquired one. A similar pattern was shown in the studies by Malsovat et al. (2004), which confirmed that learning yields better results when exercising in the conditions of high interference than in the conditions of low interference. Schmidt (1975) and Lee et al. (1991) suggested that an increase in the complexity of tasks imposed on a novice causes an interference with the previous skills and makes the novice run variations of movement thus improving motor learning. This was also confirmed in the study by Fleischman and Mumford (1998). Thus the previously derived motor movements in short-term memory create a motor program allowing subjects to perform complex motor movements. Coordination as a motor ability is part of motor learning, but in case of the analysis in this paper the speed of motor learning and quality of task performance can be partly attributed both to the fact that the participants in this analysis had above average motor abilities due to the fact that they were physical education students and to their daily physical activity regimen. For these reasons, the results of such studies carried out on average population would be indirectly affected by the explosive force and conative personality traits, and the fear of performance, caused by the very unusual and very demanding structure of movement in tasks. Our results confirmed the research by Vera et al. (2008) who pointed out that participants with better motor skills can adapt to high contextual interference more easily than the participants with lower motor abilities. Moreover, Entyre and Pointdexter (1995) warn that the reason for the differences between the groups obtained in their research in which they used a balance task may be the fact that the group with a better score consisted mostly of athletes. Since no coordination tests or motor learning tests with a clear factor structure could be found, complex tests with different items were introduced, where each following item is structurally more complex than the previous one. This is one way to reduce the effect of learning on the results of the test. The number of repetitions per task is an indicator of the speed of motor learning. During the speed of motor learning research the subjects must be given complex tests that they take for the first time and where a pre-motor experience will not affect the result of the test. The jumping while squatting test was used for the first time for the purposes of this study.

Conclusion

Research on coordination and motor learning is more and more frequent and it aims to identify the cognitive abilities of information processing and to analyze the appropriateness of tests that are used to assess the quality of human motor skills. The general factor of coordination, among other things, depends on how fast people can form their own motor programs. Since coordination consists of the speed of motor learning and the reorganization of stereotypes, this study aimed at determining the role of motor learning during the performance of different motor structures in order to assess coordination. The results of tests that evaluate the ability via the performance of complex motor movements are affected by the speed of motor learning and the formation of motor programs that serve as a basis to more complex motor structures on the one hand, and by the familiarization with the test on the other. The jumping while squatting test, which was used in this study, proved to be a quality means of assessing the speed of motor learning. The factor of coordination of the whole body in space had the largest impact on the results of motor learning tests.

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MOTORIČKO UČENJE BEZ VANJSKOG FEED-BACKA U TESTIRANJU MOTORIČKE KOORDINACIJE

Sažetak

Svrha ovog istraživanja je bila utvrđivanje jesu li odgovarajući testovi za procjenu motoričkih odgovora i brzine motoričkog učenja oni kod kojih se čestice razlikuju u strukturi ili oni kod kojih se isto gibanje ponavlja nekoliko puta. Uzorak od 172 muška studenta (prosječnog uzrasta 19 godina, SD =2.11) izvodio je zadaće koordinacije, od kojih se svaka sastojala od tri različita gibanja. Podaci su interpretirani, kako se vidi, na način da motoričko učenje doprinosi očuvanju konzistencije i točnosti izvođenja. Ovo je iz razloga koordinacije cijelog tijela i brzine motoričkog učenja. Rezultati testova su bili pod utjecajem brzine motoričkog učenja i razvoja motoričkih programa koji su blisko povezani s kompleksnim motoričkim strukturama baš kao i poznatošću testovnih zadataka.

Ključne riječi*: motoričko učenja, testiranje, motorička koordinacija*

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