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Estimation of the parameters of quality control test of professional competence of staff

Abstract. ***Purpose:*** *to develop a method for estimating the reliability of the control of functional competencies of staff with limited test sample.* ***Material and Methods:*** *statistical process control, sampling by attributes.* ***Results:*** *the dependence of the reliability of the sampling of the sample size and the population of test questions, the control plan, methodical error sampling with a given probability.* ***Conclusions:*** *the proposed method of selecting control plan that allows correct (with a given probability) decision criterion to choose the implementation of process control professional competencies of staff with limited test sample.*
Keywords: *alternative features, reliability control, the acceptance number, level of quality.*

Introduction. Any kind of activity will be successful if professionals of a high level are engaged in it, possessing necessary competences in their area. In physical culture and sport (especially professional) requirements to the qualification of coaches, arbitrators are not only very rigid (this activity is directly connected also with health of a person), but also are continuously growing. The professional development is an indispensable attribute here. In the modern world computer methods of testing (competence estimation) are even more often used. Especially quickly it extends when training students within the credit and modular system, pupils. And it extends not only at the estimation of knowledge in the exact sciences, but also at the exposure of grades in physical culture [1; 2].

It is impossible to check all the possible (demanded) competences at a control (estimation, testing) of professional competences of the personnel by testing or carrying out an examination. Really an employee (an examinee) is offered to answer the limited quantity (selection) of questions from the whole massif (the test program) which is completely defining the demanded competence. Thus there is a statistical problem of the determination of reliability of a result of testing: the made decision on compliance or discrepancy of competence of a examinee in the conditions of the limited test selection and a really received result – a share of the correct answers (solutions) from a total number of the proposed in a selection.

Such task arises at the examination of the personnel about safety measures, the detection of a real competence of a candidate for a workplace, the assessment of results of the professional development, the estimation of knowledge of pupils and students and so on [3].

A control – is an obligatory process of any quality management system [4]. The stability of quality of any process considerably is defined by the chosen method (way) of the realization of its management: control of parameters, criteria and reliability of an adoption of the correct decisions.

The determination of the level of reliability isn't a problem task and is regulated by normative documents at the quality control of technical products [5]. In the case of estimation of such subjective indicator as knowledge (competence), direct application of the standardized control methods (testing) is impossible. It is impossible to define the law of distribution of a random variable, it is impossible unambiguously (an identical way within the massif) to define a source of a random variable. Possible values and distribution of a methodical error of drawing up questions (tasks) and another aren't defined always [6].

Communication of the research with scientific programs, plans, subjects. The research was carried out within the research works of Kharkov national university of radio electronics, in particular on the subject "Methods, models and information technologies of the development of a social and economic educational and scientific network for the purpose of integration into the European space".

The objective of the research: the development and the improvement of methods of estimation of reliability of the process of control (estimation) of functional competences of the personnel by testing or carrying out the examination at the limited test selection.

The research tasks. The probability of an adoption of the correct decision on results of a control (test) is often used as the general indicator of reliability of a control. It is necessary to be guided by the following reasons at a choice of a quantitative measure of reliability of testing which can be executed in various ways. The reliability of testing has to depend functionally on volume and the accuracy of measurement (assessment) of parameters, it is easy to be calculated and allow solving rather simply the return problem – to determine the volume of test selection and the level of quality of a control by its set reliability.

In this sense there is a need to answer the following questions:

– what minimum volume of test selection at the set reliability level?

– what acceptance number of questions (tasks) for the test selection (number of negative answers) allowing with a sufficient share of confidence to make the decision on a negative or positive result of testing.

Material and methods of the research. General scientific methods of the analysis, synthesis, comparison, statistical information processing was used in the course of researches. Methods of a statistical control, procedure of a selective control for an alternative sign allowed improving a method of estimation of reliability of testing of knowledge (professional competences) at a selective control. The computer data processing was carried out with the use of package Excel and Turbo Basic.

Results of the research and their discussion. ***Features of the statistical massif of test examination questions.*** As the quality of decisions at the control (testing) is estimated by probabilities of mistakes, reliability of testing can be defined in the following look:

$$D=1-\alpha-\beta, \quad (1)$$

where α, β *– mistakes of 1 and 2 sort.*

Risk of an employee ("supplier") α: obviously a sufficient level of competence of an examinee mistakenly admit for insufficient.

Risk of an employer («consumer») β: an insufficient level of competence of an employee mistakenly is accepted to the sufficient.

If to reject personal characteristics of the examinees and to submit them as carriers of competences (knowledge, skills), it is possible to apply methods of a statistical selective control on an alternative sign at the estimation of the quality of testing.

We will designate the following parameters:

– a total quantity of questions in the test program (the population size) – *N*;

– a quantity of the questions making the test (volume of test selection) – *n*;

– a quantity of questions from a set of *N* which didn't receive the correct answer (number of a defect in population), – *M*;

– a share of the questions from a set of the size *N* which didn't receive the correct answer (a share of a defect in population) – *q, q=M/N*;

– a maximum number of the questions in a test selection which didn't receive the correct answer, (acceptance number) which is criterion for making decision on a positive or negative result – A_c.

The plan of a control – is a set of requirements and rules which should be observed at making decision on passing of a test. The type of the plan for the selective control unambiguously is determined by an alternative sign as (N, n, A_c) [7]. DSTU ISO 2859-1-2001 "Plans of the chosen control which is defined by the accepted level of quantity for the consistent control of parties" in this case doesn't allow choosing the plan of a control. The essential arguments of it are the following:

– perhaps a rather small size of population;

– perhaps a big (concerning population) volume of a test selection and accident of its size;

– unlike entrance control of technical production where risk of the supplier α and risk of the consumer β are set directly from economic indicators and often normative, at a control of knowledge (competences) of a value α and β are connected with financial expenses indirectly, and, in fact, demand a definition.

Thus, the research objective is the definition of the plan of a test selective control of knowledge (competences) of employees in the field of physical training and sport at which the probability of an error of adoption of a wrong decision ($\alpha+\beta$) will be improbable.

Definition of the plan of an entrance control. The equations for an assessment of probability of adoption of the correct decision on positive passing of a test and negative respectively are fair for any plan of an entrance control [6]:

$$P(q_0) \geq 1-\alpha$$
$$P(q_m) < 1-\beta, \quad (2)$$

where q_0, q_m – the acceptance and rejection levels of quality respectively.

Then the error of the 1st sort is a negative decision on results of testing of the employee with the level of quality $q<q_0$ (sufficient). The error of the 2nd sort is a positive decision at the level quality $q>q_m$ (insufficient).

The probability of that, that a number of negative answers of *m* in a test selection don't exceed an acceptance number of A_c, is equal:

$$P(q) = P_0 + P_1 + \cdots + P_{A_c} = \sum_{m=0}^{A_c} P_m \quad , (3)$$

The probability of that, that in selection by the volume of *n* taken from population by the volume *N* will appear exactly *m* of negative answers, is from the equation for a hyper geometrical distribution:

$$P_m = \frac{C_M^m C_{N-M}^{n-m}}{C_N^n} \quad , (4)$$

where $C_M^m = \frac{M!}{m!(M-m)!}$ – is a number of combinations from *M* to *m* (other combinations are calculated similarly).

Therefore, the equations have an appearance for the plan of a control:

$$1-\mathrm{a} = \sum_{m=0}^{A_c} \frac{C_{M_0}^m C_{N-M_0}^{n-m}}{C_N^n} \quad , (5)$$

$$\mathrm{b} = \sum_{m=0}^{A_c} \frac{C_{M_m}^m C_{N-M_m}^{n-m}}{C_N^n} \quad , (6)$$

where $M_0=N\cdot q_0$, $M_m=N\cdot q_m$.

Determination of reliability of results of a selective control. It is necessary to solve the following problems for the definition of probability of adoption of the correct decision:

1) to determine the minimum volume of test selection *n*;
2) to define the acceptable level of quality q_m;
3) to define an acceptance number A_c;
4) to define a dependence of reliability of testing on value of an acceptance number A_c for various amount of a test selection *n*;
5) to define the greatest possible value of reliability of results of testing for the chosen values of a level of quality and acceptance number.

The number of defect in population – is a population mean of a share of negative answers in selection $M\left(\frac{m}{n}\right)$. Therefore the rule of decision-making for the test selection would have to be formulated as follows: at $M\left(\frac{m}{n}\right) \geq q_m$ the negative decision is made (the test isn't passed); at $M\left(\frac{m}{n}\right) < q_m$ the test it is passed. However it is impossible to define $M\left(\frac{m}{n}\right)$. It is possible to establish only a share of negative answers in a concrete selection by volume. It differs from $M\left(\frac{m}{n}\right)$ at a size with some confidential probability [6]. It is recommended to set $P_д=0,9$. That is, the recommended volume of selection of *n'* will provide a selective mistake ε less or equal to the set with a confidential probability 0,9.

The real volume of a selection of *n* is equal to quantity of questions in the test.

If $n \geq n'$, such value of acceptance number of A_c is set at which value of reliability *D* for this volume selections of *n* accepts the maximum value.

As a result of testing the number of negative answers *m* is defined. If $m \leq A_c$, then the decision is made that a test is passed with confidential probability of $P_д=0,9$ and reliability of $D=D(n)_{max}$. Otherwise the decision on a negative result of testing with confidential probability of $P_д=0,9$ and reliability of $D=D(n)_{max}$ is made.

If $n \leq n'$, a confidential probability of the positive or negative solution of $P_д$. Is paid off. At value low P_a it is necessary to increase the amount of a test selection *n* to *n'*.

A standard value of reliability of control D_i is recommended to be set equal 0,8. If the $D(n)_{max} \leq D_i$, the made decision on results of testing is doubtful and it is necessary to increase the volume of selection *n*. At the $D(n)_{max} \leq D_i$ value of acceptance number A_c is set similarly, as well as for a case with $n \geq n'$.

If the rule of decision-making to replace on almost realized, at $\frac{m}{n} \geq q_i$ is required to make the negative decision, at $\frac{m}{n} < q_i$ – is positive. And it will be fair with the probability corresponding

$$t = \frac{\mathrm{e}}{\mathrm{s}_{\frac{m}{n}}} \quad (7)$$

If the value of this probability is set (for example, $P_д=0,9$) and the accuracy is established with which a replacement $M\left(\frac{m}{n}\right)$ on $\frac{m}{n}$ is allowed (by default $\varepsilon = 0,1$), from the last expression it is possible to find the necessary volume of a selection of test *n*.

A dispersion of a possible share of a defect in population corresponds:

$$D\left(\frac{m}{n}\right) = \frac{1}{n^2} D(m) = \frac{q(1-q)}{n} \cdot \frac{N-n}{N-1}. \quad (8)$$

From here the necessary volume of selection is from a condition [5; 7]:

$$\mathrm{e} = t\sqrt{\frac{q(1-q)\cdot(N-n)}{n(N-1)}}, \quad (9)$$

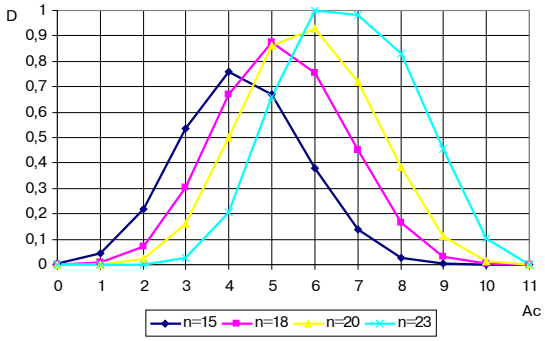
And it will be also equal:

$$n = \frac{n_0 N}{n_0 + (N-1)}, \quad (10)$$

where $n_0 = \frac{t^2 q(1-q)}{\mathrm{e}^2}$

Modeling of possible situations at a selective testing. If a share of a sign *q* in population is unknown in advance, for scoping of a selection, it is necessary to set $q=0,5$ to exclude the underestimation of volume of a selection since then the maximum value of numerator is reached.

In pic. 1 options of situations on a subject matter "Means and ways of diagnosing of various systems of an organism" are simulated for the quantity of questions in the test program $N=30$. The computer data processing was carried out with the use of the package Excel [8; 9].



Pic. 1. Dependence of reliability of a selective testing from an acceptance number for various amount of a selection

The calculated dependences of $D(A_c)$ are given in a drawing for various n – sizes of a test selection provided that a limit error of a selection $\varepsilon \leq 0,1$ with a confidential probability $P_д=0,9$.

For example, the reliability (correctness) of decision-making at the volume of a test selection of $n=20$ and an acceptance number of $A_c=6$ will make $D=0,92$ – the maximum value of $D(A_c)$ for a curve $n=20$.

Conclusions: The developed method allows correctly (with the set probability) to choose criterion of decision-making at the realization of the process of testing of the professional competences of coaches, arbitrators, students of sports higher education institutions with the limited test selection. This method of an assessment of reliability of a test control is rather flexible and open to the adaptation under new conditions. The method can be used both for the computer assessment of knowledge (competences), and at the realization of usual internal examinations.

Prospects of further researches are connected with the determination of properties and parameters of tests in general and their separate components (difficulty and transparency of tasks, limits of absolute competence, testing time, a share of residual knowledge and another) for the definition of their influence on reliability of the realization of the offered criteria of decision-making.

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