COMPUTER-ASSISTED BONNARDEL'S SINUSOID FOR GROUP ADMINISTRATION WITH MINE-CLEARING PERSONNEL

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ABSTRACT

In the late 1995 psychologists of the Ministry of the Interior Medical Service were assigned the task of selecting candidates to be trained for mine-clearing duty, which involved clearing millions of mines left throughout the territory of Croatia from the Homeland Defence War.

Along with a paper-and-pencil test to cover mental abilities and personality traits, selection project proposed the use of a psychomotor abilities test encompassing oculomotor coordination and movement precision, the two factors that play the role when doing the mine clearing job. Unable to count on commercial test appliances, the alternative was co-work with electronic specialists, which indeed resulted in the development of computer-assisted Bonnardel's sinusoid for group administration.

Modern microprocessing technology has made possible a thorougly new type of Bonnardel's sinusoids applicable for strictly controlled concurrent administration with up to 20-respondent groups. New appliances have compensated classic sinusoid structural shortcomings which precluded its group administration. This, modernized version of the test enables testing the factors of oculomotor coordination and hand precision on a relatively large sample of respondents in a new and time-saving way.

Historic frame

Psychomotor abilities and human effectiveness in various fields had been correlated since some time ago, hence the research in the matter is extensive. The interest in the matter has had theoretical and especially practical reasons. A strong impetus to measurement of individual differences was contained in theoretical foundations and anthropometric laboratory founded in the second half of 19th century by Galton, the pioneer in differential psychology. Mc Keen Cattell, then assistant in Wundt's laboratory, begin the employment of laboratory reaction meter to determine individual differences. He also introduced the concept "test" (1890) related to psychological differences measurement serving to determine individual differences with possible pragmatic repercussions.

In time, appliances from experimental psychological laboratories were increasingly used in practice, and proved valuable tool in selecting candidates for different professions. Industrial advancement called for valid, reliable and sensitive testing instrument to measure practice-relevant characteristics such as accuracy, precision, voluntary hand movement steadiness. Efforts to devise objective tests for the aforementioned features yielded in a group of test appliances named "tracing tests". Before them, a procedure had been used, known as "writing movement"(Bryan, 1892), where a respondent had had to draw a line on the paper by a sharp pencil, thereby demonstrating speed and precision of movement. Steadiness and precision of movement as the basic idea was eventually concretised into appliances.

Among the earliest apparatus tests is also Bagley's test from 1901. Respondents had to draw a metal needle along the slit between two thin metal stripes distant 1 mm. The needle with electrically isolated handle was connected to the negative pole of the battery, while the stripes were connected to the positive pole. Each time the needle touched the stripes was measured on an electric counter, or was simply signalised to the testing supervisor by activation of telegraph bell. On hearing the bell, the supervisor could press the telegraph key and register the error. In the later versions of the test sensitivity were improved by means of the test containing a gradually narrowing or entirely winding slit (path) (Whipple, 1910). The test measured speed and accuracy.

Advancement in psychotechnics brought new selection procedures too. (Munsterberg, 1913). An excellent review of psychotechnical application of different test apparatuses is provided in Strien's paper (1997). Among various selection procedures were also apparatuses for psychomotor abilities, which, although gradually modified, basically employed the principles of the original tracing tests. To highlight is Moede's "zweihandprufer", or "two-hand tests", based on an idea from 1919 (Moede, 1930). By moving two handles vertical to each other, respondents would coordinately move the pencil along the dotted complex path drawn on the paper placed on a small plate, trying to make it as precisely and quickly as possible. Performance indicators were the speed and the accuracy. Moede's test was subsequently modified, for instance as Poppelreuter test, where respondents moved the mobile plate and path with two hands under a fixed pencil (1928). With Ruppe's test (1924) respondents moved the pencil across the fixed path with two levers (Moede, 1930. Bingham, 1937). These tests employ the principle of turner's lathe.

Ricossay introduced a special principle in precision measuring tests (Lesjak, 1964), with the path carved along the metal plate of the apparatus; respondents had to draw a spike of a determined width without touching path edges. A useful example of the principle is the "turner test" by Lahya, where respondents are supposed to move the metal cone along the middle of spiral path gouged into the fixed plate, by coordinately turning small wheels on the sides of the apparatus.

Using the principle of carved path, Raymond Bonnardel devised a series of quality psychomotor abilities tests, differing from each other in the shape of the path and mechanism handling principle. Those were the bi-manual coordination tests, such as "double-maze test" (1946), the Omega test (1947), "la Grecque"test, "le Mexicain"test (1951), and the particularly interesting "Bonnardel sinusoid" – a hand precision measurement test devised in 1950. (Figure 1)

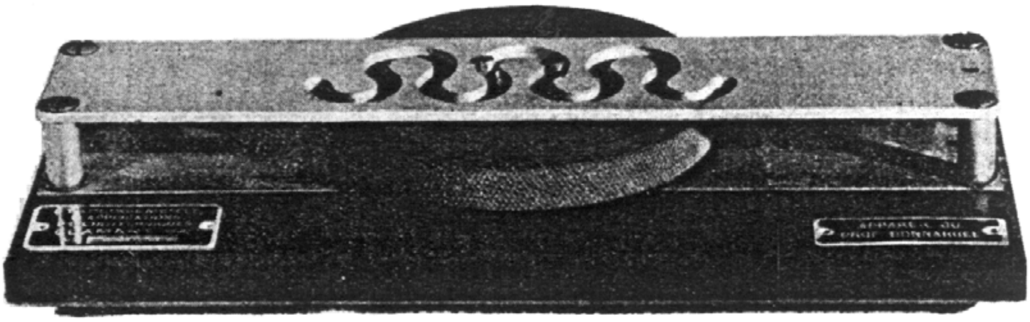


Figure 1. Bonnardel's sinusoid.

Bonnardel sinusoid consists of a metal plate with sinusoid-shaped path. The middle part of the path is 23 cms long and 5 mms wide. Under the metal plate (with carved path) there was a small wheel of insulate material with two 3-mm metal spikes. By holding the wheel with their thumbs and middle fingers, respondents are supposed to move the spikes along the path, without touching path edges. At some points they will pull the wheel against themselves, at others rotate it clock- or counter-clock-wise, which means complex hand movement. The contact of either spike with the path edge is entered as error. While other tests include one, Bonnardel's sinusoid has two spikes, therefore its sensitivity is greater. Also, unlike other oculomotor coordination tests, Bonnardel's test precludes advantage of respondents who already have taken some similar psychomotor test or a mechanical device. Correlation between scores on Bonnardel's sinusoid and tests such as Turner test, Omega test, Double-maze test range between 0.55 to 0.75.

In Croatia, psychomotor abilities tests have been employed in vocational guidance in Zagreb Institute of Crafts since 1932. Along with the aforementioned tests, some tests with original path construction were used. Closer to our days, Lesjak (1964) devised a bi-manual oculomotor coordination test called OMNARC (in Latin Omnes arcus - all arches). By coordinately moving the screws, respondents moved the metal spike along the 16.5 cm-long path of a particular shape. The main advantage of OMNARC path were its symetric sectors requiring several different coordinated hand movements on a relatively short path.

In the 1980ies Jerneić and Rohaček of the Zagreb University Psychology Department began research of basic characteristics and optimal conditions of use of Bonnardel's sinusoid. Also, a special statistic procedure was employed to compensate construction deficiencies of the original sinusoid, to determine true indicators of effect and factors affecting the scores on this test (Jerneić et. al., 1980/81; Rohaček et. al., 1981). The hardware modification of the original Bonnardel sinusoid was executed by technological standards of that time. This version of the sinusoid was familiar to a limited psychological public, and it proved useful in selection.

Psychomotor tests validity problem

Integration of psychomotor tests into the selection procedures demanded their validity tested. There had been attempts indeed to investigate psychological structure responsible for the score on those tests. Bagley (1901) for instance, detected inversion between intellectual development and efficiency on speed, calmness and movement precision tests. Bolton (1903) found intellectual development in children associated with progressing score on speed, steadiness and movement precision tests. Perin (1921) applied 17 motor tests, detecting no significant correlation to ascribe to factor of general motor abilities. He held three groups of factors having impact on tests performance:

1- factors of activity transfer from one test to another;
2- learning processes,
3- emotional factors. Based on employing simple motor tests. Muscio (1922) concludes, having found no significant correlation among simple motor tests he applied, that there is no general motor ability. He found no relationship between motor capacity and intelligence. His research is especially worthy for carrier counselling for proving that each routine performance requiring specific motor activity requires a specific motor test too. In other words, motor tests used in selection or career counselling for a job requiring motor abilities must activate the motor capacities relevant for the respective job. Farmer (1927) found slight correlations on a few sensorimotor tests, but also group factors involved in motor coordination. Akroyd (1928) investigated correlations between the performance on different motor tests involving oculomotor coordination, and found minimal correlations even between scores on related tests, which led him to conclude that selection and career counselling demand a separate psychomotor test for each specific combination of movements characteristic of a job.

Controlled and repeated studies by Earle and Gaw (1930)(Cox, 1934) on intercorrelations of scores on different motor tests led to extraction of motor factors of speed and precision determining score variance. In his earlier studies of motor activities Seashore (1940) detected precision factor and movement coordination factor, which was followed by detection of several group and specific psychomotor factors in later analyses of relationships among different motor activities.

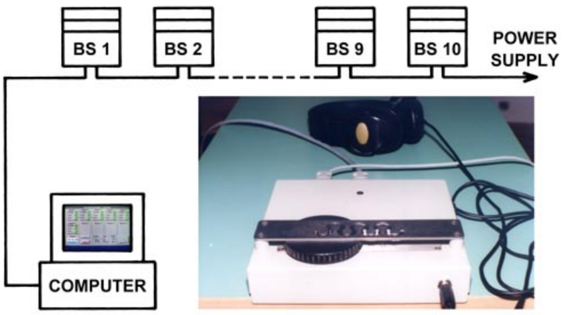
In conclusion, selection for different jobs should include psychomotor tests measuring psychomotor capacities that determine the performance in a profession, to obtain necessary practical prognostic validity of a test.

Computer-assisted Bonnardel sinusoid

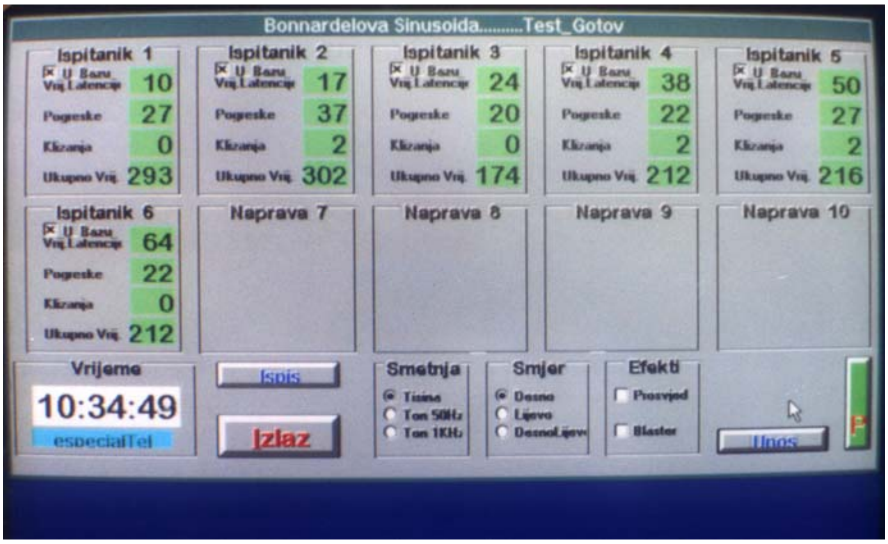
In late 1995 psychologists of the Medical Service of the Ministry of the Interior were commissioned with selection of candidates for mine-clearing training and job (which consisted in clearing huge amounts of explosive devices left from Homeland War). Selection had to deal with a great number of candidates motivated by prospects of great pay and, along with paper-and-pencil tests, included psychomotor abilities tests (oculomotor coordination, hand movement precision) - the factors crucial for mine engineers while lifting minefields.

Research by Guilford and Lacey (1947) showed that a right combination of paper-and-pencil tests and psychomotor tests can magnify multiple correlation of predictors and criterion variable and thereby increase predictive validity of tests used in selection for professions where psychomotor abilities are necessary. Psychomotor testing thus became an indispensable part of selection. Psychologists had at their disposal a pair of modified Bonnardel's sinusoids with electric counter designed to the model of the apparatuses used by Jerneić and Rohaček et. al. As the sinusoid and the procedures previously applied with student respondents in a short time turned out ineffective with mass of oculomotor coordination in adult respondents of different educational background and intellectual capacity, entirely new Bonnardel sinusoids were introduced, that were supposed to make up for constructional deficiencies of similar apparatuses and enable measurement of new parameters.

With electronic engineers of the "Telespecijal-Zagreb" company a joint project was initiated on a computer-assisted Bonnardel's sinusoid for group administration.The path on the new apparatus remained the same - the path was gouged in the plate of stainless steel, resistent to sweat, mechanical pressure and easy to clean. Under the plate it had a wheel with two steel spikes insulating material maximising the visual contrast between the wheel and spikes and the plate respectively. The start and the end was signallised magnetically, by means of sensors inheld in the apparatus. Each apparatus contained a microprocessor registering separate measure parameters and forwarded them to the computer. Sinusoids of the kind were serially linked (10 in a group), with one end connected to the computer port and the other to the power source.



The score presentation software was executed in "Visual BASIC" for Windows. Test apparatuses were again placed at the edge of table, retaining the same position with respect to respondents. With measurement going on, through the earphones respondents get alarmed of each error, that is of each contact of spike and the edge of the path.



Through the earphones they also receive acoustic interference definable in advance.

The measurements on all apparatuses completed, the scores obtained are displayed on the computer screen and registered on both the hard disk and the floppy disk.

A special computer order can provide a printout of results of measurements on individual apparatuses, be it a short printout containing data on hesitation time, number of errors, total error time and path pursue time, or a long one, containing the time and duration of error too.

The computer-assisted Bonnardel's sinusoid has several advantages:

1) covers the main deficiencies of the previous version (inability to control the sliding along the path and the starting moment)
2) computer-assisted version enables simultaneous and controlled administration with groups of 10 (20) examinees
3) more measurement parameters registered
4) measurement possible with different kinds of interferences
5) measurement possible in different directions of path pursuing
6) time-saving observing and registering of overall behaviour of examinees during the testing
7) wide and time-saving applicability with large groups of examinees

Measurement parameters and procedure

Computer-assisted Bonnardel's sinusoid enables measurement of the following parameters -
1) hesitation time (period from starting time to first movement)
2) errors made while pursuing the path (number of spikes and path edge contacts)
3) duration of each error
4) time points of errors
5) total time spent on errors (sum of all error times)
6) total time of path pursue
7) number of slidings (errors exceeding 0.5 seconds)
8) ratio between error time and total pursue time

These parameters can be measured in tone-free environment, in 50 Hz and 1 KHz-tone environments respectively. Respondents' performance can be interferred by acoustic arousal containing emotional "charge" (some words, screams etc.). Activation of the "protest" toolbar button each time an error exceeds 0.5 seconds increases gradually the intensity of the warning signal to the unbearable point.

The movement of the wheel under the plate can be directed to the left or to the right only, combined to the right and to the left without stopping. On reaching the final point respondents receive a characteristic signal. Prior to the measurement, all apparatuses are checked out to verify they are in starting position. A respondent who starts beforehand gets eliminated by the computer and his error is registered, of which the respondent gets notified.

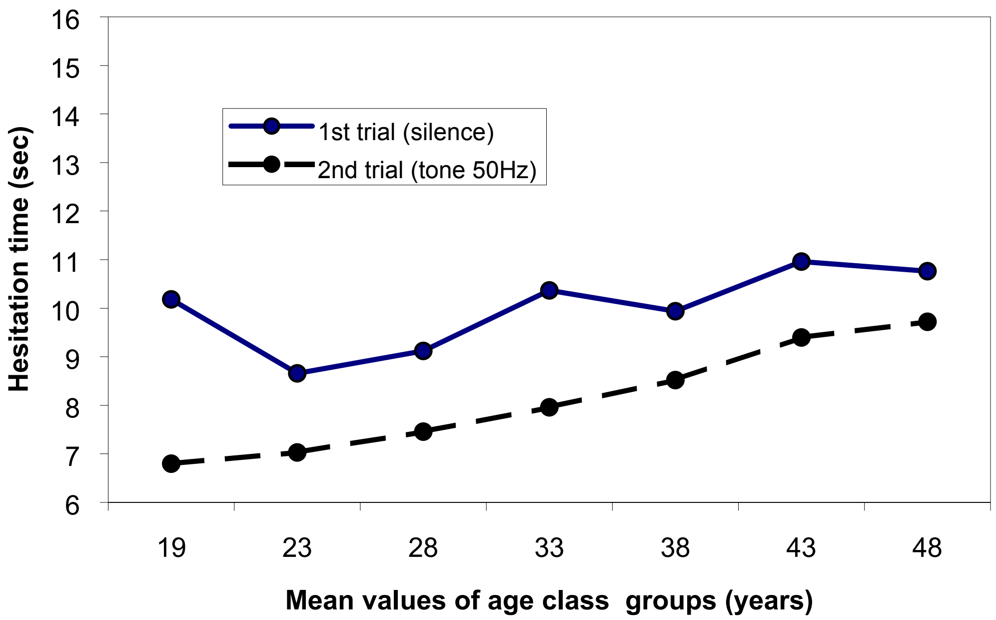
The measurement procedure consists of 3 steps:
a) all relevant bio-data are filed (name, family name, age, occupation, company as well as data on the physical aspect or present physical condition of a respondent) and the number of the apparatus is assigned to each respondent
b) next, the instructions are given and a short 70-sec exercise is administered
c) the exercise is followed by the measurement procedure during which respondents have to follow the path as quickly and accurately as possible.The pursue is first administered in calm conditions, and later with 50Hz-tone interference.

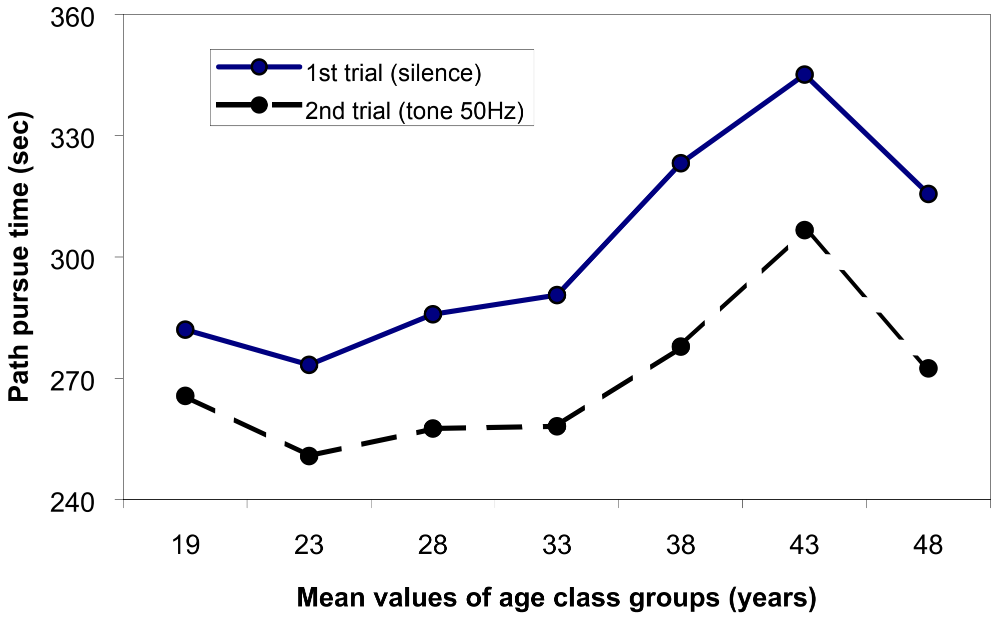
The measurement also involves observing of overall behaviour of respondents, and relevant comments are stored into respondents' files.

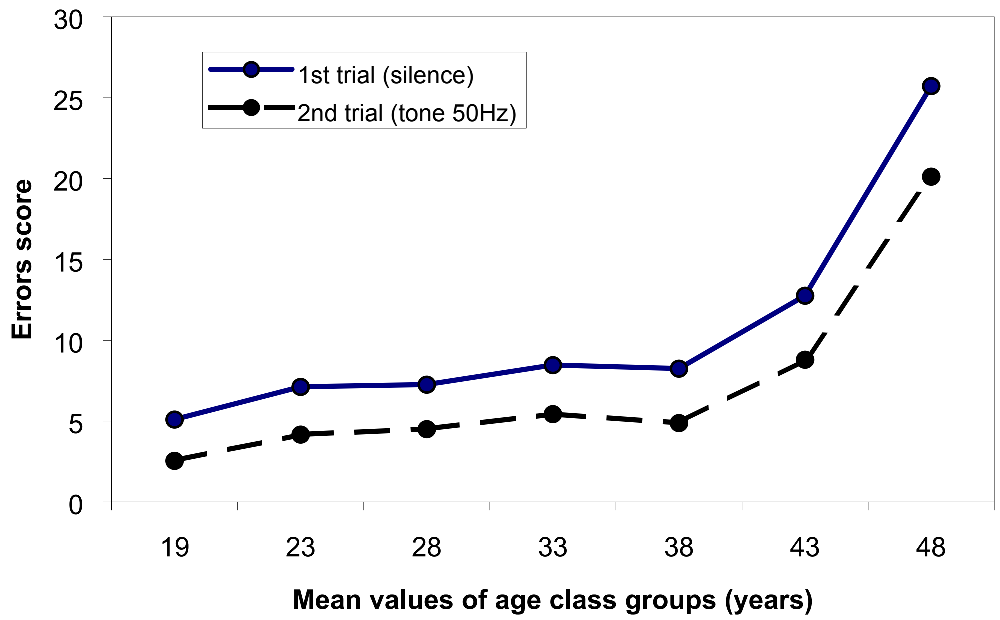
Results

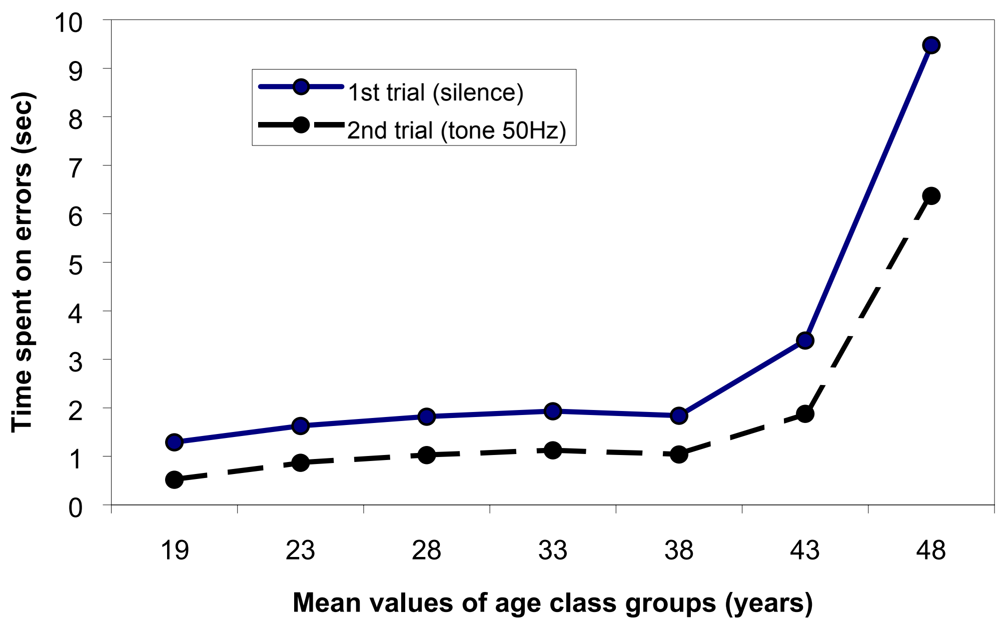
Among the many applications of Bonnardel's sinusoid the author of the paper singled out the results of his own administrations. The sample was N=1010 and was age-cross-cut. Mean values of parameter measurements from individual classes were presented on charts. For clearer changes in individual measurement parameters as a function of the age the linear interpolation procedure was used.

Figures (**Fig.4, Fig 5, Fig 6, Fig 7**) show changes in individual parameters as a function of the age.









The changes were best visible with the precision factor. Hand movement precision can be presented either through the error frequency or total duration of errors. It appears that at the age of 40 a significant decrement occurs in precision capability required in the Bonnardel's test.

As the 20-30 age range sees no statistically significant differences in main parameters, as the number of respondents in such a sample is relatively large for a measurement of the kind and as mine engineers belong to this age group, Table 1. and Table 2 contain orientation norms for the precision factor and speed factor.

Distributions of results of the speed factor and of precision factor were found asymmetric both in tone-free environment and in 50-Hz tone environment. However, while the distribution of results of measurement of total time of path pursue approached normal distribution values, the distribution of the number of errors was positively skewed. (Fig. 9).

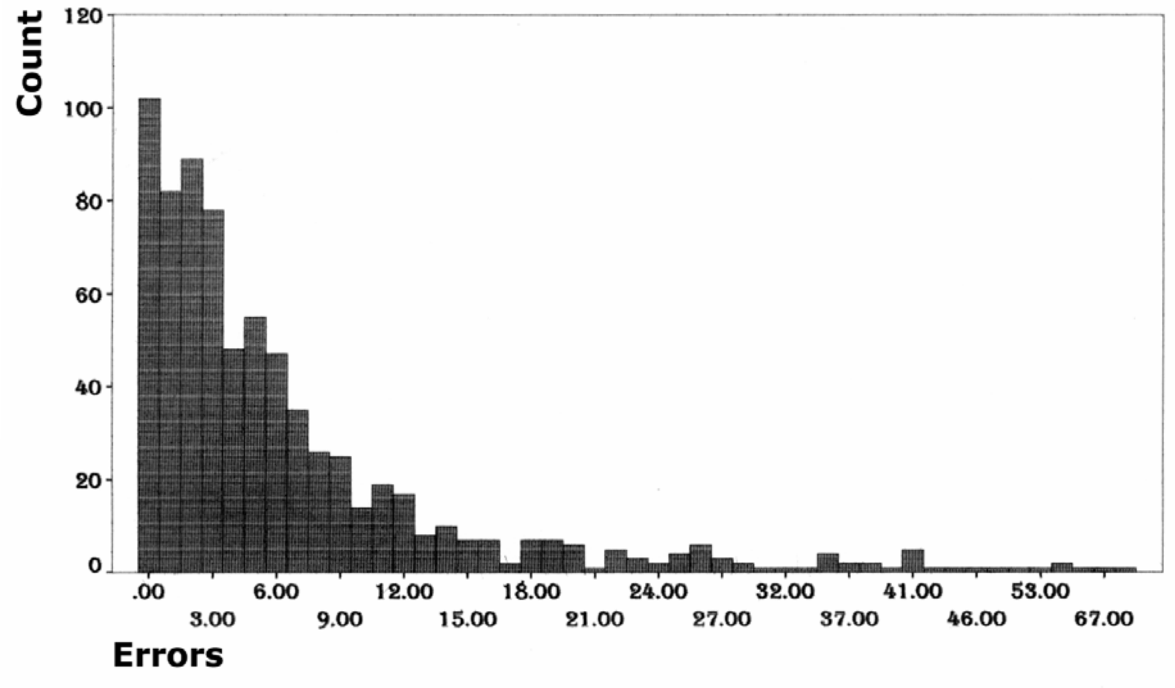


Fig. 8.: Histogram of results of measurement of total time of path pursue

Table 1 Orientational norms of precision factor for examinees in the 20 - 30 age class

AGE	N	ERRORS (silence)		ERRORS (noise)	
		M	σ	M	σ
20 – 30	745	7.02	9.60	4.16	7.70

Table 2 Orientational norms of speed factor for examinees in the 20 - 30 age class

AGE	N	PATH PURSUE TIME (sec) (silence)		PATH PURSUE TIME (sec) (noise)	
		M	σ	M	σ
20 – 30	745	277.03	103.64	253.30	85.00

Fig. 9. Frequency of individual error times

Factor analysis of our results for the tone-free situation (Varimax rotation in 4 iterations) yielded 3 factors (table 3).

Table 3. Factor saturations of individual measurement variables

Variables	Factor 1	Factor 2	Factor 3
Errors	0.920	-0.132	0.006
Time Errors	0.988	0.011	-0.008
Sliding	0.930	0.104	-0.006
Total time	-0.006	0.986	0.141
Hesit.time	-0.004	0.139	0.990

In conclusion, the variance of results of our measurements is determined by F1 (precision), F2 (speed) and F3 (not yet extracted) factors. Presumably F3 regards psychological structures related to personality aspects. The same factor structure is obtained with analyses applied with measurements in 50 Hz tone conditions.

During the measurement overall behaviour of respondents is observed, and remarks are filed into a record.

Evaluation and prognostic validity

The linear relationship between predictors and criteria in most cases is well known, whereby better performance on a predictor also guarantees performance on a criterion variable. However, the relationship between psychomotor tests as predictors and performance in actual job (criterion) is not linear, whereby a rise in predictor after reaching a certain level does not necessarily imply enhanced working performance (Petz, 1969). Also, prediction error in criterion variable is major with predicting from optimal score of predictor variable, and minor when predicting poor psychomotor test score. Furthermore, the decisive factor for performance in a job is not average or above average score, but rather not a poor score. The problem that remains is that of determining the "poor" score, as it is usually a function of strictness of selection.

Bearing in mind this principle and some known standards previously determined on Bonnardel's sinusoid on a sample of young people, we chose the "cut off point" precision and speed factors for "average" scores. In other words, a respondent is categorized as "acceptable" if his score equals or exceeds the average regardless of his chronological age, whereby older individuals who meet the criteria set with the younger population pass the selection. Raising the selection threshold would of course let in only individuals with superior psychomotor abilities, but that would result in lack of candidates for a job. The present selection criteria proved relevant in practice.

Finally, there is the crucial question on pragmatical validity of the selection applied, which is of "*a priori"* nature which is not easy to solve. There are data, however, that indirectly prove the validity of selection procedures for mine engineer job.

Croatian Mine Action Centre has data on mine engineers from Croatia and Bosnia and Herzegovina who lost their lives or got disabled. The comparison of the data of the two countries is justified, because the mines, minefield principles, terrain, war experience and educational background of mine engineers are very similar. Also, mine engineers in both countries are motivated for the job, and have been trained for it too. The only difference consists in Croatian mine engineers' obligation to pass rigorous medical and psychological selection prior to their specialist training.

Table 4 compares figures on killed and disabled engineers in Croatia from 1998 - (3 June) 2000 and in Bosnia and Herzegovina in 1999:

Table 4. Comparison of average mine-cleared surfaces per (1) engineer in Croatia and Bosnia and Herzegovina

	Croatia	Bosnia and Herzegovina
1 casualty	2.24 km^2 cleared surface	0.27 km^2 cleared surface
1 fatal	5.2 km^2 c. s.	0.62 km^2 c. s.
1 serious wounding	5.2 km^2	0.83 km^2
1 wounding	15.6 km^2	1.25 km^2

The data clearly advocates the selection procedure applied, even in case when no strict psychometric validation of predictor variables is employed.

Conclusion

The practice has shown that interconnected computer-assisted Bonnardel's sinusoids provide reliable and precise data on oculomotor coordination and hand movement precision. Psychomotor test devised as described here and computer-assisted assist psychologists in selection of large groups of respondents. Bonnardel's sinusoid as a psychomotor test appears to be a crucial component of selection and subsequent survey of psychomotor abilities of mine-engineers.

References:

1) Akrojd, F.: Some tests and correlations of hand-eye coordination. The Forum of Education, 1928, 6, 127-143.
2) Bagley, W.C.:On the Correlation of mental and motor ability in school children. American Journal of Psychology, 1901, 12, 193-143
3) Bingham, W. van D. : Aptitudes and aptitudes testing. Harper &Brother Publ., New York and London, 1937
4) Bolton, T. I. : The relation of motor power to intellingence. American Journal of Psychology, 1903, 14, 351-367
5) Bonnardel, R.:Le test du double labyrinthe B.19-D.L. Le Travail Humain, 1946, 9, 212-218
6) Bonnardel, R.:Une nouvelle epreuve de precision mecanique le test omega. Le Travail Humain, 1947, 10, 104-107
7) Bonnardel, R.: Une nouvelle epreuve de precision des mouvements des mains. Le test sinusoide. Le Travail Humain, 1950, 13, 270-273
8) Bonnardel, R.: Une nouvelle epreuve de precision de la coordination des mouvements Le test B 23, "La Grecque". Le Travail Humain, 1951, 14, 254-257
9) Bonnardel, R.:Un test de precision: Le "Mexicain" . Le Travail Humain, 1951, 14, 321-325
10) Bryan, W. L.:On the development of voluntary motor ability. American Journal of Psychology, 1892, 5, 123-204
11) Cattell, J. McKeen: Mental tests and their measurements. Mind 15, 373-380
12) Cox, J.W. Manual Skills: Its organization and development. Cambridge Univ. Press, London, 1934
13) Farmer, J. A group factor in sensorimotor tests. Brit. Journal of Psychology, 1927, 17, 327-334

14) Jerneić, Ž., Rohaček, A., Rimac, I. Prilog postupku ispitivanja okulomotorne koordinacije. ("On the oculomotor coordination test procedure) Zbornik radova "Dani psihologije"1980/81 Filozofski fakultet Zadar, 163-167
15) Lesjak, V. Omnarc - Jedna varijanta figure trase na aparatu za testiranje psihomotorike ruku. (A variety of path shape on a two-hand test apparatus); Zbornik radova II Kongresa psihologa, Zagreb 253-258 16) Moede, W. Lehrbuch der psychotechnik. Verlag von Julius Springer, Berlin, 1930
16) Munsterberg, H. Psychology and industrial efficiency. Houghton Mifflin Co., Boston and New York, 1913
17) Muscio, B. Motor capacity with special reference to vocational guidance. Brit. J. Psychol.,1922, ¸ 13, 157-184
18) Perin, F.A.C. An experimental study of motor ability. J. Exp. Psychol., 1921, 4, 24-56
19) Petz, B. Metode i tehnike praćenja i statistička obrada podataka.(Methods and techniques of observation and statistics processing of data) Iz: Praćenje u profesionalnoj orijentaciji. Republički zavod za zapošljavanje, Zagreb, 1969, 21-45
20) Poppelreuter, W. Psychologische begutachtung der erwerbsbeschrankten. Urban und Scharzenberg, Berlin, 1928
21) Rohaček, A., Jerneić, Ž., Rimac L., Vodanović, M.: O ispitivanju okulomotorne koordinacije Bonnardelovom sinusoidom. (Oculomotor coordination testing by Bonnardel's sinusoid) Primijenjena psihologija, 1986, 7, 49-54
22) Seashore, R. H., Baxton, C. E., McCollon, I. N.;Multiple factorial analysis of fine motor skills. American Journal of Psychology, 1940, 53, 251-259
23) Seashore, R.H: Work and motor performance. Stevens, S.S. Handbook of experimental psychology. John Wiley and Sons, Inc. New York, 1951, 1341-1362
24) van Strien, P.J. Die psychotechnische verwerdung von laboratoriumsgeraten. Albert. D., Gunlach, H. (Hrsg) Apparative Psychologie:Geschitliche entwicklung
25) Whipple, G. M.: Manual of mental and physical tests. Warwick and York, Baltimore, 1910
26) Data of Croatian Mine Action Centre, Sisak, Hrvatska (personal communication, 8 Sept. 2000)