

Measurements of non-physical quantities

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Abstract. The aim of the paper is to suggest an approach to development of a theory of measurements for non-physical quantities. For these measurements it is not possible to ensure traceability because of their exclusive nature as substantiated by the author. This theory is presented as particularly important one for social and human sciences.

1. Introduction

The science of measurements, **METROLOGY**, is an integral part of the theory of epistemology, **GNOSEOLOGY**. It is the main instrument of obtaining accurate quantitative knowledge. It is also an instrument whereby we apply this knowledge in practice making it possible to facilitate scientific and technical progress, to promote trade relations, to increase the level of life and to improve its quality.

The science that deals with measurements of physical quantities (PQs) has a rich history and clear prospects for further development. This cannot be said about measurements of non-physical quantities (NPQs) that have nothing to do with metrological methodology. However, this gnoseology instrument is now experiencing a great demand [1, 2, and others]. If we agree with Immanuel Kant, who considered that “*in any special doctrine of nature there can be only as much proper science as there is mathematics therein*”, it appears then that all human sciences are not properly sciences, because they do not use such instruments as those that are used for NPQ measurements (in the metrological sense) and thus they are devoid of a strict quantitative basis. Let us not forget that results of researches pursued by historians, philosophers, teachers of social sciences, lawyers, sociologists, philologists, psychologists, political scientists, culture experts and a vast number of other scientists are used in decision making at all levels of governments and economy management, i.e., they touch upon fundamental interests of all people.

2. Non-physical quantities

By analogy with the definition of PQ, **by NPQ we will understand an immaterial property that, speaking in terms of quality, is common to many objects of the material and immaterial world that surround us. However, speaking in terms of quantity, this property is individual for each of these objects.**

Among the objects of our surrounding **material world** there are objects in our environment, such as: nature, urban infrastructure, household, society, family, cars, things, tools, goods, products, services, etc., that really exist in the spatio-temporal continuum. *Immaterial properties* of these objects (NPQs) are: *usefulness, beauty, necessity, importance, actuality, quality, expediency*, etc.

The **immaterial world** (noosphere¹) includes the people's spiritual world, whose NPQs are as follows: *high-mindedness, tactfulness, giftedness, moral rectitude, vulnerability, spirituality, enthusiasm, falsity, meanness, equity* and many others.

Thus, NPQs exist only in the mind of people either as reflections of properties of the real material world (PQs), or in the form of people's own understanding. They also can be formed on the basis of insights (NPQs) of other people.

¹ Noosphere (from Greek νοῦς - mind and σφαῖρα - sphere) - sphere of mind; it is used here in the direct sense of the word without loose and broad interpretations. The term was introduced by Édouard Le Roy, professor of mathematics at the Lycée Saint-Louis in Paris, and Pierre Teilhard de Chardin, French philosopher and Jesuit priest, who together attended lectures of Vladimir Vernadsky at the Sorbonne in 1922-1923.



Just as PQs are subdivided into base and derived quantities, NPQs could be categorized as *simple* and *compound* quantities. The *simple* PQs are constituent parts of the *compound* quantities, the latter being composed of a set of simple or compound quantities of a lower level. For example, such *compound* NPQ as “*high-mindedness of a human*” includes a number of more simple NPQs (i.e. immaterial properties of that person’s nature): *culture, politeness, tactfulness*. Sometimes, the *simple* NPQs constituting compound quantities are called constituent parts or components, indications, symptoms (as in psychiatry), etc.

2.1. Measure and measurement unit

“*Things are to you such as they appear to you*”, affirmed Protagoras. All that appears to us is a fruit of our mind and belongs to the immaterial world. Insofar as the objects of such world and their *immaterial properties* are **the products of imagination** that exist only in people’s mind, they cannot be measured by the same measuring instruments as those used for measurements of the PQs. Their only measuring instrument is the **HUMAN MIND**.

Protagoras believed that “*of all things the **measure** is man, of the things that are, and of the things that are not*”. Ancient Greeks proclaimed that the last and the highest gift of Gods to men is the **sense of proportion**. According to the teachings of Protagoras the world is perceived through human **senses**. Now we would rather clarify this statement by saying that we cognize the material world by means of our **sense organs** through organoleptic measurements of its quantitative characteristics (PQs), while the immaterial world is perceived through measurements of its quantitative characteristics (NPQs).

For instrumental measurements of the PQs **artefacts** can be used, such as length gauges (rulers) to measure the *length* and mass gauges (weights) to measure the *mass*. However, the noosphere has no material measures. The only **measure** here is the human **OPINION**.

It is believed that the use of **opinions** in **measurement** tasks has a big drawback: an **opinion is a subjective estimate** largely depending on people’s specific features, e.g., their qualifications, erudition, experience, knowledge, personal preferences, tastes, health, etc. However, there is nothing to be surprised at: something similar happened when people used *anthropometric* measuring tools.

Opinions can be expressed in different forms. Therefore, for centuries, without any connection with the measurement science – metrology, have been emerging and used empirically such procedures for measurements of NPQs as decisions, surveys, sociological investigations, referenda, votes, tests, expert examinations, etc. Some of them were provided with theoretical grounds (theory of estimation, psychometry, methods of expert evaluations).

When we express our opinion about the fact that a certain immaterial property manifests itself in one case to a larger extent than in another case, we give our comparative quantitative estimate, i.e. we make a *single measurement* by an ordinal scale [3]. **Accumulating** a posteriori information enables us to proceed to a *repeated (multiple) measurement*. To do it, it is necessary to obtain an array of experimental data. In that case the **NUMBER of opinions** coinciding with the initial estimate could be a **quantitative characteristic of an NPQ**, i.e. a *result of a multiple measurement*², one **opinion** being the *measurement unit*.

The use of an **opinion** as the *measurement unit* having no fixed dimension means but one thing: measurements of the NPQs are performed on the basis of a **DECENTRALISED** realization of the measurement unit.

2.2. A way to measure NPQs

According to the second axiom of metrology, **any measurement essentially consists in empirical comparison of dimensions** [3]. As immaterial properties that exist only in people’s mind have no **material** dimensions, it is possible to compare their quantitative characteristics only if they manifest themselves in some way. In this case, the **measurement** of an immaterial property boils down to a

² In practice a dimensionless relative index (fraction of such opinions in the general count [5]) is used as the result of multiple measurement. Its numerical values are within the interval [0; 1].

comparison of manifestations of this property, and, as a result, the question about when the property has manifested itself in a greater degree can be answered.

Nature has endowed us neither with the ability to compare quantitatively different properties with each other, nor to compare their manifestations. So, **the only way to estimate non-physical quantities is to compare their manifestations by the ordinal scale**.

2.3. *Methods of NPQ measurements*

When measurements are made using the ordinal scale, the comparison with a zero dimension becomes especially important. In the theory of PQ measurements, the zero dimension means the absence of this quantity, and a positive result of comparison with such a dimension is called **detection** of this physical value [3]. Manifestations of NPQs have no dimension, but the absence (i.e., 0) of any manifestation is considered as the absence (i.e., 0) of NPQs. If we have an expert **opinion** about the presence of at least one manifestation of an NPQ, it is **believed** that the NPQ has been **detected**. When the **detection method** is used for such measurements, the quantitative characteristic of an NPQ is determined by the **NUMBER of its manifestations**².

The second method of NPQ measurements is the **matching method**. It has two variations: **method of ranking** and **method of pairwise comparison**. When **matching method** is used, the quantitative characteristic is determined by the **NUMBER of preferences**² identified as “ranks” (each preference being an opinion about the “rank” to be assigned to the NPQ).

2.4. *Exclusivity of NPQ measurements*

Insofar as any **opinion** tends to be subjective, it is not possible to **provide its traceability to a reference**, which is the main concern of the legal metrology [4, 5]. Hence arises this question: As “*no two minds think alike*”, why is it necessary to measure non-physical quantities? The following answer springs to mind: **measurements of physical quantities (PQs) and those of non-physical quantities (NPQ) have different fields of application**.

Measurements of NPQ are:

- **a way to perceive the material world through its reflection in human minds**, which depends on their world view, creed, perception of the world, value system, priorities and a great number of other factors determining their personality. Results of measurements of the same NPQs in the material world, obtained by different people, cannot be the same IN PRINCIPLE.
- **a way to perceive the immaterial world of each person through its understanding (or lack of understanding) by other people**, acceptance or rejection of their value system and priorities, moral principles and actions, decisions, intentions and behavioral norms in the ordinary life and in emergencies. The results of such measurements obtained by different people cannot but differ from each other.

The requirement to ensure the **traceability** of PQ measurements gives way to the requirement to ensure the **exclusivity of NPQ measurements**. Not the manipulation with averaged results of NPQ measurements, but the respect of each individual person’s **opinion**, taking into account his personal **opinion** when solving the most important social, political and socioeconomic tasks, are keys to the harmonious progress of civil society and to founding many social and human sciences on a strict quantitative basis.

2.5 *Setting priorities*

The exclusiveness of NPQ measurements can be increased by taking into account the *importance*, significance and cogency of its components. In most cases it is legislatively mandated by means of weighting factors. However, the *importance* being itself an NPQ, it can be measured as such. The iterative procedure to determine weighting factors by a commission of experts is described in details in [6]. At certain conditions, which are usually always met, it provides the values of weighting factors that

strictly reflect correlations of importance among the objects of the expert examination once the initial data have been established by the experts.

The provision of exclusivity of measurements of *satisfaction* in different groups of users and parties interested in the quality of products, goods and services by means of weighing factors is discussed in [7].

The method of setting the priorities in accentuating the exclusiveness of different NPQs is widely used in pedagogy. In 1993 - 2011, important administrative decisions were taken on its basis in Russia [8-10]. At present, this is the main instrument to increase the exclusivity of NPQ measurements for the interest of individuals or groups and segments of the people.

2.6 Intransitive preferences

The ordinal measurement scale is characterized by the property of *transitiveness*. If the non-material properties A, B, C collated in pairs with each other are logically interrelated by proportions of preferability: $B \rightarrow A$ and $C \rightarrow B$, then the property of transitiveness means that $C \rightarrow A$. However, in processing the results of NPQ measurements, as in the case of PQs, gross errors (or so-called “blunders”) may occur. The latter can be explained by the lack of concentration of the experts, lack of confidence or absent-mindedness, which lead to the breach of transitiveness.

For example, an expert submits to the expert commission secretary the following table of pairwise collations of five examined objects for further treatment of the results:

Table 1. Results of a pairwise collation of five examined objects

	a	b	c	d	e
a	x	↑	↑	↑	↑
b		x	←	↑	↑
c			x	←	↑
d				x	↑
e					x

The direction of preferences in Table 1 is indicated by arrows. If, when determining the ranks, the preferences marked by arrows, the objects of the expert examination will have the following ranks: $R_a = 0$; $R_b = 2$; $R_c = 2$; $R_d = 2$; $R_e = 4$. Thus, although the preferences for each pair of expert examination objects have been established, there cannot be solution in the form of ranked series, because there are *intransitive preferences*. In this case the *intransitive preferences* form a triangle (see Fig. 1), where the ranks of the expert examination objects are given in brackets.

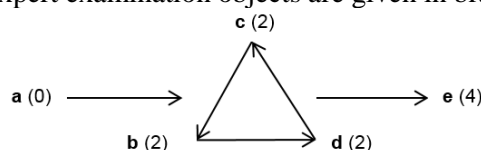


Figure 1. Results of pairwise collation of five expert examination objects

Similar ranks of certain terms of ranked series are indicative of the *intransitive preference*. They can occur everywhere: in the beginning, at the end and in the middle of the series. Intransitive references have the closed form of triangles, squares, polygons. Sometimes complex topological spaces can be present among experimental data. These spaces can include unions, absorptions, intercepts of *transitive* and *intransitive subsets*, which presupposes the possibility to use the Boolean algebra in processing the results of expert examinations. Such issues are discussed in [11].

The presence of *intransitive preferences* in the ranked series is not a singular phenomenon. The paper [9] sums up an extensive experiment performed in Russia during 10 years. From 1993 to 2003 a number of higher schools were certified according to the procedure adopted by the Russian State

Inspectorate for Certification of Educational Establishments [8]. Over 50 higher schools were certified during this campaign. The procedure allowed for taking into account opinions of pedagogical staff members about the *importance* of the factors used for certification of their educational establishments. This NPQ (*importance*) was measured by the academic councils of higher schools. In ten years of the certification campaign, *intransitive preferences* in the experimental data submitted by members of these Academic Councils for processing were detected in all cases.

It is possible to eliminate all intransitiveness by reversing one or several opinions of the expert:

$$a \rightarrow c \rightarrow b \rightarrow d \rightarrow e; \quad a \rightarrow b \rightarrow d \rightarrow c \rightarrow e; \quad a \rightarrow d \rightarrow c \rightarrow b \rightarrow e.$$

Usually the expert decides himself which opinion he is ready to reverse. If he is not available, the decision is up to the expert commission.

2.7 Quality of NPQ measurements

In measuring an NPQ by the **detection method**, the expert either notices the presence of the NPQ, or not, i.e. he acts as an *index*. A theory that regards indexes as instruments measuring on the ordinal scale is set forth in [3].

The expert **opinion** formed as a result of the measurement carried out on the ordinal scale is the **decision**. According to the 3rd axiom of metrology, its character is random, i.e., it can be *correct* or *incorrect (wrong)*. Thus, the probability that the *quality index* of the measurement result obtained on the ordinal scale is correct appears to be an obvious quality index.

Not less frequent practical *quality index* of a decision is the probability of its being wrong. The larger is the probability of mistake, the worse is the quality of a measurement result.

Wrong decisions taken when measuring on the ordinal scale are classified into mistakes of the 1st and 2nd kinds [3]. Decreasing the probability of an error of the 1st kind (P_I) entails increasing the probability of an error of the 2nd kind (P_{II}) and vice versa. Therefore, the natural desire to minimize the errors is a contradictory one.

The decisions that in the best possible way comply with contradictory requirements are called *optimal* decisions. Ideally, the best (*optimal*) decisions would be those when the observer (operator, controller) are totally exempt from errors or, at least, when their probability (P_{err}) is minimal. Therefore, the optimization criterion $P_{err} = P_I + P_{II} = \min$ is called *ideal observer criterion*. From this condition, in the case of technical devices an *optimal detection threshold* is calculated and assigned, which thus becomes a normalized metrological characteristic of the *index* as a measuring instrument. When measuring NPQs, it is impossible to calculate, assign or verify an *optimal detection threshold*. Each expert has its own threshold and it is impossible to influence his *opinion* which is, in fact, his *decision*. However, the *reasonableness of a decision* should be confirmed by a high probability of its being correct: $P = 1 - P_{err} = 1 - P_I - P_{II}$, where the probabilities P_I и P_{II} are assigned a priori from experience.

3. Conclusions

We live in the world that does not consist exclusively of material objects. In our mind there exist notions about good and evil, justice and injustice, presumption and modesty, moral rectitude and meanness, friendliness and hostility, as well as many shades of interpersonal relations and properties of our environment. However, being manifested in larger or smaller degree, they are characterized quantitatively and, consequently, can be measured. There is no need to speak about the great importance of information exchange in the quantitative measure with respect to people's intercommunication. It is needless to mention how large could be the qualitative leap in the development of human sciences, once they have turned to be "exact" sciences in the contemporary understanding of this word, if they become founded on strict quantitative calculations. "Science begins since they start measuring. Science is inconceivable without measures" (D.I. Mendeleyev). Such qualitative leap is possible due to NPQs' measurements.

NPQs exist only in the noosphere. The material sphere and the noosphere are fundamentally different and their differences drastically affect measurements in these spheres of human activity.

1. The noosphere is individual. It is formed as a result of many years' experience, and each person has its own noosphere.
2. The instrument to measure with in the noosphere is the human (expert) mind.
3. The result of a single measurement in the noosphere is the opinion of a human (expert).
4. The result of a multiple measurement is the number of opinions². In this case one opinion is equivalent to a measurement unit.
5. Opinion has no fixed dimension. This means that measurements in the noosphere are made on the basis of decentralized realization of the measurement unit.
6. The result of an NPQ measurement depends on the noosphere of the expert and it has subjective character. It is not correct to raise the question about providing traceability of measurements in this case.
7. The requirement of traceability for PQs' measurements gives way to the requirement to provide exclusiveness of NPQ measurements, i.e. the adequacy of their results to the noosphere of each individual and to the interests of different groups or segments of the people.

The exclusivity of NPQ measurements allows us to investigate the spiritual world of each individual, to understand his interests and preferences and to build productive relationships with him taking into consideration particularities of his noosphere. While average characteristic values are used in the material world when developing national, departmental, regional and sectorial programs of the economy, production scheduling programs and preparing statistical reports, the use of such average values is not possible in providing targeted assistance to the people, distributing the products, goods and services according to the needs, wishes and preferences of the consumers. Only through the study of real consumer demand and taking into consideration and respecting the opinion of every customer about the consumer properties, as well as by satisfying his personal needs, wishes and expectations, it will be possible to establish civilized market relations acceptable for all parties of this process.

Knowledge and consideration of and respect for particularities of the spiritual world of every individual in social medium that have become feasible due to the latest information technologies are tokens of the harmonious development of social relations capable of creating a conflict-free society in the foreseeable future.

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