THE DIAGNOSIS OF MOTOR COORDINATION

by

**JOACHIM RACZEK, GRZEGORZ JURAS,
ZBIGNIEW WAŚKIEWICZ***

An objective cognition of human motor area is strictly related with and dependant upon the performed diagnostic procedures, methods and tools. The need for application of precise solutions in this area seems to be one of the essential conditions, which allow to determine the basis and laws in different aspects of human motor potential. The main goal of this paper was to determine the level of valid and reliable diagnosis of coordination with the use of Vienna Test System (VST) and other computer supplemented tests. Secondly, the attempt to describe the most representative tests of VST in researched area was undertaken. The research was conducted on 77 female and 107 male students from the Academy of Physical Education in Katowice aged from 20 to 23with the use of Vienna Test System as well as laboratory and field tests. The performed measurements allowed to determine that the structure of motor coordination should include the following elements: reaction time, motor adjustment, sense of rhythm, kinesthetic movement differentiation, movement frequency, space orientation, sense of balance and movement combining. In conclusion it should be stated that the future development of research in the area of motor coordination is possible only as a result of improvement of diagnostic tools.

Keywords: motor coordination, diagnosis, computer

Introduction

An objective cognition of human motor area is strictly related with and dependant upon the performed diagnostic procedures, methods and tools. The need for use of more precise solutions in this area seems to be one of the essential conditions, which allow to determine the basis and rule in different aspects of human motor potential. Hitherto existing measuring tools i.e. field test are unquestionably insufficient and limited to diagnose the human

* Academy of Physical Education, Katowice, Poland

coordination at the scientific level, however they still may be used in physical education. Ignorance or, what even may be worse, disregarding of this facts may lead in consequence to misleading results and conclusions. Contemporary research in kinesiology should be focused on determination and characteristic of elementary neurosensory and psychomotor functions as a basis of the process of motor control and movement organization.

The above mentioned facts form the basis of research projects formulated in the Department of Motor Control in Academy of Physical Education in Katowice. During the last decade attempts to adjust existing diagnostic tools to computer procedures in order to quantify and objectivize research in motor control were undertaken. One of the examples of the construction of new diagnostic methods is the MOTORYK computer system designed by Juras and Waśkiewicz (1998). On the other hand some experiments were focused on implementation of the Vienna Test System (Dr Schuhfried, Austria), which originally was designed to be used in psychology and psychology of work, to test the functions of motor coordination.

It seems to be obvious that presented computer diagnostic tools are valid and reliable, however we should not forget about some realities and practical implications. All these procedures should be performed in everyday life and sport activity situations and should be related to specific sport effects or psychomotor behaviors. Authors hope that this philosophy will allow to extend the penetration of coordination area as a basis of top level sport achievements.

The main objective of this paper was to determine the level of valid and reliable diagnosis of coordination with the use of Vienna Test System (VST) and other computer supplemented tests. Secondly, the attempt to describe the most representative tests of VST in researched area was undertaken.

Material and methods

The research was conducted on 77 female and 107 male students from Academy of Physical Education in Katowice aged from 20 to 23*. Following research methods were used in diagnosis of motor coordination:

- field tests –target march, turns on the bench, limbs drumming, Ditrich's stick, jump with and without countermovement,
- psychomotor apparatus and chosen biomechanical and computer procedures – mirror drawing, stereometer, dynamometer, tensometric platform, MOTORYK,
- Vienna Test System – decision, reaction, precise motor, rhythm, space perception and bimanual coordination tests.

Mentioned above diagnostic tools are relatively well known, described and verified with regard to validity and reliability, and their usefulness was presented in earlier publications. Vienna Test System (Dr G.Schuhfried GmbH, Mödling, Austria) consists from computer supplemented tests constructed in assumptions to diagnose neurophysiological predispositions of human movement. It was used successfully in clinical psychology, psychiatry and work psychology and physiology from 1978 and currently is adopted in many scientific disciplines. It seems obvious while taking into account the area of human organism abilities which are tested with the use of 60 specific tests (each tests includes subtests) depending on the aim of the research.

VTS consists from main system (PC, interface, managing system – MENUE and operation system – RSX) and peripheral panels (configurable and adjustable) where the test can be performed. Some of tests may be conducted with the use of the computer screen, light pens, pedals and other devices. The main peripheral devices used in the VST are:

- Reaaktiongerät (RG),
- Deciziongerät (DG)
- Motorische Leisstungsserir (MLS),

---

* This paper presents part of the results from the research project "The research of Upper Silesia children and youth motor coordination" realized by Departament of Motor Control in Katowice in cooperation with Foundation of Polish-German Cooperation (director: J.Raczek)

- Flicker fusion analyzer (FLICKER),
- Tachistoskop (TACH),
- Physiorecorder (PHYSIO).

Second group of diagnostic methods includes the computer tests with computer monitor:

- Tapping (TAP),
- Bimanual coordination (2 HAND),
- Signal detection (SIGNAL)
- Three-dimensional point tracking (3PTR),
- Non-verbal intelligence (SPM),
- Memory span (CORSI).

Specific devices and tests from VST, in light of expert analysis and existing experimental data, allows to diagnose the following aspects and predispositions of coordination:

- reaction time (simple and complex, visual and auditory),
- precise control of lower and upper limbs,
- different aspects of movement frequency,
- sense of upper and lower limb rhythm,
- bimanual coordination,
- chosen aspects of space orientation (visual range, visual receptors sensitivity, space perception),
- motor adjustment.

The data presented in this paper are results of the following subtest and options performed with the use of VTS:

a) RG – S5 parametric block (simple reaction for visual stimuli),
b) DG – S1 parametric block (complex reaction for visual and auditory stimuli) using upper (5 coloured lamps and two sounds) and lower (2 pedals with the reaction on two lamps),
c) MLS - S1 parametric block (uni- and bilateral fast tapping, target pointing and pins inserting),
d) TAP - S1 parametric block (uni- and bilateral rhythm tapping with lower and upper limbs),
e) 2HAND – S2 parametric block (bimanual coordination tracking task with joystick control),

f) signal detection – S2 parametric block (60 signals detection during 12 min. in rectangular space – space perception),

The presented above tests resulted in the following variables:

a) RG – median of speed of reaction, median reaction time and time of simple movement,
b) DG – amount of proper reactions and mean reaction time,
c) MLS – amount of taps in uni- and bilateral tapping, amount of errors, time of errors and time of trial and amount of errors in stick inserting,
d) TAP – error in synchronization and continuation phase,
e) 2HAND – mean trial time, error time in percents, coordination coefficient,
f) SIGNAL – amount of proper detections and median of detection time.

The main statistical method used in this research was factor analysis (Hotteling's principal components methods with Varimax rotation (Weber 1980). The analysis was conducted at two stages, what allowed to determine inner structure in following models:

a) the results of VTS test,
b) all tests results (VTS representative and other tests).

Results and discussion

The statistical analysis begun with the determination of validity and reliability. The reliability coefficients were calculated on the basis of test–retest method (Magnusson 1991, Atkinson, Nevill 1998) and for all tests were sufficient. The correlation coefficients (depending on analyzed variable) were equal to: RG – from .81 to .95, DG – from .81 to .92, MLS – from .60 to .92, TAP – from .78 to .91, 2HAND – from .85 to .96, SIGNAL – from .74 to .86. These values are acceptable and useful in the individual and group diagnosis of motor coordination and psychomotor performance (Lienert 1969, Neumeier 1983, Magnusson 1991). In case of this experiment the validity coefficients calculation with the use of traditional method of correlation coefficient between analyzed test and test recognized as valid was impossible because of lack of the last ones. In relation to this the "factor validity" method was performed and results of this methods are interpreted as perfect when t=1.00, very good t>.85, good – from .84 to .80, sufficient – from .74 to .70. This results are presented in each table with as a first column. In case of equality of factor validity coefficients the variable with higher factor loading is more valid (Meining 1975, Weber 1980).

Among the results of diagnosis of motor coordination performed with the use of VTS among female students of Academy of Physical Education in Katowice the following factors (explaining 71.60% of common variance) were extracted:

1. Simple reaction time (17.42%)
2. Movement combining (13.79%)
3. Precise coordination (11.23%)
4. Complex reaction time (8.56%)
5. Sense of rhythm (8.01%)
6. Movement frequency (6.94%)
7. Space orientation (5.73%)

Table 1

Factor loadings of VTS variables among female students

Variables	**FV**	**Factors**						
		1	**2**	**3**	**4**	**5**	**6**	**7**
Simple reaction time	.67	-.54	-.11	-.19	.23	.07	-.26	-.45
Speed of reaction	.91	**-.90**	.03	-.11	.05	-.08	-.17	-.23
Time of movement	.80	**-.85**	.16	.02	-.12	.02	.03	.18
Amount of complex reactions	.49	.13	-.45	-.19	.05	.25	.17	.37
Complex reaction time	.96	-.25	.17	**.74**	-.50	-.03	-.20	-.18
Rhythm synchronization error	.70	.03	.02	-.14	.14	**.78**	.20	-.10
Rhythm continuation error	.50	.13	-.05	.15	-.03	**.67**	-.11	.01
Amount of unilateral taps	.84	.18	.08	.01	.06	.07	**.89**	-.05
Amount of bilateral taps	.83	.00	.11	.10	.00	.01	**.89**	.13
Amount of error in target pointing	.94	.09	-.05	**.96**	-.03	-.08	.05	-.02
Time of errors in target pointing	.91	.01	-.02	**.95**	.02	.04	.04	.00
Time of trial in target pointing	.64	-.17	.48	-.15	-.25	.47	.00	.27
Bimanual coordination time	.84	-.10	**.87**	-.10	-.12	.05	.20	.07
Bimanual coordination error	.71	.01	**-.82**	.00	-.18	.02	-.04	.08
Coordination coefficient	.59	-.22	.26	.03	.48	.22	-.11	.43
Time of pins inserting	.56	-.20	.22	.05	**-**.51	.27	-.35	-.13
Signal detection time	.58	.07	-.05	.00	**-.75**	-.09	-.01	.07
Amount of detected signals	.56	.14	.01	-.04	.03	-.12	.03	**.72**
Percent of common variance		**17.42**	**13.79**	**11.32**	**8.56**	**8.01**	**6.94**	**5.73**

FV – factor validity

The factor analysis calculated among male students, similarly as in case of female, extracted 7 factors explaining 71.90% of common variance. They may be interpreted as:

1. Simple reaction time (19.47%)
2. Precise coordination (13.25%)
3. Movement combining (11.00%)
4. Fast coordination (8.67%)
5. Complex reaction time (7.15%)
6. Movement frequency (6.35%)
7. Sense of rhythm (6.01%)

Table 2

Factor loadings of VTS variables among male students

Variables	**FV**	**Factors**						
		1	**2**	**3**	**4**	**5**	**6**	**7**
Simple reaction time	.64	**-.73**	-.19	-.03	.10	.16	.02	-.19
Speed of reaction	.96	**-.96**	-.07	-.03	.05	.15	-.05	-.05
Time of movement	.69	**-.80**	.09	-.02	-.05	.05	-.11	.14
Amount of complex reactions	.74	.31	-.02	.09	.16	**-.75**	-.18	.11
Complex reaction time	.70	-.25	.04	.03	.30	**.68**	-.28	.04
Rhythm synchronization error	.49	.15	.01	.02	.07	-.44	.00	**.52**
Rhythm continuation error	.61	-.03	-.16	.05	-.08	.12	.02	**.75**
Amount of unilateral taps	.75	-.03	.16	-.02	-.03	.04	**.85**	.04
Amount of bilateral taps	.73	.24	.18	.10	.18	-.07	**.77**	-.02
Amount of error in target pointing	.87	.01	**.91**	.00	.12	.01	.15	.02
Time of errors in target pointing	.85	.08	**.91**	.06	-.01	.03	.10	-.06
Time of trial in target pointing	.69	-.02	.26	-.09	**.76**	-.00	.10	.15
Bimanual coordination time	.76	.01	-.21	**-.80**	.04	.19	-.20	.00
Bimanual coordination error	.89	.01	-.02	**.94**	.01	.00	-.04	.04
Coordination coefficient	.54	.20	-.12	**.67**	-.10	.14	-.10	.03
Time of pins inserting	.57	.02	.05	-.05	**.61**	.14	-.01	.41
Signal detection time	.65	-.07	-.07	.01	.08	**.72**	.04	-.33
Amount of detected signals	.60	.33	.29	.19	-.36	-.09	.02	.48
Percent of common variance		**19.47**	**13.25**	**11.00**	**8.67**	**7.15**	**6.35**	**6.01**

Resuming, it is possible to state that performed factor analysis extracted the same number of factors in both sexes. Unless some differences in types of factors, generally the interpretation of acquired results is quite similar. It is worthy to underline the greater amount of common variance explained with "simple reaction time" factor in both sexes than the rest of factors. Simultaneously two other factors "precise coordination" and "movement combining" can be characterized by higher common variance explained. The common variance explained by this three factors is significantly higher than the other four factors, so it is possible to state that they play the most important role in the determined structure.

Second part of this paper was focused on determination of structure of motor coordination with the use of VST, laboratory and chosen field tests. The main aim of this part was description of as many as possible factors describing the coordination aspects of human motor potential. At the first stage the following aspects of motor coordination were determined: reaction, differentiation, movement combining, sense of rhythm, frequency of movement and space orientation. However extending the amount of tests with additional ones diagnosing the sense of balance (stabilometer and tensometric platform) and other abilities (i.e. MOTORYK and laboratory methods) may allow for more precise determination of coordination structure and more valid exploration of this area.

The results of factor analysis performed with the 19 variables battery (including 8 the most representative from the first stage) are presented in table 3. The extracted factors explained 70.57% of common variance in females and they were interpreted and presented hierarchically as:

1. Reaction time (12.19%)
2. Motor adjustment (10.70%)
3. Sense of rhythm (9.80%)
4. Strength differentiation (8.97%)
5. Movement frequency (8.77%)
6. Space orientation (7.06%)
7. Sense of balance (6.88%)
8. Movement combining (6.20%)

Table 3

Factor loadings of different aspects of coordination among female students

Variables	**FV**	**Factors**							
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Simple reaction time	.74	**-.76**	.21	-.07	-.07	.18	-.26	.11	.02
Complex reaction time	.57	**.61**	.20	.33	.01	-.09	.08	.14	.14
Ditrich's stick	.57	**-.72**	.01	-.07	.07	-.03	.09	-.13	.11
Precision of adjustment	.74	-.04	**.81**	.24	-.06	.11	.06	.07	.07
Rhythm continuation error	.74	.16	-.21	**.75**	.12	-.07	-.22	.12	-.15
Limbs drums	.62	.05	-.03	.14	**-**.56	.26	.39	.08	-.24
Amount of unilateral taps	.66	.31	-.05	.04	-.11	**-.69**	.22	.11	-.09
Amount of detected signals	.68	.01	.05	-.09	.03	-.02	**.81**	.09	.01
Target march	.46	-.19	.03	-.13	.33	.03	**-**.51	.09	-.16
Stereometer	.72	-.30	-.03	-.02	-.09	.39	**.63**	.23	.12
Jumping coefficient	.73	.01	-.03	.02	-.09	-.05	.00	.00	**.85**
Bimanual coordination error	.42	.17	.51	.04	.17	.22	-.02	.06	.23
Amount of errors in target pointing	.53	.15	.15	-.46	-.01	-.24	-.20	-.12	-.40
Time of errors in target pointing	.50	-.42	.27	.12	-.11	-.24	.23	.04	-.33
Strength differentiation	.75	.05	.08	.14	**.84**	.09	.10	-.02	-.04
Mirror drawing	.35	-.24	-.09	.08	.00	-.48	-.14	.13	.12
Bench turns	.62	-.09	.03	-.02	.01	-.09	.08	**.77**	.01
Static balance	.60	-.30	-.13	.00	.01	.25	-.07	**.65**	-.08
Percent of common variance		**12.19**	**1.70**	**9.80**	**8.97**	**8.77**	**7.06**	**6.88**	**6.20**

In effect of factor analysis calculated in males the set of 19 variables was reduced to 9 hypothetical factors explaining 70.30% of common variance (tab. 4). The theoretical interpretation and classification extract the following factors:

1. Reaction time (11.59%)
2. Sense of rhythm (9.72%)
3. Movement frequency (8.59%)
4. Motor adjustment (7.66%)
5. Space orientation (7.33%)
6. Sense of balance (6.87%)
7. Space movement differentiation (6.68%)
8. Strength differentiation (6.26%)
9. Movement combining (5.60%)

Table 4

Factor loadings of different aspects of coordination among male students

Variables	FV	Factors								
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Simple reaction time	.71	**-.76**	-.17	.14	.10	.01	.11	-.15	.19	.04
Complex reaction time	.64	**.70**	.05	-.15	.05	.02	.07	-.23	.26	-.04
Ditrich's stick	.38	-.06	-.22	.02	.13	.54	.03	-.05	.08	.09
Precision of adjustment	.75	-.09	-.08	.00	**.77**	-.06	.06	-.02	-.31	.19
Rhythm continuation error	.63	.03	**.74**	.21	.02	-.09	-.09	-.09	-.10	.05
Limbs drums	.57	.12	-.06	.23	.05	**-.60**	.07	.19	.29	-.10
Amount of unilateral taps	.58	.20	.01	**.72**	.05	-.10	.03	.06	.04	.04
Amount of detected signals	.65	**.71**	-.23	-.04	.09	-.01	.00	.04	.14	.25
Target march	.41	.00	-.57	-.05	.26	.10	-.04	-.02	.03	-.0
Stereometer	.77	.04	.02	.01	-.10	**.83**	-.13	.15	-.09	-.15
Jumping coefficient	.67	-.23	.22	-.03	.12	.10	-.07	.04	.02	**.73**
Bimanual coordination error	.68	.18	.05	.09	-.02	.00	.14	.02	.09	**.78**
Amount of errors in target pointing	.68	.03	-.04	-.07	.03	.05	.21	**.72**	.12	-.31
Time of errors in target pointing	.44	.11	-.02	-.16	.21	-.33	.08	.39	.07	-.29
Strength differentiation	.58	-.05	-.20	.23	.19	-.08	-.05	.09	**-.64**	-.14
Mirror drawing	.57	.12	.13	.48	.26	.02	-.03	-.13	-.06	-.47
Bench turns	.55	.21	.00	-.11	.34	.31	.48	.19	.12	.00
Static balance	.74	.10	.04	-.07	-.04	.08	**-.84**	-.02	-.05	-.06
Percent of common variance		11.59	9.72	8.59	7.66	7.33	6.87	6.68	6.26	5.60

In light of the acquired results it is possible to confirm a theoretical model of specific aspects of coordination. Model which includes 8 elements should be treated as valid and fully acceptable in area of motor coordination in male and female students. It should be mentioned that two factors were extracted i.e. motor adjustment and movement combining, which were not identified earlier. The only exception is data from Juras and Waśkiewicz (1998). Simultaneously the results of this experiment allow to determine the test battery which will fully and reliably describe the area of coordination potential. It should include the following variables:

a) simple reaction time (from RG),
b) error in continuation time (from TAP),
c) unilateral tapping (from MLS),
d) precision of motor adjustment (from MOTORYK),

e) streometric vision or amount of detected signals (from stereometer or SIGNAL),
f) static balance (from tensometric platform),
g) hand dynamometry or target pointing (from MLS),
h) jumps with or without countermovement or error in bimanual coordination (from 2HAND).

The above presented test battery seems to be optimal and the most precise in case of coordination diagnostic. Among all used at this stage tests only one is field tests what underlines the necessity of conducting research in coordination area with the use of more precise diagnostic tools especially computer supported. As the factor validity coefficients show the field tests are characterized with significantly lower values and should not be included in testing motor coordination in scientific research. It should be especially underlined that VTS allows for precise and reliable diagnosis of 6 from 8 determined aspects of motor coordination (except motor adjustment and sense of balance)*. In this situation the VTS system seems to be multifunctional device diagnosing chosen aspects of motor control and its predispositions.

Presented above results justify that field tests are not reliable and valid in precise diagnosis of motor coordination aspects. Factor analysis which is valuable method, not only in structure determination and number of variables reduction, but also in calculation of factor validity showed that field tests have a generally complex character. It is caused probably by different and multilevel background of these properties. Simultaneously it allows to conclude that field tests may be useful in cross-sectional studies (large populations) and physical education. The complexity of these test allows to diagnose more aspects of coordination in one test, but one has to remember that the acquired results will not be sufficiently reliable and precise for scientific conclusions.

Resuming it is possible to underline the complexity of presented in this paper problems in theoretical and methodological aspects of motor coordination diagnosis. The necessity of verification of presented conclusions and interpretations in further research projects and experiments is absolutely beyond

* In current research the 3PTR test, which in light of not published yet data seems to diagnose the motor adjustment, was not performed.

discussion. It should be clearly stated that most of the used diagnostic research tools was presented on that scale in Poland for the first time, however it does not allow to treat the problem of diagnosis of motor coordination as solved. Contrary, results of this research opened many questions and showed future research directions, and none of them seems to be justified.

Conclusions

Presented above results and the analysis of existing theoretical basis in the area of motor coordination allows to formulate the following conclusions:

1. The structure of motor coordination should include the following elements: reaction time, motor adjustment, sense of rhythm, kinesthetic movement differentiation, movement frequency, space orientation, sense of balance and movement combining.
2. The use of precise diagnostic tools allows to penetrate motor coordination and its predispositions.
3. The future development of research in the area of motor coordination is possible only as a result of improved diagnostic tools.

REFERENCES

ATKINSON G., NEVILL A. M. (1998) Statistical methods for assessing measurement error (reliability) in variables relevant to sports medicine. *Sports Medicine*, 26, 217-238.

BERNSTEIN N. A. (1988) *Bewegungphysiology*. Leipzig, Barth Verlag.

HIRTZ P. (1985) *Koordinative Fähigkeiten im Schulsport.* Volk und Wissen, Berlin.

JURAS G., WAŚKIEWICZ Z. (1998) *Time, space and dynamic aspects of coordination motor abilities.* Acad. of Phys. Ed., Katowice (in Polish, English summary).

LATASH M. L. (1993) *Control of Human Movement*. Human Kinetics Publishers, Champaign.

LIENERT G.A. (1969) *Testaufbau und Testanalyse*. Berlin.

LOOSCH E. (1999) *Allgemeine Bewegungslehre*. Limpert, Wiebelshelm.

MAGNUSSON D. (1991) *Introduction to the test theory*. PWN, Warszawa (in Polish).

MEINING D. (1975) Zur Bestimmung der Validität sportmotorischer Tests. *Theor. und Prax. der Körperkultur*, 1, 51-66.

MULLINEAUX D.R., BARTLETT R.M., BENNETT S. (2001) Research design and statistics in biomechanics and motor control. *Journal of Sports Sciences*, 19, 739-760.

NEUMEIER A. (1983) *Sportmotorische Tests in Unterricht und Training*. K. Hofmann Verlag, Schondorf.

RACZEK J., MYNARSKI W., LJACH W. (1998) *Theoretical and empirical basis for developing and diagnosing of co-ordination motor abilities.* Acad. of Ph. Ed., Katowice (in Polish, English summary).

RACZEK J., WAŚKIEWICZ Z., JURAS G. (1997) *Raum-, zeitliche- und dynamische Aspekte koordinativ-motorischer Leistungsvoraussetzungen - ein Objektivierungsversuch der Diagnostik.* (W:) P. Hirtz, F. Nuske (red.): Bewegungskoordination und sportliche Leistung integrativ betrachten. Schriften der Deutschen Vereinigung für Sportwissenschaft. Czwalina Verlag, Hamburg, 87, 293-300.

ROTH K., WILLIMCZIK K. (1999) *Bewegungwissenschaft*. Rowohlt, Reinbeck.

SCHMIDT R. A., LEE D. A. (1999) *Motor Control and Learning: A Behavioral Emphasis.* Champaign, IL: Human Kinetics.

TURVEY M. T. (1990) Coordination. *American Psychologist*, 45, 938-953.

VINCENT W. V. (1999) *Statistics in Kinesiology*. Champaign, IL: Human Kinetics.

WAŚKIEWICZ Z., JURAS G., ZAJĄC A., RACZEK J. (1999) Computer supplemented diagnosis of the sense of rhythm. *Journal of Human Kinetics*, 2, 67-78.

WEBER H. (1980) *Grundriss der biologischen Statistik*. VEB Gustaw Fischer, Jena.