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# Why Has the Field of Psychology Not Developed Like the Natural Sciences?

Sam S. Rakover

*Haifa University*

The article suggests an answer to the question of why the natural sciences such as physics have been able to develop unified theories that provide satisfactory and efficient explanations for many natural phenomena, while psychology has failed to develop unified theories to explain psychological phenomena. The article's answer is based on the observation that in physics, the units of measurement (UMs) have an expression in theoretical terms that are the equivalent of observational terms (UMs-equivalency). In contrast, in psychology, UMs have an expression only in theoretical terms. The UMs-equivalency in physics is not a sufficient condition for constructing successful unified theories, but it is a necessary condition. Not every physical theory that maintains UMs-equivalency becomes a successful theory, because the theory may not properly represent the processes in reality. This article develops and justifies this idea and suggests that it is difficult to imagine a successful unified theory in psychology because UMs-equivalency does not exist in this field.

Keywords: measurement, methodology, scientific development

The present article suggests an answer to the following question: Why is there a wide gap between the scientific development of the natural sciences, physics in particular, and the development of psychology? This question regarding what I call the "developmental gap" is connected directly to the general problem of whether psychology can be considered a science like physics. If it transpires that psychology has developed in a direction that differs from physics, one may justifiably argue that psychology does not resemble the natural sciences. Briefly, the answer to the above developmental-gap question is that while physics has developed successful unified theories (e.g., Newton's), psychology has failed in this regard. What is the explanation for this failure?

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The answer to the latter question is based on the following observation: in physics, the units of measurement (UMs) are expressed in theoretical terms as well as in observational terms (called "UMs-equivalency"), whereas in psychology the UMs are expressed only in theoretical terms.[1] For example, in physics[2] the theoretical term "length" has a real expression. In contrast, in psychology, there are no real, empirical UMs for concepts such as love, hate, interest, memory, or intelligence (see a historic discussion on these topics in Michell, 1999).[3] These terms are measured in psychology by using "operational definitions," i.e., by specifying the procedures for observing the behavior that relates to the concept under investigation (e.g., Rakover, 1990). For example, the intuitive concept of intelligence is defined operationally by the appropriate test scores that are expressed by the IQ. As can be seen, the definition does not fulfil the requirement of UMs-equivalency since a psychological concept can be hinted at by many behavioral indexes. (Note that operational definitions are applied also to the independent variables; for example, the method section of an experimental paper includes a description of the stimulus and the conditions of its presentation.)

Physics and other natural sciences use the International System of Units (SI), based on seven fundamental UMs: meter, kilogram, second, ampere, kelvin, mol, and candela. From these seven basic measures, new terms of measurement are constructed, such as speed, acceleration, energy. The physical theory and the

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[1] The distinction between theoretical and observational concepts has been subjected to severe criticism. For example, it has been argued that observational concepts are theory-laden (Bogen, 2013; Clark and Pavio, 1989; Lambert and Brittan, 1992; Rakover, 1990). Nevertheless, I believe that this distinction is of great importance theoretically and practically, and psychologists continue to use it. Few psychologists would confuse concept group (I) [reaction time, pressing on a pedal, eye movement, heartbeat, and breathing] with concept group (II) [ego, instinct, visual scheme, consciousness, perception, and long-term storage]. Similarly, psychologists would not suggest that group (I) contains theoretical concepts or that group (II) contains observational concepts. Further, they would not say the two groups are the same. Clark and Pavio (1989, p. 510), who conducted empirical studies on this issue, have summarized the discussion about the theoretical–observational distinction and propose "that the distinction is generally valid.… [S]cientists do and ought to maintain distinct attitudes toward observational and theoretical terms when thinking or communicating scientific ideas."

[2] I am concentrating on classical physics for the following two reasons. First, most scholars have adequate knowledge of classical physics but very little knowledge of the theories of relativity and quantum physics. Furthermore, very few have even minimal knowledge in neurophysiology and modern research on the brain. Second, the units of measurements referred to here are used not only in classical and other areas of physics (thermodynamics, electromagnetics) but also in other areas of research such as chemistry and biophysics. Hence, I believe that the theoretical point I would like to make about UMs-equivalency will be exemplified by referring to classical physics, which gave enormous impetus to research in the natural sciences at large.

[3] The fact that UMs-equivalency holds for length does not mean that the measurement theory of length was developed first, and that its appropriate measurement units were developed afterwards. History teaches us that measurements of length and weight were developed before the mathematical formalization of the theory for measuring them. Therefore, what is described in this paper is the state of the art of measurement, the approach by which the theoretical term length is equivalent to the procedure for measuring length.

technology resulted from it are based on these measurement units. This can be demonstrated in a simple way: it is possible to predict, from Galileo's law of falling bodies, the distance that a body in free fall will travel as a function of the passage of time. This prediction may be confirmed by conducting the appropriate measurements. It is clear that what is calculated theoretically can be measured empirically, because the theoretical terms of time and distance are equivalent to these terms in the empirical measurement. Nothing like this has yet occurred in psychology. No real UMs have yet been found in psychology upon which it would be possible to construct unified theories.

Furthermore, the solution to the problem of the developmental gap in UMs may also constitute a solution to the problem posed by Eugene Paul Wigner, the Nobel laureate for physics in 1963. He pondered how it is possible to understand the enormous success of mathematics in describing and explaining natural phenomena (especially in physics). He wrote: "The first point is that the enormous usefulness of mathematics in the natural sciences is something bordering on the mysterious and . . . there is no rational explanation for it" (Wigner, 1960, p. 2). The essentials of the proposal for a solution to the developmental gap and to Wigner's problem are illustrated in Figure 1.

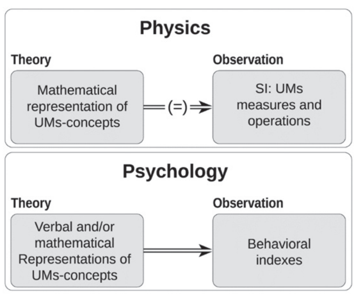


Figure 1: Comparison between physics and psychology in terms of the theory–observation relationship.

Figure 1 compares the methodological situation in physics with that in psychology by examining the connection between theory and observation. The theoretical terms and the empirical observations in physics are based on UMs, that is, on standard and real measurements according to the International System of Units. That is, the UMs in theory are equivalent to the UMs in reality (UMs-equivalency). Therefore, what is stated theoretically and mathematically also exists in the observable and measurable physical phenomena.[4]

4 UMs-equivalency assumes equivalence between exact theoretical terms (numbers) and inexact empirical terms that depend on procedures of measurement (Sherry, 2011). The discussion of the problems arising from this situation is beyond the scope of the current article.

In Figure 1, the broken arrow with the equal sign in the middle indicates two functions. The arrow signifies that it is possible to derive from the theory, under certain conditions, a specific prediction that can be tested by comparing it with the empirical observation (UMs). The equal sign emphasizes the UMs-equivalency, that is, the fact that there is equivalence between the UMs in theory and the UMs in the actual observation.

In contrast, theories in psychology are stated primarily using everyday language, although in many cases mathematical language is also used. Some of these theories represent the UMs as theoretical terms. They have no real expression in observations. That is, in psychology, UMs-equivalency does not exist.[5] For this reason, the solid arrow in the psychology section of Figure 1 fulfills a single function: under certain conditions it is possible to derive from psychological theory specific predictions that can be compared to the behavioral observations called "behavioral indices." These indices cover a wide range of behaviors: responses to stimuli (e.g., reactions, choices, answers to questions, or evaluations), speed of response, changes in the electrical resistance of the skin (measured by galvanic skin resistance [GSR]), changes in pulse rate, and changes in the blood stream in the brain (measured by fMRI). In some cases, it is possible to empirically test hypotheses about UMs and ascertain if the results support the criteria of an interval scale or a ratio scale.

In light of the above, the central argument of this article, based on UMs-equivalency is as follows: the equivalence in physics between the theoretical UMs and the observational UMs (as described in the International System of Units) is not a sufficient condition for building successful unified theories in physics, but it is a necessary condition. In contrast to physics, in psychology the theoretical UMs are not matched with the observational ones. This condition interferes with the development of unified theories in psychology.

It does not follow that any physical theory based on UMs-equivalency will be a successful theory. However, if a physical theory succeeds in representing processes in reality, then presumably this theory is successful due to UMs-equivalency. Based on this, one may propose that in psychology, in which UMs-equivalency does not exist, successful unified theories have low chances of being developed.

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[5] One may suggest that psychology also uses a theoretical term: probability of response (p(r)), which is equal to an observational term: percent (frequency) of correct response (%(r)). For example, in the well-known empirical generalization: p(r) is a learning function of motivation and training, and p(r) is estimated empirically by %(r). Nevertheless, the equivalence between p(r) and %(r) is only valid for the dependent (explained) variable. There are no UMs for motivation or training — the independent variables — which appear in the learning function and which are designed to explain behavior. To measure motivation, one uses the intuitive indices of hours of deprivation or incentives. For training the intuitive indices, repetitions or reinforcements are used. In contrast, in physics there is full equivalence between the theoretical, explanatory concepts and the observational, explained concepts, both of which are based on UMs-equivalency.

UMs-equivalency is also the answer to Wigner's problem regarding how it is possible to understand the success of mathematics in describing and explaining natural phenomena (for other solutions, see Livio, 2009.) The answer rests on the fact that the units of theoretical computations are the same units of the empirical measurements.

*The Developmental Gap between Psychology and Physics*

The question of why there is a wide gap between the scientific development of physics and that of psychology has been discussed in the psychology literature for many years (e.g., Lilienfeld, 2010; Zittoun, Gillespie, and Cornish, 2009). A simple Google search for the question "Is psychology a science?" yields dozens of articles in the professional literature, popular press, and blog communications, showing how relevant the question still is (e.g., Berezow, 2012; Henriques, 2016; Jogalekar, 2013).

In the following sub-sections, some of the main factors that prevent psychology from being considered a scientific discipline like physics are presented along with counterarguments demonstrating how these factors have been addressed in the field. (The discussion is based on the following studies: Ferguson, 2015; Lilienfeld, 2010, 2012; Pashler and Wagenmakers, 2012; Rakover, 2012; Sanbonmastsu and Johnston, 2019; Zittoun et al., 2009.)

*Experimental Control*

Due to the enormous psychological complexity of individuals (animals as well as humans) the control mechanisms that are found in natural science experiments are not possible in psychology. For example, the degree of interest or impatience of participants in laboratory experiments in psychology may vary greatly. As a result, it is not clear precisely what is being tested in the experiment and what affects a participant's behavior. The response to this criticism is that a random sampling of the participants balances the conflicting tendencies (e.g., slight interest among some is compensated by great interest in others) so that the effect of the independent variable on the dependent variable will be obtained across the sample of participants.

*Hidden Psychological Processes*

Most explanations in psychology are based on cognitive processes that cannot be observed directly. These processes are, in a way, only theoretical concepts. However, even in the natural sciences, scientists base models on theoretical processes that cannot be observed directly. For example, there is no way to directly observe the force of gravity. According to Heisenberg's principle of uncertainty, at the sub-atomic level, as the certainty about the location of a particle (e.g., electron) increases, the certainty of its momentum decreases, and vice versa. In a way similar to theories in the sciences, in psychology, theoretical concepts are indirectly connected to behavior.

*Empirical Generalization*

Frequently, the findings based on a certain sample cannot be generalized to other samples. Moreover, repeated tests are not always able to obtain the same findings, even with the same sample of participants. One reason is that a participant's memory of the first experiment is liable to influence the results of the repeated experiment. This problem can be solved by correctly planning a series of experiments using a between-subjects design. Furthermore, generalization between samples raises the inductive problem (statistics speaks of a relation between the sample and the population from which it was drawn). Science does not deal with generalization of findings from situation to situation, but with whether a certain hypothesis or theory succeeds or fails in explaining the observations under various conditions (whether the hypothesis is supported or not).

*Confirmation Bias*

There is a strong tendency among authors and journal editors to publish studies with affirmative results that support an author's hypothesis. Results that are not significant are seldom published, either because the authors do not submit the articles or the editors reject them. The result is that the published literature reflects the interests of the researchers and journal editors. In addition, criticisms have been raised that some studies are conducted in a way that leads to statistically significant results (e.g., by enlarging the sample size).

There are several responses to this criticism. First, such a tendency also exists within the field of physics. Steven Weinberg, Nobel laureate in physics in 1979, writes in his book *Dreams of a Final Theory* (Weinberg, 1993) that the analysis of results from the empirical test of Einstein's theory of relativity was influenced by knowledge of a prediction derived from this theory (bending of a light ray that passes near the sun).

Secondly, it is possible to overcome the issue of confirmation bias by publishing the research hypotheses and methods before the research is conducted. This solution, however, is not free of flaws. Developing the research question requires a large number of preparatory experiments by means of which researchers construct and modify their theoretical and empirical perceptions. Thus, when an experiment is conducted, many flaws have been filtered out by the preparatory experiments. A requirement to publish the hypothesis and methodology in advance may stand in opposition to this natural research process.

It is worth emphasizing that almost all experiments test the researcher's hypothesis against at least one alternative hypothesis. The results serve to determine which is correct among two or more hypotheses. In this respect, one may say that, although some researchers tend to promote their favored hypotheses, others will advance an alternative hypothesis based on their results. It thus appears that scientific criticism is not harmed.

*The Crisis of Replication*

In recent years, psychology has been beset by a replication crisis. The use of multiple studies (especially in social psychology) has not yielded the desired replication of the results. Hence, the methodological requirement of replication has not been met.

The response to this criticism is that it is possible to present numerous research studies in psychology, from conditioning and learning to cognitive psychology, which are replicable in an almost trivial way. Such replications would not warrant publication. For example, no journal would now publish an article demonstrating that hungry rats can learn to press a pedal in order to obtain a food pellet. Similarly, no author would submit an article about an experiment confirming the classic Müller–Lyer optical illusion (discussed below). Here again, it is suggested that the proper solution would be prior publication of the research hypotheses and methods. (However, it is unlikely that any journal would prior-publish the traditional methods for obtaining the Müller–Lyer illusion.) Moreover, it should be emphasized that certain studies in biology also cannot be replicated.

*Complexity*

Sanbonmastsu and Johnston (2019) proposed that, in comparison with physics, the development of social and behavioral sciences is inferior due to the greater complexity of the topics studied in the field of psychology. However, no consensus exists regarding the definition of complexity as applied to science; a given area of research becomes more comprehensible after a theory has successfully solved most of the problems in that research area. Still, physics is an extremely complex science as well. Even the basic and essential concept of mass is highly complicated. Its definition in Newton's theory (resistance to applied force) is different from weight, as well as from mass in the theory of relativity and in quantum theory. Moreover, the many sub-atomic particles that have been discovered and the interactions between them are so complicated that Weinberg (1993) describes how difficult it is to develop a unified theory for sub-atomic physics. To date, there is no accepted theory that unifies quantum theory and general relativity theory.

In light of the brief review presented, one may reach a number of conclusions. First, reasonable solutions have already been offered for most of the methodological problems in psychology. Second, in many cases, the natural sciences are troubled by similar problems as those in psychology. Therefore, one might suggest that psychology should be considered a science like the natural sciences; however, I believe this claim is incorrect.

A general historical overview of psychology (e.g., Leahey, 2004) indicates that no field of psychology has yet developed a successful unified theory. In contrast, in physics, the three unified theories of Newton, Einstein, and quantum physics offer acceptable explanations for a host of observations and discoveries. According to Kuhn's (1970) approach, these three unified theories constitute the basis for three scientific paradigms in physics. Kuhn also suggested that psychology is still in the pre-paradigm stage, since a unified theory in psychology has not yet been developed (e.g., Rakover, 1990).

Other researchers have reached similar conclusions. For example, Paul E. Meehl (1986) examined whether there is a connection between basic psychological science and clinical practice. Meehl's conclusion was that there is no integration between the two domains. As another instance, Allen Newell (1973), a cognitive psychologist and specialist in computer sciences, summarized articles presented at a conference on processing visual information. Newell found that every empirical paper presented had the same structure: an interesting phenomenon had been discovered and two contradictory explanations were offered such as a single memory system or dual systems; serial or parallel processing; single or multiple coding; decay of memory or interference; innate or learned processes; conscious or unconscious processes; gradual or one-trial learning; and so on (see Figure 2 in Newell, 1973). The problem is that these opposing hypotheses, supported by interesting empirical findings, do not cohere towards the development of a unified theory. He maintained that in another 30 years all one would obtain is a new collection of articles describing two opposing hypotheses to explain new empirical and cognitive discoveries. Based on the current state of psychology, it appears that Newell's prediction was correct — despite of the following attempts outlined below.

There have been several attempts to develop unified theories on the basis of artificial intelligence, such as Newell's (1992) "Soar" model. Although the model made important contributions to understanding cognition, it has received criticism and sparked controversies (see e.g., Cooper and Shallice, 1995; Garcia–Marques and Ferreira, 2011; Lewis, 2001). Soar seems not to have been accepted as a unified theory for psychology, in the way that Newtonian theory has been accepted in the field of physics.

In contrast, other psychologists propose that theories such as Freud's psychoanalytic theory, Hull's theory of learning, or Estes's stimulus sampling theory can be considered unified theories (e.g., Estes, 1950; Hilgard and Bower, 1966; Marx and Cronan–Hillix, 1987). While these theories were initially well-received, within a few decades each had been disconfirmed empirically and theoretically.[6] For example, Bower (1994) reviewed stimulus sampling theory and found that it encountered many problems when applied to new and complex behaviors. Currently, stimulus sampling theory has fallen out of favor for several reasons. Researchers are interested in new theoretical and empirical questions, and the stimulus–response approach that dominated psychology in the 1950s has been replaced by the new information-processing approach. Even the learning theory that Pavlov developed has been refuted by new experiments, although his experimental procedures are still the cornerstone of the field of research on animal learning (Kimble, 1961).

On the assumption that psychology has encountered difficulties in developing a successful unified theory, the question arises as to how this difference between psychology and the natural sciences (physics) may be explained. The answer suggested here is based on the claim that psychology has not succeeded in discovering UMs empirically, as physics has. In the following section, I discuss the topic of measurement in psychology.

## Failure to Develop a Unified Theory: The Problem of Units of Measurement in Psychology

Figure 1 highlights a basic difference between physics and psychology: the attempt to bridge the theory–observation gap. In physics, the bridge across the theory–observation gap is based on the equivalence between theoretical and real UMs (e.g., a ruler to measure length). In psychology, the bridge is based on the use of hypothetical UMs that are indexed by individual behavior. In other words, while physics uses theoretical UMs that are equivalent to UMs in reality, researchers in psychology uses hypothetical UMs that are connected to observations only through the predictions made from the theory about behavioral indices.

Psychology is influenced by two contrasting approaches to measurement. The first is offered by Norman R. Campbell, and the second by Stanly S. Stevens (for a review and discussion see e.g., Coombs, Dawes, and Tversky, 1970; Michell, 1999; Tal, 2017). According to Campbell's approach, measurement is based on an empirical discovery of the relation between a certain amount of a quantitative property and the UM of that same property. For example, given that the length of the stick (S) is 3 meters (S=3 meters), we can state that the relation between the length of S and its unit of measurement (meter) is 3 (S/meter = 3). [For a discussion of the terms "quantitative property" and "number" see Michell, 1999]. Stevens's (1946) approach holds that measurement is the ascription of numbers to objects or events according to rules. (On other approaches to scientific measurement, such as the realistic and the representational, see Tal, 2017.)

[6] The great influence of psychoanalysis on literature and everyday discourse is a different subject altogether.

An important point in Campbell's measurement approach, which I wish to emphasize, is that researchers discovered an empirical operation (e.g., counting how many times the UM fits into the length of L) that upholds mathematical properties on which the mathematical language in a physical theory is based. To illustrate this, let us examine the following two mathematical properties: transitivity and additivity. The transitive relation states, for example, that if (A = 15) > (B = 10) and (B = 10) > (C = 5), then (A = 15) > (C = 5); and the additive relation proposes that (C = 5) + (B = 10) = (A = 15). These relations exist in the group of sticks (lines) A, B, C:

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A|---------------|
B|----------|
C|-----|
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To show this, we first define a natural and arbitrary unit of measurement for length, here delineated by a dash (-). Second, we count how many times this unit fits into A (15 times), B (10 times), and C (5 times). Finally, we see that the lengths of the three sticks uphold the transitive relation, because A is greater than B, B is greater than C, and A is greater than C; moreover, the additive relation is upheld, because A = B + C.

Measurement of the length of an object by means of real and arbitrary units maintains all of the mathematical properties of numbers. Therefore, what is determined by numbers is also determined by the lengths of the measured objects. The same may be said of other quantitative properties such as weight and time. Measurement of weights is based on the use of scales, and measurement of time (clocks) is based on the use of a periodic phenomenon, such as the earth revolving around the sun. Many other measurements are derived from fundamental UMs (length, weight, time), such as speed (distance/time), acceleration, energy, etc. Some other measurements are based on physical laws for certain phenomena. For example, consider temperature; its measurement is founded on the ideal gas law and on thermal expansion (see Bringmann and Eronen, 2016; Sherry, 2011).[7]

In the field of psychology this approach to measurement is not found. Psychological properties (cognitive, mental) cannot be measured by an empirical

[7] Methodologically, Bringmann and Eronen (2016) and Sherry (2011) suggest that it would be worthwhile to think of the qualitative/quantitative status of psychological terms as analogous to the development of the term temperature. The term temperature changed from a qualitative term into a quantitative term as a result of the development of an appropriate physical theory: temperature constitutes a measure of average kinetic energy of microscopic particles. Following this analogy, one may expect a psychological term to be transformed from qualitative to quantitative status by developing a suitable theory. Although this notion is attractive, to the best of my knowledge such a development has not been achieved in the field of psychology. For example, despite the massive investment in empirical and theoretical research on the concept of intelligence, one cannot treat measurement of IQ like measurement of length or weight.

discovery of the relationship between the psychological property and the UM of that property, because such UMs are very difficult to define and observe. Neither can one appeal to an empirical psychological law by means of which it will be possible to measure some mental property. This circumstance has led researchers and philosophers such as Kant, James, and Leibovitch to cast doubt on the possibility of developing a psychological science (see discussion in Algom, 2019a; Marks and Algom, 1998).

Luce (1972, p. 96) expressed the matter thus: on the one hand, "… psychological measurement is not of a character closely analogous to either fundamental or derived physical measurement. … In brief, the reason is that psychological measures do not exhibit any fixed relation to physical measures and most likely not to one another when examined over individuals. This is reflected in the absence of any structure to the units of psychophysical measures." On the other hand, Luce proposed a hypothesis whereby "… man — and any other organism — is, among other things, a measurement device, in function not unlike a spring balance or voltmeter, which is capable of transforming many kinds of physical attributes into common measure in the central nervous system. According to this view, the task of psychophysics is to unravel the nature of that device." Hence, Luce agreed that measurement in psychology is not like measurement in physics, and instead he suggested a research approach based on the metaphor of perceiving human beings as a measurement device.

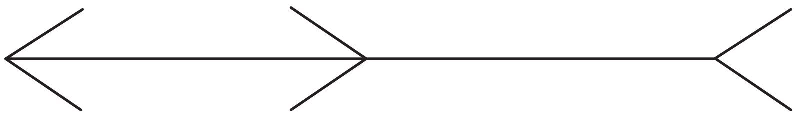
By comparison, Stevens (1946) proposed a broad definition of measurement, based on the attribution of numbers to psychological properties according to a certain rule. This definition opened the doorway to the use of numbers and mathematics in the field of psychology. On this issue, Michell (1999) wrote: "… there has been little serious scientific research undertaken to show that the relevant attributes are really quantitative and, therefore, that the relevant attributes are measurable" (p. 187). In other words, psychologists have bypassed or ignored the need to empirically show that the psychological property to which numbers are being applied is indeed a quantifiable property that can be characterized by an additive structure.

### Examples that Substantiate the Problem of Units of Measurement in Psychology

Below are five examples from the field of psychology. They serve to illustrate that measurement in psychology differs from the field of physics, and that the UMs-equivalency at play in physics does not exist in psychology.

*Illusions*

Consider the famous Müller–Lyer illusion:



Measurement according to the methods utilized in physics reveals that the length of the right-hand line is equal to that of the left-hand line, although people tend to perceive the left-hand line as shorter. The reason is that physicists measure the physical properties of this illusion objectively, while many people estimate it subjectively, according to the information processing taking place in their perceptual systems. One may measure the size of the illusion by moving the right-hand line to the left until it looks the same as the left-hand line. The difference between the subjectively adjusted length and the objective length is considered an index reflecting the degree of the illusion. However, the index is no more than an expression of the information processing taking place in one's perceptual system. In fact, this measurement procedure results in what is called the "point of subjective equality," which is different from the "point of objective equality" measured by a ruler. Given this comparison between the physical and the psychological measurement, it becomes apparent that our perceptual system makes mistakes and creates distortions.

*Intelligence Quotient (IQ)*

Over many years, and at enormous expense in empirical and theoretical research, psychology has developed tests for measuring intelligence. At the end of the test/measurement process, subjects receive a numerical grade attesting to their intelligence level, known as the Intelligence Quotient (IQ). To what extent does IQ attest to one's level of intelligence? The following example substantiates that the IQ numerical grade is extremely problematic.

As an exercise, let us assume that Einstein's intelligence level was very high, with an IQ of 150. Is it then possible to argue that his intelligence level was equal to the total intelligence level of three individuals with intellectual disability, each of whom had IQ = 50? If one assumes that IQ is a quantitative attribute (i.e., its structure is additive) then the answer is yes! But this answer is utterly ridiculous. Hence, one may propose that in many cases like this, psychology plays the math game correctly but without mirroring the psychological reality. Despite this drawback, one justification for the use of IQ grades is practical: to predict one's success in other tasks (see Coombs et al., 1970).

*Consciousness*

Several researchers argue that there is no problem in measuring, on an interval scale, subjective variables such as attitude, attractiveness, and feelings (e.g., Algom, 2019a, 2019b). I disagree. Take, for example, the variable of attractiveness and consider the following possibility: Danny is attracted to X more than to Y; Danny is attracted to Y more than to Z; but Danny is attracted to Z more than to X! The additivity relation breaks down; nevertheless, no one will be surprised by this case, just as no one will be astonished by the following results of several soccer games: Team A defeated Team B, Team B defeated Team C, but Team C defeated Team A!

Our responses and actions are not purely motor movements — they are saturated with conscious experiences: sensations, feelings, intentions, wishes, and desires. Nevertheless, no unit of measurement has yet been developed for conscious experience. For example, it seems ludicrous to define a measurement unit of love ($UM_{love}$), and say that Jacob loves Rachel 7.5 $UM_{love}$ more than he loves Leah. Thus, although Jacob may indeed love Rachel more than Leah, it is not possible to measure Jacob's love for Leah and say that it is $10UM_{love}$ while his love for Rachel is $17.5UM_{love}$. Similarly, Von Kries contends that, "One cannot explain what it means to say that one pain is exactly 10 times as strong as another" (cited in Michell, 1999, p. 88). Michell suggested that Von Kries did not realize that the quantity objection is connected to empirical testing (see also Marks and Algom, 1998).

In effect, I propose that the lack of scientific understanding of consciousness is the main reason why psychology, which adopted the methodology of the natural sciences, has not succeeded empirically in discovering real UMs for conscious behavior. If for consciousness one would discover UMs which are based on certain neurophysiological processes, a complete and satisfactory explanation of consciousness in terms of brain processes would be developed. However, as I have argued elsewhere (Rakover, 2018), to date there is no accepted theory that explains satisfactorily the relationship between mind and body, consciousness and brain.

*The "Unit-Equality" Criterion*

This criterion is built on a dimensional analysis. Accordingly, the combination of UMs on one side of a theory's equation must be identical to the combination of the UMs on the other side of the equation (e.g., Rakover, 1997, 2002). Consider Galileo's law, namely free fall of bodies: $S = 1/2GT^2$, where S is distance of fall, T is time of fall, and G is acceleration caused by the force of gravity. If S is measured using the meter as a unit, the expression $GT^2$ must also be measured by the meter unit. A simple calculation shows that it is: meter = (meter/time$^2$) x (time$^2$).

Does any psychological theory meet this criterion? No. Consider an overall structure of theory of psychology: behavior = f(stimuli, neurophysiological processes, cognitive processes, mental processes). Clearly the criterion is not met. Behavior (number of correct responses) is not identical to the units with which the stimulus is measured (loudness of the noise), to the physical units of the brain processes (differences of electrical potential), to the measurement units of cognitive processes (information processing), or to the measurement of mental processes (consciousness). Actually, here one has a correlation between the dependent variable (left side of the equation) and the independent variables (right side of the equation).

To solve the problem of unit-equality, one may introduce certain constants into the above equation, so that their multiplications by the independent variables will result in the required UM of the dependent variables (number of correct responses). Unfortunately, this solution will not work, since in psychology the constants are not invariable, i.e., they change over participants, time, and situations. The introduction of these constants is no more than ad hoc.

*Psychophysics*

It has been suggested that the just noticeable difference (JND) estimated in psychophysical experiments may very well be a UM of sensation (e.g., Baird and Noma, 1978; Gescheider. 1997; Marks and Algom, 1998; Stevens, 1975). The JND is estimated by considering the following question: Given a certain stimulus (e.g., light, sound, weight), what is the minimal change in this stimulus for a participant in the experiment to sense a difference? Weber was the first researcher to find that the minimal change, the difference threshold ($\Delta I$), increased in fixed relation to the intensity of the physical stimulus (I) for a given sensory dimension (an empirical generalization called Weber's law: $\Delta I/I$ = Constant). Given Weber's law, Fechner assumed that an increase in I matches the increase in the number of sensory measurement units of equal size — the subjective JND. This theoretical assumption about the sensory measurement unit led to the development of Fechner's law: sensation equals the product of a certain constant by the logarithm of I. Gescheider (1997, p. 11) writes: "… once a basic unit is established, one has only to count up units in order to specify the amount of a measured property. Thus, Fechner developed a scale of sensation magnitude by counting JNDs, starting at the absolute threshold." Given this, the following question arises: *Is* JND a UM of sensation similar to the UM of length (or weight)?

The answer is no. There is no parallel real measure of the subjective JND as there is, for example, for length: there is an equality between the theoretical UM of length and the empirical UM, i.e., the empirical measurement of length. The JND is a theoretical concept, which is expressed in several ways. First, Fechner discriminated between two kinds of psychophysics: inner psychophysics that deals with the relation between sensation and brain states, and outer psychophysics that deals with the relation between sensation and the stimulus. Fechner was interested in the unobservable inner psychophysics, and he attempted to infer it from the outer psychophysics. In short, Fechner's approach is filled with assumptions, including the central one about the subjective JND.

Second, several empirical results were not in accordance with the predictions derived from Fechner's psychophysical law. Furthermore, some other suggestions about the UM of sensation differed from Fechner's. For example, Stevens (1975) proposed that the UM of sensation is not fixed. This assumption led him to develop a new law according to which sensation is a power function of I. Stevens also introduced the direct method of magnitude estimation for constructing a ratio scale — a method that Fechner rejected (he believed that sensation should be estimated indirectly).

It should be emphasized once again that the term JND in Fechner's theory is nothing other than a hypothesis supported by the subject's responses to changes in the stimulus. In fact, this is precisely the empirical basis of psychophysics, and of psychology generally: the subject's response is a function of the stimulus, R = f(S); and if also one takes into account the organism itself, then R = f(S,O). The fact That JND depends on the individual's responses may lead to a possible inconsistency. Consider the following hypothetical experiment (inspired by the famous experiments of Libet, 1985).

Let us propose that scientists have invented an advanced brain detector that records a special brain signal that appears before a conscious decision is made. Assume further that this brain detector was used in a psychophysical experiment, the results of which showed that (a) there was a big difference between the average JND based on the brain detector (the unconscious JND) and the average JND based on the participants' reports (the conscious JND): the unconscious JND was much lower than the conscious JND; and (b) no significant correlation was found between the conscious and unconscious JNDs. Thus, the following questions can be raised: Which is the true JND, the conscious or the unconscious? Which should be used as a UM of sensation? Clearly, such questions do not arise with regard to the UM of length. It does not matter which arbitrary unit one uses to measure distance as there are simple formulas for transferring one unit to another (e.g., 1 inch = 2.54 centimeters)

From these five examples (illusion, IQ, consciousness, unit-equality, and psychophysics) one may reach two general conclusions. First, since psychology has not yet succeeded in discovering real UMs, it is difficult to express theoretical concepts such as sensation, perception, intelligence, and consciousness in an objectively measurable way. Secondly, the use of mathematics in some of these theories is liable to create inconsistencies because the theoretical concepts do not have identical real measurements as in physics.

## Discussion

The basic question addressed in this article is why psychology has not developed like physics. The study of this question led to the following observation: psychology has not developed unified theories as has occurred in physics. The explanation of this observation lies in the UMs-equivalency. Accordingly, in physics, unlike in psychology, empirical UMs were discovered that are equal to the theoretical UMs, that is, the empirical units uphold the requirements of mathematics, which constitutes the language of a physical theory. Several explanations for this observation were discussed and have been discarded as incongruous, except for UMs-equivalency. Here, I discuss in addition the following. First, I argue that in comparison to a psychological theory, the efficiency of a physical theory is much greater because of the UMs-equivalency. Second, I disqualify the following two alternatives to UMs-equivalency: psycho-reductionism and consciousness, and the generation of interval scales in psychology.

*Theory efficiency.* One reasonable explanation for the failure to develop a unified theory can be attributed to the fact that psychology has a problem in bridging the theory–observation gap, which is bridged in physics by the UMs-equivalency. It is well known that the efficiency of a theory is reduced when the connection between theoretical and observational concepts is unstable (e.g., the values of validity and reliability are decreased, e.g., Neal and Liebert, 1986; Rakover, 1990). The UMs-equivalency guarantees that in physics the theory–observation gap will be reduced, since the theoretical UMs are equivalent to the observational UMs.

Given this, one may raise the following question: Why does UMs-equivalency hold true in physics but not in psychology? My answer, which will be elaborated below, is this: given (a) that the phenomenon of consciousness has not yet been grasped by the conceptualization of the sciences, and (b) that most of human behavior is saturated with consciousness, it follows that it is difficult to develop an explanatory theory of behavior on the basis of the methodology that is used in the sciences and is adopted by psychology (see Rakover, 2018).

*Reduction.* One may propose that if psychology (consciousness) could be reduced to neurophysiological processes, then psychology would develop like a branch in the natural sciences. However, to the best of my knowledge this research program (reduction) has not yet been successful (Rakover, 1990, 2012, 2018). To clarify this issue, I shall describe briefly the classic methodology for inter-theory reduction, Nagel's (1961) model of reduction. A theory, which is called the reduced theory ($T_R$), is reduced to a more basic theory ($T_B$), when $T_R$ is deduced from $T_B$ together with certain "bridging laws," which connect the concepts of these two theories. Usually the bridging laws are conceived of as identities. For example, in the case of reducing thermodynamics to statistical mechanics, it was proposed that temperature equals the average kinetic energy. In this case, the field of statistical mechanics also offers an ontological (material) explanation for the macro concept of temperature through the micro concept of kinetic energy.

One of the most powerful arguments against psycho-neural reduction is that of "multiple realizations" (Fodor, 1974, 1998). To exemplify this argument, consider the state of pain. The "functionalism" approach proposes that a mental state can be realized by many different material states (e.g., various neurophysiological states) that fulfill the mental state's causal role in producing behavior. Thus, pain is a mental state that can be realized by material processes such as various neurophysiological processes found in a large number of organisms (humans, dogs, cats, fish, reptiles, etc.). Given this argument, it becomes impossible to reduce a psychological theory to a neurophysiological theory, because it is not possible to find a bridging law that will join the state of pain and a particular neurophysiological state.

A further argument against psycho-neural reduction is based on the requirement of "Unit-equality" (Rakover, 2002). I discussed this above and for convenience I will describe it again briefly. It is not possible to discover a psycho-neural law because this law does not fulfill the requirement of equivalence of units, namely identity of the units of measurement on either side of the theory's equation [e.g., MS=f(NS)]. Why? Because the measurement units of the psychological concepts are entirely different from the neurophysiological measurement units, and no common measuring standard can be found for them that will unite the psychological with the neurophysiological.

Furthermore, in-depth research has been done specifically on the question of whether consciousness can be explained by the neurophysiological system of the brain. A meticulous review of the literature regarding this question and other related issues have resulted in a negative answers (e.g., Rakover, 2018).

*Interval scales.* Given that in psychology the UMs appear only in theory, one can test these terms empirically through the derivation of predictions from the theory, that is, by testing whether these predictions are supported or refuted. I examine this approach by means of one example which deals with a mathematical model from which interval scales can be derived and also be supported empirically: the bisection experiment. In this experiment, a participant hears two tones, one high volume and one low volume, and is asked to produce a tone whose volume is halfway between these two tones. Based on this experimental task, a mathematical model was developed that generated an interval scale on which it was possible to scale the tones produced by the participant. That is, a good match was discovered empirically between the predictions deriving from the model and the participant's behavior. This supported the model and demonstrated that an interval scale can be constructed.

Given the above, Coombs et al. (1970, p. 25) maintained that: "The absence of a concatenation (or even bisection) operation in many areas of psychology has led to the development of measurement models of a different kind." In contrast, "Campbell argued that only extensive properties [based on a concatenation operation that corresponds to addition] can be measured on an interval scale, and since psychological attributes are intensive in nature [they are not extensive], no interval scale measurement in psychology is possible. The more recent research in measurement theory has shown, however, that the existence of an empirical concatenation is not necessary for an interval scale measurement, contrary to Campbell's views" (p. 19). Hence, one may be tempted to propose that psychological terms can be measured on an interval scale.

If this is possible, what in fact is the difference between psychology and physics? If it transpires that there is no substantial difference, it may be said that the basic idea of the present article regarding UMs is undermined. However, the answer is that despite the success of certain mathematical models in constructing interval scales, psychology is not equal in this matter to physics.

It seems that the creation of interval scales is limited to a small number of certain mathematical models. In psychology, the system of UMs-equivalency, which eliminates the theory–observation gap, does not exist. Furthermore, basic terms in psychology are not properly defined and thus have many interpretations — a situation that puts obstacles in the way of generating interval scales. As an example, consider the fundamental concepts in cognitive psychology: information and information processing. In physics and the computer sciences, these concepts are defined as exact. This is not the case in psychology, where these concepts are interpreted as content, meanings, associations, ways of coding, and hypothetical storage and retrieval (e.g., Palmer and Kimchi, 1986).

Another example concerns the fact that the concepts of psychology are multi-dimensional, and are interpretable from different viewpoints. In contrast, in physics complex concepts are composed of several one-dimensional components. It is hard to break down psychological concepts into their one-dimensional components. Furthermore, in psychology, because the concepts are multi-dimensional, in many cases the transitive relationship is broken (as in the above-mentioned example concerning attraction between individuals).

## *Conclusions and Summary*

The current paper proposes that the failure to develop a unified theory is a major factor that differentiates psychology from physics. One possible explanation for this failure is UMs-equivalency, which helps bridge the theory–observation gap in physics but not in psychology. Alternative explanations such as reductionism and consciousness, as well as models that generate interval scales, were additionally examined; however, they were found to be poor explanations. Hence, UMs-equivalency appears to be the best answer to the question surrounding the developmental gap between these two fields. Furthermore, it appears that UMs-equivalency constitutes the basis for a solution to Wigner's problem: the amazing success of mathematics in describing and explaining nature.

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