Running Head: MULTIPLICATION

The Unappreciated Theoretical Implications of Multiplication Versus Addition

David Trafimow

New Mexico State University

Direct correspondence to:

David Trafimow
Department of Psychology, MSC 3452
New Mexico State University
P. O. Box 30001
Las Cruces, NM 88003-8001
dtrafimo@nmsu.edu

Abstract

The thesis to be explored is that multiplication is more than repeated addition, with strong implications for theorizing in psychology. Multiplicative thinking implies the potential for more precise and creative theorizing. Moreover, multiplicative thinking facilitates cumulative knowledge acquisition and decreased fragmentation. Although this thesis admittedly seems commonsensically unlikely, the present goal is to argue contrarily with common sense. Specific examples illustrate how psychology researchers can exploit the potential of multiplicative thinking to improve theory, with improved unification in psychological science.

Key Words: multiplicative thinking; additive thinking; measurement; unification; construct

Wordcount: 6,628

To move from basic elementary school operations, such as multiplication and addition, to theoretical implications for researchers, may seem a ridiculously large leap. The present thesis that there is something valuable to be learned by considering multiplication versus addition is prima facie unreasonable. Moreover, if multiplication is simply repeated addition, then drawing a major distinction between them, with vital implications for theorizing in psychology, is again unreasonable.[1] The seeming perverseness of the present thesis renders pointless a typical introduction, so let us proceed directly to two issues in the following major section. Is multiplication merely repeated addition? Secondly, if not, so what?

Multiplication versus addition and new constructs out of old ones

Consider the following: $2 \cdot 3 = 6$. Or, using repeated addition, we could say: $2 + 2 + 2 = 6$. If we add 2 enough times, we will get the correct answer, thereby supporting that multiplication is merely repeated addition.

However, multiplication is more than repeated addition. To use a simple physics example, momentum p is the product of mass m and velocity v: $p = mv$. In contrast, there is no way to add mass and velocity. Although the multiplication is easy to perform to arrive at a new construct—momentum—the addition is impossible to perform.

And we arrive at a preliminary, but crucial point. It is possible to create new theoretical entities out of old theoretical entities using multiplication, but this is impossible using addition. Therefore, a theorist who does not use multiplication is nontrivially limited relative to a theorist who does use multiplication. This is not to say that multiplication is required to invent new theoretical entities; this claim would go too far. However, the ability of multiplication to generate

[1] The present work treats division as a type of multiplication (multiplying by a reciprocal) and subtraction as a type of addition (adding a negative value).

new entities out of old entities can be considered a tool for creative theoretical thinking. Having the tool is better than not having it.

The benefits of multiplication for unification

A standard and well-taken complaint in psychology is that there are too many theories, thereby rendering the field fragmented as opposed to the impressive degree of unification that can be observed in other sciences, such as physics. The complaint has been made often in the history of psychology, and continues to be made (e.g., Borgstede & Eggert, 2023; Cronbach, 1957; Cronbach 1975; Ellemers, 2013; Howell et al., 2014; Meehl, 1978; Henriques, 2013; Green, 2015; Fiedler, 2017; Eronen & Bringmann, 2021; Trafimow & Fiedler 2024). Might multiplication be relevant?

We have already seen a momentum example, where multiplying mass and velocity gives momentum. A basic concept is mass, and another concept is velocity, which is distance divided by time. Thus, there are three basic concepts: mass, distance, and time. These figure into many physics' concepts.

Consider kinetic energy: $e = \frac{1}{2}mv^2$. There are again three basic concepts, mass, distance and time. Or consider impulse, which is change in momentum. But we have already seen that momentum is based on mass, distance, and time, so impulse is based on these three concepts too. Or consider power. Expressed as a watt (W), the equation in units is as follows: $1W = 1kg \cdot m^2 \cdot s^{-3}$; there is a mass unit (kilograms), a distance unit (meters), and a time unit (seconds). Or consider force, expressed as a Newton: $1N = 1kg \cdot \frac{m}{s^2}$. Again, there is a mass unit, a distance unit, and a time unit. We might also consider the notion of work, expressed as a joule: $1J = 1kg \cdot m^2 \cdot s^{-2}$. And we have yet another physics concept based on the three basic concepts of mass, distance, and time.

Even in the 20th and 21st centuries, many physics concepts remain based on mass, distance and time. Consider Einstein's energy: $e = mc^2$. The letter c refers to the velocity of light, so again we are back to mass, distance, and time. Moving to momentum at near light speeds, the equation provided earlier is no longer sufficient, and it is necessary to introduce a concept called gamma γ that accounts for the relative velocities of the object of interest and light, so that $p = \gamma mv$. Still, there remain three basic concepts: mass, distance, and time.

Moving to the quantum level, consider the momentum of a photon, which can be determined using Planck's constant h: $p = h/\lambda$ or Planck's constant divided by the wavelength of the photon. Rearranging the equation implies the following: $h = p\lambda$, so that Planck's constant again depends on mass, distance, and time, as figured into p, and wavelength λ is a distance concept, so that even at the quantum level, we remain with mass, distance, and time.

It is possible to continue for many pages about how physicists have used multiplicative thinking to form new concepts out of mass, distance, and time, but the foregoing is sufficient illustration. As the same basic concepts permeate throughout various new concepts that creative physicists have formulated across centuries, no wonder physics seems a particularly unified science. And all this is based, in no small part, on the ability to use multiplicative thinking to create new concepts out of old ones!

Other sciences

Although the admirable simplicity of physics theories renders physics especially suitable for illustrating the power of multiplication, other sciences also have benefited. Consider the ideal gas law in chemistry where pressure P is the product of amount of substance n, a constant R, and temperature T, divided by volume V: $P = \frac{nRT}{V}$. Thus, a new entity, pressure, is created out of old entities. In biology, the solute potential of a solution Ψ_S is the product of ionization constant i,

molar concentration C, pressure constant R, temperature T, and -1: $\Psi_S = -iCRT$. Thus, again, a new entity is created out of preexisting ones. The creation of new entities, as products of old ones, is a strong force for unification because a few basic entities remain crucial even as new entities continue to be created. In psychology, it is exceedingly rare for researchers to exploit multiplication to create new entities out of old ones. Without a core set of concepts upon which to build, it is no wonder that psychology is so fragmented. When new theoretical entities come out of the left field because there is no way to create them from old entities, fragmentation is tantamount to inevitable, the current state of much of psychology.

Multiple regression

There are many psychological examples of researchers depending on multiple regression or related methods to aid their theorizing. Standard operating procedure includes using several independent variables to predict (or postdict) a dependent variable. Often, the result provides grist for theorizing. The researcher proposes a theory whereby all the statistically significant predictors, using more generalized language than the exact measures used, are alleged to cause the dependent variable. Aside from the issue of whether such a paradigm justifies causal conclusions, the key point for the present argument is that the paradigm promotes additive as opposed to multiplicative thinking. To see why, consider a standard regression form: $Y = b_0 + b_1X_1 + \cdots + b_kX_k$. Each b_kX_k is added to each other b_kX_k, thereby constituting a strong push in the direction of additive thinking with little opportunity to see how different entities could be multiplied to form new ones.

Of course, there are psychology exceptions where theories are based heavily on multiplication. But these are few and far between. And even then, researchers rarely exploit the potential of multiplication to form new entities out of old ones. For example, consider a classic

theory about how groups combine individual preferences into a group decision, termed social decision schemes theory (e.g., Davis, 1973). Although the theory is heavy on multiplicative thinking, the result is that probabilities pertaining to individual preferences are translated into probabilities of group preferences, but without the formation of new concepts. Despite the limitation, the social decision schemes theory is arguably the most important theory in the history of the social psychology of groups. For another example, this time from perceptual psychology, consider signal detection theory (Swets et al., 1961; see Wickens, 2002 for a review). The theory features multiplicative thinking, but the units are standard deviation units, and so again there are no new concepts formed out of more basic ones. Like the social decision schemes theory, signal detection theory is an extremely important theory in the history of the psychology of perception, despite the limitation. However, it is interesting to speculate about how much more valuable these theories would be if their multiplicative thinking included new concepts formed out of old ones, as has occurred frequently in the history of other sciences.

In summary, psychological research paradigms tend to push additive thinking, not multiplicative thinking. Of course, there are exceptions featuring multiplicative thinking, but even these exceptions, though providing positive examples of psychological successes, are nevertheless limited because of the lack of new concepts formed out of old ones.

Measurement

From an empirical standpoint, exploiting the ability of multiplicative thinking to form new concepts out of old ones arguably requires measurement capabilities. Consider, again, that momentum is the product of mass and velocity. Suppose a researcher used a slippery surface to investigate how objects of various masses, propelled with various velocities, would impact the velocities of other objects of various masses. Based on the conservation of momentum, a

prediction would be that the sum of the products of masses and velocities of the totality of objects in the system before impact would approximately equal that after objects impact each other.[2] However, to test this prediction, it is necessary to be able to measure the masses of all the objects and their velocities, both before and after impacts. This seems reasonably straightforward in physics, but there are complications when we move to psychology that have been discussed extensively elsewhere.[3]

Physics measures either have clear zero points (e.g., zero mass, zero distance, zero time elapsed) or can be thusly converted (e.g., a Centigrade temperature without a clear zero point can be converted to a Kelvin temperature relative to absolute zero). Thus, multiplication is sensible. However, in psychology, it is not clear what zero neuroticism, zero attitude, zero associative strength, and so on would mean. To be sure, many experiments in psychology use response time, where there is a sensible zero point, but even here it is not clear how reaction time maps onto psychological concepts of interest. For example, a cognitive researcher might be interested in the associative strength with which activating "bread" causes "butter" to activate too. It is not clear how the time it takes to perform, say, a lexical decision task with respect to "butter," after being primed with "bread," indicates the associative strength. It is one thing to show that response times are shorter in a primed than unprimed condition, but it is quite another thing to make convincing pronouncements about the exact amount of the associative strength involved.

Thus, psychological measures are inappropriate for multiplicative thinking that works so well for physics. Psychological measures either lack zero points or, in the rare cases where zero

[2] Of course, assuming the ideal case of no conversion of energy to heat, object deformation, and so on.
[3] Michell (2000) provided an excellent and well-cited review of critical literature with a strong argument concerning how psychological measurement falls short.

points are sensible (such as response time), it is still unclear how the measure maps onto a concept in a theory.

One might consider interval measures sufficient for meaningful multiplication, but they are not. Consider temperature where, in Kelvin, 5 x 2 = 10; that is, 10 degrees Kelvin is 5 times as hot as 2 degrees Kelvin. In Centigrade, where zero does not denote absolute zero, it is no longer the case that 10 degrees Centigrade is 5 times as hot as 2 degrees Centigrade. Multiplication can be highly deceiving at the interval level where it is not at the ratio level of measurement.

The problems that plague psychological measurement pose a dilemma. On the one hand, we have seen the undeniable value of being able to multiply concepts—such as mass, distance, and time—to form new concepts (e.g., momentum, energy, etc.). On the other hand, psychological measurement is not at the level where multiplication is valid. Thus, the present author is painted into a corner. Why argue for multiplicative thinking when we do not have the measurement technology for proper tests of implications?

But we can still pretend

Let us consider again that momentum is the product of mass and velocity, but this time pretending that there is no ratio level way to measure mass or velocity or momentum. Commonsense suggests that without this ability, there is no way to determine if the totality of momenta of all objects in a system, before and after objects impact each other, remains constant. Therefore, in this scenario, the concept of momentum provides no benefit.

However, the conclusion may be too pessimistic, as directional predictions could still be made as in the social sciences. For example, an experimenter could set up a system where an object impacts a second object and then make a prediction about whether momentum is

transferred to a third object. Even without quantification, the experimenter could still make a qualitative prediction that momentum would be transferred down the line from the first object, through the second object, to the third object. To be sure, the gain would be much less than in actual physics history; but "less" is far from the same as "no gain whatsoever."

This example suggests a way out for social scientists. The present author was painted into a corner by, on the one hand, arguing for multiplicative thinking but, on the other hand, acknowledging that measurement technology in the social sciences is insufficient. However, the momentum example shows it is possible to gain the ability to make directional predictions from the results of multiplicative thinking that do not depend on ratio level measurement. Thus, the present proposal is that social scientists pretend, perhaps during the context of discovery phase of research, as if we had ratio level measurements of all our constructs and proceed to form new constructs out of them via multiplicative thinking. Social scientists then can proceed to make directional predictions as they do now.

The recommendation may seem impossible to implement. To show that it is not, consider two related examples.

Example 1: Evaluative propensity

Possibly the most famous attitude theory in the history of social psychology is the theory of reasoned action (e.g., Ajzen & Fishbein, 1980; Fishbein, 1980; Fishbein & Ajzen, 1975), that has since then become more complex (Fishbein & Ajzen, 2010). For present purposes, it is sufficient to consider a portion of the simple version, that attitudes (evaluations of behavior) cause behavioral intentions (what people intend to do or not do), and that behavioral intentions cause actual behavior. On the other hand, Fazio et al. (e.g., 1982; 1989) suggested that a crucial factor in the extent to which attitudes cause behavioral intentions or behavior is whether they are

accessible. Even until the present, there has been a remarkable lack of cross-fertilization between the Fishbein tradition and the Fazio tradition.

Nevertheless, such cross-fertilization is possible using a multiplicative process. To move in this direction, let us define a new concept termed *evaluative propensity* (EP) and suggest the following equation: $EP = k \cdot EV \cdot EA$ where k is a constant, EV is evaluation valence, and EA is evaluation accessibility.

A potential counter is that even if one's evaluation of a behavior is accessible, it might not have much effect if the valence is weak. Therefore, perhaps the evaluation valence should be squared, as follows: $EP = k \cdot EV^2 \cdot EA$.

Of course, given measurement difficulties in the social sciences, there is no way to have ratio level measures of all the variables, and so there is no way to test the equations as a physicist would and as would be ideal. However, imagine a simple experiment where the researcher orthogonally manipulates evaluation valence (near zero or positive or highly positive) and evaluation accessibility (evaluation primed or not), with a measure of behavioral propensity involving participants clicking on a continuum. Both formulations predict an interaction, but the nature of the interaction differs. According to $EP = k \cdot EV \cdot EA$, the positive (or highly positive) cells should be larger than the additive implications of the two factors. Furthermore, however, in the primed condition of the evaluation accessibility factor, the means of the three conditions of the evaluation valence factor should follow a linear trend. In contrast, according to $EP = k \cdot EV^2 \cdot EA$, although there also should be an interaction, the trend in the primed condition should be nonlinear. This is testable despite the nontrivial measurement limitations.

In summary, by thinking multiplicatively, it is possible to unify two separate literatures with a new concept—behavioral propensity—that is explicitly and clearly linked to evaluation

valence and evaluation accessibility. Nor is the new concept of behavioral propensity the same thing as the common 'behavioral intention.' Behavioral intention is measured on a scale from -3 to +3, with labels of 'extremely' (+3 or -3), 'quite' (+2 or -2), 'slightly' (+1 or -1), or neutral (0) (e.g., Ajzen & Fishbein, 1980, Appendix A). Some problems with the notion of behavioral intention are (a) neither work by Fishbein and colleagues nor by Fazio and colleagues links accessibility to behavioral intention so there is no way to know what to expect in our thought experiment; (b) in the Fishbein scheme, behavioral intention is an additive result of two other constructs, via multiple regression, not a multiplicative result, and so it is not created out of more basic constructs whereas evaluative propensity *is* created out of more basic constructs; and (c) from a measurement perspective, the behavioral intention measure is categorical rather than continuous whereas the behavioral propensity measure is continuous. Therefore, we have seen that despite vastly imperfect measurements in psychology, the multiplicative approach can be an effective tool for creating new constructs out of old ones and for unifying previously distinct research traditions too.

Example 2:

Much literature shows that both cognition and affect influence what people intend to do or do (Abelson et al., 1982; Breckler, 1984; Breckler &Wiggins, 1989; Crites et al., 1994; Trafimow & Sheeran, 1998; Trafimow et al., 2004). A typical methodology might be for researchers to enter cognition and affect separately into a multiple regression equation that produces regression weights for each and the multiple correlation coefficient for predicting behavioral intentions. For most behaviors, both cognition and affect matter. The present multiplicative thinking suggests the possibility of multiplying cognition (c) and affect (a) to create a new variable called *behavioral momentum* (BM), analogous to momentum in physics

that is the product of mass and velocity. In addition, given the large literature emphasizing the outsized importance of affect, it is possible to create a new variable termed *behavioral energy* (BE), analogous to kinetic energy in physics that features mass and velocity squared. Equations for behavioral momentum and behavioral energy are bullet-listed below.

- $BM = lca$, where l is a constant.
- $BE = mca^2$, where m is a constant.

How might these be useful?

One problem that plagues the psychological literature is that although behavioral intention is sometimes a good predictor of behavior, it often is not (e.g., see Armitage & Conner, 2001 for a meta-analytic review). One explanation is that the behavior might not be under the person's control, but the present thinking suggests additional explanations. For example, perhaps behavioral intention only seems to work well—some of the time—because it is correlated with either behavioral momentum or behavioral energy, and it is behavioral momentum or behavioral energy that really cause behaviors. One way to address this would be to develop measures of behavioral momentum and behavioral energy and see how well they compete with behavioral intentions to predict a wide range of behaviors. This can be done even with the limitation that the measures of behavioral momentum and behavioral energy doubtless will not be at the ratio level.

Another way would be to have multiple levels of cognitive manipulation and of an affect manipulation and determine the effect on behavioral momentum and behavioral energy. According to the behavioral momentum construct, there should be an interaction between the cognitive and affective manipulations. Furthermore, the means in the different levels of affect manipulation should show a linear trend within each level of the cognitive manipulation, and vice versa. In contrast, there should not be linearity with respect to behavioral energy because of

the specification that affect is squared. Although none of these tests are as good as those physicists—with their ratio level measures—would conduct, they would likely instigate progress and show the value of multiplicative thinking to create new constructs out of old ones.

Not to deny addition

The present recommendation to include multiplicative thinking in the toolbox for creative theoretical thinking is not meant to deny that addition can be useful too. For instance, consider threat theory, where multiple kinds of threat cause prejudice against outgroups (Stephan & Stephan, 2000). Although the original theory specifies four types of threat, it is not difficult to imagine expanding these to any number of threats. Suppose we defined a generalized threat as the product of the different threat types $(T_1, T_2, \dots, T_n)$: $Threat = T_1 T_2 \dots T_n$.

A potential problem with this equation is an implication that even if a person is feeling highly threatened with respect to some of the threats, if any of $T_1, T_2, \dots, T_n$ equals 0, then $Threat = 0$. A way out might be to depart from multiplicative thinking thus far supported and consider additive thinking. For example, we might imagine that the different kinds of threat nevertheless have a similarity—they all can be considered as sharing a "threat unit," and so because they share a common unit, addition is permissible in this special case. Thus, we might amend the equation as follows: $Threat = T_1 + T_2 + \cdots + T_n = \sum T_i$.

We might even have competing ideas. A possibility is to assume that threat is the result of an averaging rather than summative process: $Threat = \frac{\sum T_i}{n}$. These could be tested against each other. One way would be to present participants with, say, two strong threats in experimental and control conditions, but with the addition of a weak third threat in the experimental condition, only. According to the summative process, the addition of a third threat, despite it being a weak one, should nevertheless increase feelings of threat (or prejudice). In contrast, according to an

averaging process, because the third threat is weak, it should decrease the average and thereby decrease feelings of threat (or prejudice) relative to the control condition. Thus, even with limited measurement capabilities, it is nevertheless possible to test $Threat = \sum T_i$ versus $Threat = \frac{\sum T_i}{n}$.

Unification

Psychology is replete with integrative papers. These might be integrative reviews, such as can be found in journals such as *Psychological Review*. Or they might be meta-analytic reviews, such as might be found in journals such as *Psychological Bulletin*. A limitation of such work is that, as the late, great, science philosopher Wesley Salmon (1998) informed us, integration is different from unification. It is one thing to discuss different ideas in the same article, pointing out the ways they are interrelated (integration), it is quite another thing to find a new principle that unifies them.

To provide an example of the possibilities, consider a potential unification of the threat (or any) literature on prejudice or discrimination with the attitude literature, a unification that has never been attempted but is obviously desirable.

A reason why people care about threat theory, or any theory of prejudice, is an underlying assumption that prejudice causes discriminatory behavior. If prejudice were shown to have no behavioral consequences, whatsoever, then interest in the voluminous prejudice literature would disappear quickly. A problem is that prejudice is only weakly correlated with discriminatory behavior. However, if the goal is to understand and predict, and hopefully even demonstrate causality, pertaining to discriminatory behavior, then a seemingly obvious step is to bring in more general literature pertaining to behavior. However, this obvious step has not been accomplished, possibly because of a lack of clarity about how to go about it. To move in this

direction, let us review the definitional equations from earlier, this time numbering them for easy referral.

1) $EP = k \cdot EV^2 \cdot EA$.
2) $BM = lca$.
3) $BE = mca^2$.
4) $Threat = (T_1 + T_2 + \cdots + T_n)$.

Let us begin with threat. It is not difficult to imagine a person who feels threatened by an outgroup and experiences cognitions and affects towards that outgroup. We might say that threat causes cognition and affect to increase in the direction towards greater behavioral momentum and behavioral energy against the outgroup, consistent with Equations 2 and 3. However, these increases need not indicate an increased probability of performing discriminatory behavior against the outgroup. There is the possibility of being sued or fired for discrimination, or at least being socially ostracized, any of which might decrease or even reverse the direction of evaluative valence. Moreover, the threat might or might not be accessible at the opportune time to perform the discriminatory behavior, thereby displaying the relevance of evaluative accessibility. More generally, there is the issue of evaluative potential given in Equation 1, that is a function of both evaluative valence and evaluative accessibility.

Using causal language, we might postulate that $Threat$ causes BM and BE, either of which causes EV and potentially EA too. Moving on, EV and EA cause EP. In turn, EP causes discriminatory behavior. Or we might avoid causal language, and use a larger equation, but that will involve the creation of more variables.

Although BE is obviously relevant to EV, it is not the only factor as there may be good reasons for the latter to be low or even negative even if BE is large and positive. We might

postulate two kinds of BE, one of which is positive and one of which is negative, so there is BE_{pos} and BE_{neg}, each of which is a function of positive cognitions and affects or negative cognitions and affects, respectively. Alternatively, it might be that negative affects matter much more than positive ones, it only makes sense to square affect when it is negative, so that Equation 3 needs to be modified, as follows.

3*) $BE_{pos} = mca$

3**) $BE_{neg} = mca^2$

Assuming BE_{pos} and BE_{neg} are in similar units though different in direction, perhaps they can be summed up to obtain BE: $BE = BE_{pos} + BE_{neg}$. In turn, EV might be a function of BE; for example, perhaps EV is half (or some other dividend) of BE. In that case, avoiding causal language, we might postulate something like Equation 5, depending on exactly which assumptions are favored:

5) $EP = k \cdot EV^2 \cdot EA = k\left(\frac{BE_{pos}+BE_{neg}}{2}\right)^2 EA = k\left(\frac{mca(pos)+mca^2(neg)}{2}\right)^2 EA.$

Can these ideas be tested? Consider the bifurcation of behavioral energy into positive and negative. In terms of cognitive processes, the assumption would be that the positive cognitions and affects would be considered together to form BE_{pos}, and the negative ones would be considered together to form BE_{neg}. Thus, imagine that participants are asked to write down their thoughts. The bifurcation implies that the positive items should be cognitively associated with each other, and the negative ones cognitively associated with each other, but with few associations between positive and negative items. Consequently, the order in which people write down the items should be diagnostic. If the items are highly clustered by whether they are positive or negative, then that supports the bifurcation notion whereas if there is little clustering

the bifurcation notion is contradicted. More generally, the new ideas multiplicative thinking imply are testable even with measurement limitations.

Potential straw people

There are many ways to misinterpret the present thesis. A few of these are discussed below.

Ideas formed through multiplicative thinking are always true

As is hopefully obvious by now, this is not part of the present thesis. According to the present thesis, ideas formed through multiplicative thinking might or might not be true. The value is in providing a way towards creating new theoretical ideas that otherwise might be unlikely to come to mind and towards making psychology more cumulative and less fragmented. The present author has no way to know whether all, or even any, of the foregoing equations are true, but that was not the point. The point was to show how psychology researchers can exploit the potential of multiplicative thinking for creative theorizing, and the foregoing equations are merely examples.

Relatedly, there is no way to know how any of the proposed empirical projects would come out, if performed. However, an advantage of performing them would be (a) if they came out in strong support of one or more of the foregoing equations, this would be an obvious gain for psychological science and (b) if not, there likely still would be gain because researchers would have a better idea of how to propose equations that perform well empirically. More generally, all the examples point to a different way for psychology researchers to think creatively and in a unificatory manner; they do not point to a specific theory for which it is appropriate yet to make assertions about truth.

The present author supports ordinal or interval level measures

My argument is quite different. Ratio level measures are better, in which case psychology research might eventually evolve to the state of rivaling the physical sciences in the precision with which they test theories. However, with the qualifications discussed earlier, the social sciences simply lack measures at that level. There is little point in pining for what we do not have. Although hopeful that eventually psychology researchers will one day figure out how to have interval level measures of psychological constructs, until that time, it is necessary to do without. The examples show how, in principle, progress can be made even without ratio level measures. Put another way, the present thesis is not that present measurement technology is sufficient; it is not. But being stuck with less-than-optimal measures need not hamstring us completely. It is possible to make progress anyhow, and the imaginative use of multiplicative thinking to create new variables out of old ones provides an avenue towards accomplishing that progress.

Qualitative homogeneity

It is usually a mistake to assume that the same mental structures and processes work in the same qualitative way for everyone, with only quantitative differences (e.g., Richters, 2021; Iso-Ahola, 2024). One might be inclined to assume that the present proposal is assuming qualitative homogeneity, as a physicist might assume that all electrons work the same way though they might have different positions, momenta, etc. On the contrary, the present proposal explicitly eschews qualitative homogeneity as the criticisms leveled against it are strong and well-argued. However, denying qualitative homogeneity does not imply that there is no point in having theoretical constructs. Theoretical constructs, and theorized connections between them,

might apply to a substantial number of people or might apply statistically even if not to everyone (Iso-Ahola, 2024).

Perhaps the key is to avoid hubris. It is not difficult to imagine a scenario where a researcher uses the multiplicative thinking proposed here to invent new constructs that lead to new empirical hypotheses confirmed by experiments. The researcher might easily be carried away by the string of empirical victories and conclude that the system of research really does apply to everyone in the same qualitative way, with only quantitative differences. The present subsection might be considered a warning not to get so carried away. Some degree of researcher modesty is in order, but such modesty should not be allowed to deter researchers from the creative use of multiplicative thinking to create new constructs. Some degree of researcher confidence is in order too.

All psychological processes are multiplicative

There is no such claim here. It is more likely that some are and some are not. In fact, a *threat* example was presented earlier where an additive process makes more sense than a multiplicative one. Unfortunately, psychological science has not yet advanced to the point where it is reasonable to make a blanket statement about whether psychological processes are multiplicative. What can be said, however, and it bears many repetitions, is that psychology is a highly fragmented science and multiplicative thinking provides a potential remedy. Even if future researchers find that putative multiplicative processes are not multiplicative after all, the constructs created via multiplicative thinking may nevertheless help advance the field.

Multiplicative theoretical thinking should replace all other theoretical thinking

There are many ways to discover theories, and the multiplicative thinking proposed here is only one of them. As mentioned earlier, multiplicative thinking can be considered a tool or

procedure in the service of creative theorizing, but not as constituting all tools or procedures. A more accurate summarization of the present thesis is that a toolbox with multiplicative thinking in it is better than a toolbox sans multiplicative thinking. Or to speak more generally, a toolbox with more tools is usually better than a toolbox with fewer tools.

Conclusion

The present thesis commenced with the notion that multiplication is different from addition because there is no way to add two or more different variables, but they can be multiplied to form a new variable. Other sciences, especially physics, have taken maximal advantage of the ability to multiply old variables to form new ones, thereby creating a science that is much more unified than psychology. Although multiplicative thinking is not the only factor contributing to physics being impressively unified, the relevance is undeniable.

A major fly in the ointment is the relative lack of ratio level measures in psychology. Although the desirability of employing multiplicative thinking to create new variables out of old ones is clear, not having ratio level measures could be argued to contraindicate the thesis that psychology researchers should move in the recommended direction.

The way out is to pretend that we have ratio level measures and mentally perform the recommended multiplicative thinking anyhow. Several examples show how this can be done in psychology despite important measurement limitations that prevent tests analogous to those in physics. Examples were provided to demonstrate how psychologists can engage in the recommended type of reasoning, and how the products of such reasoning can be tested, including tests of opposing predictions based on alternative theoretical possibilities. Hence, psychology researchers can avail themselves of much of the creative and unifying benefits of multiplicative thinking, despite limitations inherent to the field. Many have complained about psychology

theories being too vague, not promoting cumulative knowledge, and the field being highly fragmented. Therefore, with other approaches to theorizing having been found wanting, there is little to lose by trying out the present recommendation of using multiplicative thinking to create new theoretical constructs out of old ones.

References

Abelson, R. P., Kinder, D. R., Peters, M. D., & Fiske, S. T. (1982). Affective and semantic components in political person perception. *Journal of Personality and Social Psychology, 42*(4), 619–630.

Ajzen, I., & Fishbein, M. (1980). Understanding attitudes and predicting social behavior. Englewood Cliffs, NJ: Prentice-Hall.

Armitage, C. J., Conner, M. (2001). Efficacy of the theory of planned behaviour: a meta-analytic review. *British Journal of Social Psychology*, *40*(4):471-99. doi: 10.1348/014466601164939.

Borgstede, M., & Eggert, F. (2023). Squaring the circle: From latent variables to theory-based measurement. *Theory & Psychology*, *33*(1), 118–137. https://doi.org/10.1177/09593543221127985

Breckler, S. J. (1984). Empirical validation of affect, behavior, and cognition as distinct components of attitude. *Journal of Personality and Social Psychology, 47*(6), 1191–1205. https://doi.org/10.1037/0022-3514.47.6.1191

Breckler, S. J., &Wiggins, E. C. (1989). Affect versus evaluation in the structure of attitudes. *Journal of Experimental Social Psychology, 25*(3), 253–271. https://doi.org/10.1016/0022-1031(89)90022-X

Crites, S. L., Fabrigar, L. R., & Petty, R. E. (1994). Measuring the affective and cognitive properties of attitudes: Conceptual and methodological issues. *Personality and Social Psychology Bulletin, 20*(6), 619–634. https://doi.org/10.1177/0146167294206001

Cronbach, L. J. (1957). The two disciplines of scientific psychology. *American Psychologist, 12*(11), 671–684. https://doi.org/10.1037/h0043943

Cronbach, L. J. (1975). Beyond the two disciplines of scientific psychology. *American Psychologist, 30*(2), 116–127. https://doi.org/10.1037/h0076829

Davis, J. H. (1973). Group decision and social interaction: A theory of social decision schemes. *Psychological Review, 80*(2), 97–125. https://doi.org/10.1037/h0033951

Ellemers, N. (2013). Connecting the dots: Mobilizing theory to reveal the big picture in social psychology (and why we should do this). *European Journal of Social Psychology*, *43*(1), 1-8. https://doi.org/10.1002/ejsp.1932

Fazio, R. H., Chen, J., McDonel, E. C., & Sherman, S. J. (1982). Attitude accessibility, attitude-behavior consistency, and the strength of the object-evaluation association. *Journal of Experimental Social Psychology*, *18*(4), 339-357. https://doi.org/10.1016/0022-1031(82)90058-0

Fazio, R. H., Powell, M. C., & Williams, C. J. (1989). The role of attitude accessibility in the attitude-to-behavior process. *Journal of Consumer Research*, *16*(3), 280–288. http://www.jstor.org/stable/2489509

Fiedler, K. (2017). What constitutes strong psychological science? The (neglected) role of diagnosticity and a priori theorizing. *Perspectives on Psychological Science, 12*(1), 46–61. https://doi.org/10.1177/1745691616654458

Fishbein, M. (1980). Theory of reasoned action: Some applications and implications. In H. Howe, & M. Page (Eds.), *Nebraska Symposium on Motivation* (Vol. 1979) (pp. 65–116). Lincoln: University of Nebraska Press.

Fishbein, M., & Ajzen, I. (1975). *Belief, attitude, intention and behavior: An introduction to theory and research*. Reading, MA: Addison-Wesley.

Fishbein, M., & Ajzen, I. (2010). *Predicting and changing behavior: The reasoned action*

approach. New York, NY: Psychology Press (Taylor & Francis).

Green, C. D. (2015). Why Psychology Isn't Unified, and Probably Never Will Be. *Review of General Psychology*, *19*(3), 207-214. https://doi.org/10.1037/gpr0000051

Henriques, G. (2013). Evolving from Methodological to Conceptual Unification. *Review of General Psychology*, *17*(2), 168-173. https://doi.org/10.1037/a0032929

Howell, J. L., Collisson, B., & King, K. M. (2014). Physics envy: Psychologists' perceptions of psychology and agreement about core concepts. *Teaching of Psychology*, *41*(4), 330-334. doi: 10.1177/0098628314549705

Iso-Ahola S. E. (2024). Science of psychological phenomena and their testing. *The American Psychologist*, 10.1037/amp0001362. Advance online publication. https://doi.org/10.1037/amp0001362

Meehl, P. E. (1967). Theory-testing in psychology and physics: A methodological paradox. *Philosophy of Science*, *34*(2), 103–115. doi: 10.1086/288135

Meehl, P. E. (1978). Theoretical risks and tabular asterisks: Sir Karl, Sir Ronald, and the slow progress of soft psychology. *Journal of Consulting and Clinical Psychology*, 46(4), 806–834. https://doi.org/10.1037/0022-006X.46.4.806

Meehl, P. E. (1990). Why summaries of research on psychological theories are often uninterpretable. *Psychological Reports*, *66*(1), 195–244. https://doi.org/10.2466/PR0.66.1.195-244

Michell, J. (2000). Normal Science, Pathological Science and Psychometrics. *Theory & Psychology*, *10*(5), 639-667. https://doi.org/10.1177/0959354300105004

Richters, J. E. (2021). Incredible utility: The lost causes and causal debris of psychological

science. *Basic and Applied Social Psychology*, *43*(6), 366–405. https://doi.org/10.1080/01973533.2021.1979003

Salmon, W. C. (1998). *Causality and explanation*. Oxford, UK: Oxford University Press.

Stephan, W. G.; Stephan, C. W. (2000). An integrated threat theory of prejudice. In Oskamp, S. (Ed.) *Reducing Prejudice and Discrimination* (pp. 23–45). Mahwah, New Jersey: Lawrence Erlbaum Associates.

Swets, J. A., Tanner, W. P., Jr., & Birdsall, T. G. (1961). Decision processes in perception. *Psychological Review*, *68*(5), 301–340. doi:10.1037/h0040547

Trafimow, D., & Fiedler, K. (2024). An exploration of physics envy with implications for desiderata of psychology theories. *American Psychologist.* Advance online publication. https://doi.org/10.1037/amp0001416

Trafimow, D., & Sheeran, P. (1998). Some tests of the distinction between cognitive and affective beliefs. *Journal of Experimental Social Psychology*, *34*(4), 378-397. https://doi.org/10.1006/jesp.1998.1356

Trafimow, D., Sheeran, P., Lombardo, B., Finlay, K. A., Brown, J., & Armitage, C. J. (2004). Affective and cognitive control of persons and behaviors. *British Journal of Social Psychology*, *43*(2), 207-224. doi: 10.1348/0144666041501642

Wickens, Thomas D., (2002) *Elementary Signal Detection Theory*. New York: Oxford University Press.