Total Duration Weighted by Frequency: A Meaningful Measure?

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In their article, Powell and Dickie wrestle with several important problems in measurement. We were impressed by their opening moves and their obvious good training and style. But, unfortunately, they never scored a takedown and rarely appeared to be at an advantage.

Powell and Dickie began with the important point that, though measures of both rate and total duration are used in behavior analysis, they are not well integrated empirically or conceptually. Empirically, it is effortful and awkward to present both measures, and they frequently show inconsistent relations, raising questions about what is being measured. Conceptually, agreement is no better. For example, Skinner (1938) claimed that operant rate was the critical measure, while Premack (1965) argued that duration was the measure of choice.

To resolve this problem, Powell and Dickie combined rate and duration measures in a single common metric of Kinetic output (K_o). As is the case for any response measure, it is important to establish why Kinetic output should be used. Beyond the justification provided by tradition, response measures are typically defended on three grounds: First, the measure is conceptually reasonable, that is, it makes contact with important concepts and their relations. Second, the measure is useful in testing and answering the questions in which we are interested. Third, the measure is well behaved. Unfortunately, the measure of Kinetic output does not seem to satisfy any of these criteria.

Is Kinetic Output Conceptually Reasonable?

Recall that a measure is "conceptually reasonable" when it makes contact with important conceptual and theoretical issues. Thus, response rate and duration

measures are used because they map directly on to the concept of reinforcement. Reinforcement supposedly "strengthens" behavior, an interpretation compatible with the increase in frequency or duration of responding as a function of reinforcement.

Though we agree with Powell and Dickie that this mapping needs to be improved, their alternative measure of Kinetic output is not clearly connected to any concepts. Powell and Dickie claimed to have "derived" the Kinetic output equation via dimensional analysis, but an equation is derived when it follows from prior conceptual and/or mathematical assumptions. The authors do not present their prior assumptions or any other theoretical justification for the arrangement of the terms or the logarithmic transformation. It appears they simply picked a combination of variables and a transformation they liked, or a combination that was dimensionless.

As a result, though Kinetic output does vary with levels of important independent variables, such as frequency and duration of reward, this variability does not appear interpretable. No justification comes to mind for why a fundamental measure of operant responding should be a product of the average duration of reward multiplied by the square of its frequency.

Can the Measure of Kinetic Output Answer Interesting Questions?

In the absence of any relation to a conceptual system, it is difficult to know what questions Kinetic output can be used to answer. It is, however, possible to ask whether Kinetic output relates in an interpretable fashion to existing data and paradigms. Unfortunately, the K_o measure appears to answer several choice questions inappropriately.

Consider a rat eating pellets, and assume it takes a rat 10 seconds to consume .1 grams of food. Further assume that the session is 300 seconds long. If the rat consumes four .1 gram pellets, K_o equals -0.27 (i.e., $\log([4 \times 40]/300)$). If the rat consumes two .4 gram pellets, K_o is also equal to -0.27 (i.e., $\log([2 \times 80]/300)$). Using the K_o metric, the two situations are equivalent. Yet it seems highly unlikely that a rat would choose .4 gram of food over .8 gram of food (see de Villers, 1977).

Consider the matching law (Baum, 1974; Herrnstein, 1970). According to the matching law, the ratio of responses should match the ratio of reinforcers. This relationship has been confirmed empirically in a number of situations (Baum, 1979). If we follow the authors' suggestion that reinforcement is equivalent to time allocation (i.e., Baum & Rachlin, 1969) and assume a constant reinforcer duration, the Kinetic output measure predicts that the ratio of responses will match the ratio of the squares of the rates of food delivery for the two schedules. Such a result would entail "overmatching," a rare result (Baum, 1979).

Finally, consider Timberlake and Allison's (1974) response deprivation theory. According to response deprivation, "reinforcement" effects occur when the ratio of instrumental requirement to contingent payoff is greater than during baseline. The Kinetic output measure predicts reinforcement effects when the ratio of the instrumental requirement to the contingent payoff equals the ratio of the baselines. The former prediction has been empirically supported. The latter has not.

Is the Kinetic Output Measure Well Behaved?

The authors argued that the Kinetic output measure is better behaved than rate or duration measures because K_o was less variable in a test. But their test was questionable for three reasons. First, they performed a log transformation of the Kinetic output measure, but not of the rate and duration measures. A major attribute of logs is to compress divergent large

scores and, thus, decrease variability if the initial distribution of scores is asymmetrical. The authors didn't justify why the K_o measure was transformed, nor why the rate and duration measures were not.

A second potential confounding factor was that, to the extent that frequency and total duration are negatively correlated, multiplication will reduce the variability relative to the individual measures. There is some indication of such a negative correlation in the reported data. In the "Attending Behavior" measure, there was a moderate negative correlation between rate and duration ($r = -.32$), and the variability for these subjects was relatively low (mean $V = 35.4$). Whether such negative correlations produce the major part of the reduction in variability cannot be determined in the absence of the relevant individual data.

A third issue is that the authors examined the variability of K_o for two behaviors, but only a single condition. It would have been much better to evaluate the extent to which the variability of a metric changes over different values of a number of independent variables.

Conclusion: Where Do We Go From Here?

An underlying theme of Powell and Dickie is that a single response measure is "better" than multiple response measures. The authors offer two reasons why this is true: It is confusing to present multiple measures, and the measures do not always covary in predictable ways. These reasons alone cannot justify the use of a single response measure.

Nature is rarely as parsimonious as we would like. Behavior is complexly determined, and there is no a priori reason to believe that it can better be described by an arbitrary combination of two reasonable measures than by one of the measures alone. At the least, other combinations should be investigated.

There are a number of procedures that might be used to explore the relation between rate and duration. Empirically, researchers could pit the two measures against each other as predictors, deter-

mine the circumstances (independent variable values) under which each is the more appropriate, and examine the relative contribution of the two measures using a form of multiple regression analysis. Conceptually, theorists could analyze the common features of the different measures or tie them to specific theories of how responses are controlled. For example, Timberlake and Allison (1974) showed that duration and rate could be treated the same in predicting the circumstances of reinforcement.

In summary, the problem of describing the relationship between rate and duration of operant responding is both important and difficult. However, the guess that operant responding will be described better by the weighting of total response duration by frequency of occurrence does not seem psychologically, analytically, or empirically justified. This is not to say that the Kinetic output measure cannot be justified, but the authors have not managed it in this article. It seems more likely that alternative measures will arise in the old fashioned way—through novel theories, careful analysis, and clever tests.

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