The Combined Gas Law and a Rasch Reading Law

Many physical laws are expressed as universal conditionals among variable triplets. Newton's second law, for example, formalizes the relationship between mass and acceleration when holding force constant (i.e., conditioning on) as F = MA. Similarly, the combined gas law specifies the relationship between volume and temperature conditioning on pressure. After transformation (e.g., log pressure + log volume - log temperature = constant, given a frame of reference specified by the number of molecules), each of these laws can be abstracted to a common form (a + b - c = constant). Note that these laws permit causal claims expressible as counterfactual conditionals. If we have 20 Liters of a gas at 2000°K under 20 atmospheres of pressure and we cool the gas to 1000°K, we will observe a decrease in the pressure to 10 atmospheres.

The value of such laws may lie more in the explicit causal organization of key constructs than in accuracy of prediction in the real world. Cartwright (1983) made a useful distinction between "the tidy and simple mathematical equations of abstract theory, and the intricate and messy descriptions, in either words or formulae, which express our knowledge of what happens in real systems made of real materials" (p. 128). This distinction led Cartwright to the view that "fundamental equations do not govern objects in reality; they govern only objects in models [i.e., idealizations]" (p. 129).

The human sciences, for the most part, lack laws such as those stated above and consequently lack causal stories that are universal in application: "Lacking a 'complete (causal) theory' of what influences what, and how much, we simply cannot compute expected numerical changes in stochastic dependencies when moving from one population or setting to another" (Meehl, 1978, p. 814, emphasis in original). In this note we build on the abstracted formalism derived above and imagine the form of a Rasch Reading Law.

Table 1
Comprehension Rates for Readers of Different Ability with Texts of the Same Readability
or How Reader Ability and Comprehension Rate Relate Under Constant Text Readability

ReaderAbility	Sports Illustrated Readability	Comprehension Rate
500L	1000L	25%
750L	1000L	50%
1000L	1000L	75%

1250L 1500L	1000L 1000L	90% 96%

Contemporary reading theory recognizes three related constructs: reader ability (a stable attribute of persons), text readability (a stable attribute of text), and comprehension (the rate at which a particular reader makes meaning from a particular text). As a result of 25 years of ongoing research, we know that comprehension is a function of the difference between reader ability and text readability (Stenner & Burdick, 1997). Table 1 illustrates the relationship between reader ability and comprehension rate with text readability held constant. With increasing reader ability, the model forecasts increasing comprehension rate conditioning on text readability. This description of the relationship between reader, text, and comprehension echoes the description of the combined gas law (Table 2).

Table 2 How Temperature and Pressure Relate Under Constant Volume		
Temperature Volume Pressure		
2000°K 1000°K 500°K 250°K 125°K	20 Liters 20 Liters 20 Liters 20 Liters 20 Liters	20.0 atm 10.0 atm 5.0 atm 2.5 atm 1.25 atm

In fact, logit transformed comprehension rate + text measure - reader measure = the constant 1.1 (given a frame of reference that specifies 75% comprehension whenever text measure = reader measure). Therefore, a + b - c = constant holds as the common abstracted form of both the combined gas law and the Rasch Reading Law as well as many other physical laws. Below are several causal corollaries of the Rasch Reading Law.

(1) For any reader (and thus for all readers), an increase in text measure causes a decrease in comprehension.

(2) For any reader (and thus for all readers), a decrease in text measure causes an increase in comprehension.

(3) For any text (and thus for all texts), an increase in reader ability causes an increase in comprehension.

(4) For any text (and thus for all texts), a decrease in reader ability causes a decrease in comprehension.

Corollaries such as those above are consequences of the highly abstracted a + b - c = constant, holding in a domain of enquiry. Tables 1 and 2 concretize this abstraction for the gas law and reading law. The Rasch model, in concert with a substantive theory, is a powerful tool for discovering and testing the adequacy of such formulations. Note, however, that the fact that data fit a Rasch model says nothing about causality. Rasch models are associational rather than causal. Substantive theory provides the causal story for the variation detected by a measurement procedure. Specification equations formalize these causal stories and allow precise predictions.

These causal explanations have truth built into them. When I infer from an effect to a cause, I am asking what made the effect occur, what brought it about. No explanation of that sort explains at all unless it does present a cause, and in accepting such an explanation, I am accepting not only that it explains in the sense of organizing and making plain, but also that it presents me with a cause. (Cartwright, 1983, p. 91)

If one of our children cannot summarize what he just read in his fifth grade science text, we explain this by pointing out that he is a 580L reader and the text book is at 830L. The equation that models comprehension rate as a function of the difference between reader measure and text measure produces an expected comprehension rate below 50%. We hypothesize that the child's failure to produce a good summary has a cause: low comprehension. Suppose that we go to the Web and find a 600L article on the same science topic, and the child reads the article and produces a coherent summary of the text. We conclude that, indeed, low comprehension was the cause of poor summarization. Manipulating the reader-text match caused an increase in comprehension, which in turn caused a change in summary performance. Clearly I am inferring from effect to probable cause. Note that this explanation is unintelligible "without the direct implication that there are [readers, texts and comprehension rates]" (Cartwright, 1983, p. 92).

We wonder how many other variable triplets in the human sciences can be abstracted to the form a + b - c = constant. The implications of this kind of law-making for construct validity should be evident (see Borsboom, 2005).

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