On the existence of general properties as a problem of measurement science

L Mari1, A Maul2, M Wilson3
1 School of Industrial Engineering, Università Cattaneo, Castellanza, VA, Italy
2 Gevirtz Graduate School of Education, University of California, Santa Barbara, CA, USA
3 Graduate School of Education, University of California, Berkeley, CA, USA

E-mail: lmari@liuc.it

Abstract. The characterization of measurement as an empirical process implies that the general properties intended to be measured must in some sense exist, and the existence of a general property is then a necessary condition for its measurability. This paper explores the problem of justifying the existence of properties by identifying two general cases, related to direct asynchronous methods and indirect methods of measurement, and discussing the complementary issues they pose.

1. Introduction

What does it mean for a property to be measurable? Traditionally, solutions to the problem of measurability have focused on identification of the algebraic conditions that make the application of the methods of measurement possible. A conservative starting point was proposed by Campbell, who asked “why can and do we measure some properties of bodies while we do not measure others?” Under the consideration that “measurement is the process of assigning numbers to represent properties”, he considered it “obvious to inquire whether [measurability] may [...] be due to some greater resemblance between number and measurable properties than between numbers and immeasurable properties.” [1]. As clearly synthesized by Rossi [2], this position – assuming that so-called fundamental measurement only applies to additive quantities – strongly influenced the following discussion and generated a wide array of reactions, up to Stevens’ opposing claim that “measurement is the assignment of numerals to objects or events according to rule, any rule” [3] (see also [4]).

In the context of measurement science much less explored is a condition of measurability which is preliminary to any algebraic characterization: in order to be measurable, a property must exist.

Despite the complexity of the condition – what guarantees the existence of a property? – it seems hard to escape this point, provided that measurement is accepted to be an empirical process, as assumed in particular by the International Vocabulary of Metrology (VIM) according to which measurement is a “process of experimentally obtaining one or more quantity values that can reasonably be attributed to a quantity” [5]. Indeed, in principle nothing can be empirically (or experimentally) obtained from a non-existing property.
A basic clarification is required. The term “property” is used to refer to both entities such as length and shape, and entities such as the length of a given rod and the shape of a given body. Let us call the former “general properties” (other terms are “properties in general sense” or “kinds of properties”) and the latter “individual properties” or simply “properties of objects” (we follow the VIM here, and consider quantities to be specific properties: hence in discussing properties we include also quantities). Thus, the former is the focus of this paper.

The existence of an individual property is first of all contingent upon the object that bears the property. For example, liquids do not have a shape (though their containers might) and so the length of a given amount of water does not exist, and therefore cannot be measured. Hence, the existence of a (candidate) measurand (i.e., an individual property) depends on the conditions of its identification, what is sometimes called the “measurand definition” (for example, “the mass of the tenth planet of our solar system” is a verbally well-defined individual property, but it does not identify any existing property). On the other hand, it is not controversial that even in these case shape and length and mass are considered to be existing general properties. From the perspective of measurement science, this paper explores the issue of existence of general properties as a pre-condition for their measurability.

2. The problem of the existence of general properties from the perspective of measurement science

The societal relevance of measurement is justified by its empirical grounding: measuring instruments are designed so as to be able to interact with instances of given general properties (calipers with lengths, thermometers with temperatures, etc). Were it accepted that a non-existing property can be properly measured, the very concept of measurement would be called into question.

This may become clearer by highlighting the distinction between empirical properties and mathematical variables. An (existing) empirical property can be modeled by a mathematical variable, the identification of the conditions that make this possible being the basic contribution provided by the representational theories of measurement (which, peculiarly, call “qualitative” the structure of empirical quantities) [6]. The usual assumption of formally designating the quantity and the variable with the same symbol is handy, as thus justified for example by the Guide to the expression of uncertainty in measurement (GUM): “for economy of notation, in this Guide the same symbol is used for the physical quantity (the measurand) and for the random variable that represents the possible outcome of an observation of that quantity” [7]. On the other hand, this does not reduce the difference: a mathematical variable can be unproblematically considered to exist (in its mathematical world) as soon as it is defined, but this is not so for the quantity it might purport to represent. The definition of a mathematical variable is a formal statement, and therefore it is not sufficient to guarantee that there exists something in the empirical world modeled by that variable. From the perspective of measurement science, we propose to analyze the problem of the existence of general properties in reference to two paradigmatic cases. Let us call them simply “Case A” and “Case B”.

Case A situations originate from the observation of transduction effects, interpreted as empirical processes that produce variations of a (response, effect, output) property as effects of variations of one or more (stimulus, cause, input) properties. Whenever such a transduction effect is sufficiently well known, it may become the basis of an asynchronous direct method of measurement [8]: through the calibration of the transducer the values of the output property (i.e., the indication) are functionally related to values of the input property (i.e., the measurand). For example, temperatures are measured by means of differences of electrical potential via the thermoelectric effect. Case B situations originate from the fact that within an existing system of quantities (i.e., a “set of quantities together with a set of noncontradictory equations relating those quantities” [5]) a new quantity can be proposed as a function of quantities of the system. Whenever such a function is sufficiently well known, it may become the basis of an indirect method of measurement [8]: through the previous measurement of the input quantities of the function a value of the output quantity (i.e., the measurand) is computed. For example, densities are measured by computing ratios of masses and volumes.
Both Case A and Case B examples connect the problem of the existence of a candidate property (in the sense of candidate-for-existence: a property of whose actual existence we are not yet convinced) to a process in which such a property is supposed to be measured. While understandable in the light of our interest for measurement science, this could be accused of some sort of reductionism: as if we were claiming that a property exists only if it is measurable (i.e., measurability as a necessary condition of existence). Of course, this is not our position. Rather, what we claim is that
i. for a property to be measurable it must exist (i.e., measurability as a sufficient condition of existence; in other words, there can exist properties which are not measurable, but all measurable properties do exist), and that
ii. the only evidence that a property exists is in some manifestation of its causal role in empirical interactions that are understood in a scientific theory (and are at least in principle observable), and finally that
iii. measurement is a tool for investigating and assessing/checking causal relationships: even though a non-existing property cannot be measured, the trials for measuring a candidate property can be useful to provide insights about its actual existence.

Hence the identification of a causal role is the ultimate solution to both Case A and Case B problems of existence. There is a difficulty in both of these cases, and they have an interesting asymmetry. In Case A, as long as an effect is observed, we need not doubt that there has been at least one cause, and hence at least one candidate property must exist, and the problem is then to identify what is the property that has caused the transduction effect. In Case B, we can compute the value of a variable, but the problem is that we do not know whether that value corresponds to a causal effect of a property: thus, we can identify much about the candidate property, but still do not know whether it exists. An example of Case A could be phlogiston, where a state transition of a calorimeter was observed and (amount of) phlogiston was proposed as the cause (and hence attempts were made to measure it), but later new knowledge led to the rejection of the existence of phlogiston, and the proposal of a different set of properties (in particular, oxygen) as the causes of observed variation of calorimeters (and the flammability of objects). An example of Case B could be the (claimed) quantity hage, defined as the product of the height and the age of individuals [9]. Given the measured values of the height and the age of person, multiplying the two values is not problematic, but, does it mean that that person has a property hage, and that we have measured it, or that we just created a mathematical variable which does not provide any new information on the person under consideration?

3. Sketches of a solution
In the case of at least many established physical quantities, justification of the existence of the quantity can be given by the role the quantity plays in a network of lawful relationships, modeled in terms of equations on which a system of quantities is built, consistently with what Finkelstein termed “hard measurement” [10]. However, such systems are not always available, especially in the earlier stages of the development of a field of study, as can be seen both historically (including in physics), and currently (in fields such as psychology). In the absence of such a system, a new candidate property might be proposed as an explanation for variation in existing phenomena, such as when Spearman [11] proposed the concept of g (general intelligence) as an explanation for the observation that performance on different cognitive tasks tend to correlate highly in the general population. The justification for such a proposal might be considered a form of inference to the best explanation [12]: in the absence of a more plausible competing hypothesis, it might be tentatively accepted that the best explanation for some set of observations is the existence of a given property. (What constitutes a “best explanation” is left unspecified here, but in general refers to the explanation that optimizes some combination of explanatory power and parsimony, possibly along with other context-specific criteria.) Initially, in the absence of any competing explanations, the evidence available to support this proposal might be very thin, perhaps even to the point of tautology (for example, intelligence defined as the property causally responsible for variation in scores on IQ tests: “intelligence is what the tests test”, as Boring wrote [13]), a problem often recognized in discussions of the role of operationalism in the psychological
sciences. As a field develops, more evidence both for and against a given explanation for observed phenomena may be developed, possibly strengthening the justification for accepting the existence of a given property.

Thus, we might consider structural justifications for the existence of a property to fall somewhere on a continuum, with networks of lawful relationships on one end, and purely operationalist explanations on the other end. In between, one might find a range of abductive arguments at varying levels of strength. But despite the differences in the amount of evidentiary support that might be found for a given explanation at a given time, the forms of the justification of the existence of properties are structurally identical for both physical and non-physical properties. Put simply, the issue at stake is whether the candidate property can be shown to play a causal role in observed phenomena.

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