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SINUOSITY AND THE AFFECT GRID: A METHOD FOR ADJUSTING REPEATED MOOD SCORES[1]

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Summary.—Sinuosity is a measure of how much a travelled pathway deviates from a straight line. In this paper, sinuosity is applied to the measurement of mood. The Affect Grid is a mood scale that requires participants to place a mark on a 9 × 9 grid to indicate their current mood. The grid has two dimensions: pleasure–displeasure (horizontal) and arousal–sleepiness (vertical). In studies where repeated measurements are required, some participants may exaggerate their mood shifts due to faulty interpretation of the scale or a feeling of social obligation to the experimenter. A new equation is proposed, based on the sinuosity measure in hydrology, a measure of the meandering of rivers. The equation takes into account an individual's presumed tendency to exaggerate and meander to correct the score and reduce outliers. The usefulness of the equation is demonstrated by applying it to Affect Grid data from another study.

"Mood" refers to a "background emotional state [that] rises and dissipates slowly" (Beedie, Terry, & Lane, 2005, p. 871; cf. Zelenski & Larsen, 2000). For as long as psychologists have studied mood, they have devised methods for measuring it (see Larsen & Fredrickson, 1999). One of the many mood measures that have been introduced is the Affect Grid (Fig. 1), introduced by Russell, Weiss, and Mendelsohn (1989) as a simple, one-item, undisguised measure of mood. The Affect Grid is theoretically based on the circumplex model of affect (Russell, 1980), whereupon a person's emotional state can be mapped onto a two dimensional Cartesian plane where the x-axis represents a pleasure–displeasure continuum and the y-axis represents an arousal–sleepiness continuum. Early studies of mood ratings (e.g., see Russell, 1980, pp. 1162-1163) showed that these two dimensions tend to be orthogonal. Russell (1980) supported the two-dimensional model by examining the spatial clustering of emotion-related words by asking participants to sort the words into groups according to similarity (for a critique of the circumplex model, see Remington, Fabrigar, & Visser, 2000). Killgore (1998) reviewed the effectiveness of the Affect Grid by correlating it with three similar measures of mood and affect (cf. Russell, *et al.*, 1989, pp. 497-498). In 284 participants tested on all four scales, Killgore found the correlations were moderate, concluding that the

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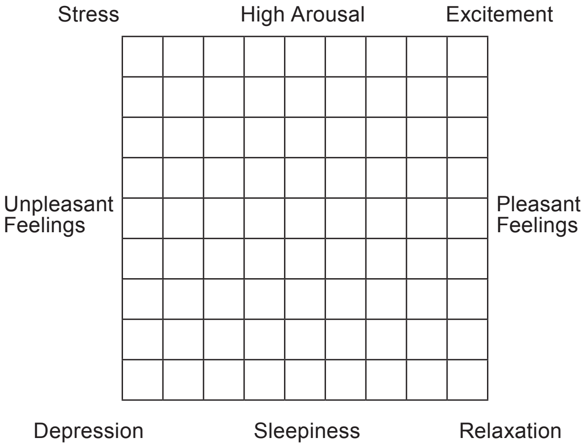

FIG. 1. The Affect Grid

Affect Grid was valuable as a quick and easy mood measure, even though it afforded less detail than other measures.

As shown in Fig. 1, the Affect Grid is in the form of a 9 × 9 grid; the respondent is instructed to mark an X in the one square that indicates how he is feeling at that moment (Russell, *et al.*, 1989; cf. diagrams in Russell, 1980, and Remington, *et al.*, 2000). The participant must think in the two dimensions simultaneously. Horizontally, the scale ranges from "unpleasant" (negative) to "pleasant" (positive). Vertically, the scale ranges from "sleepiness" to "high arousal." Fig. 2 provides examples on the meaning of different responses. When using the Affect Grid, responses generate two separate scores ranging from 1 to 9. This can be expressed as positive coordinates. For example, if a person feels completely neutral, then they should mark the middle square (score = 5, 5). There are four additional labels (stress, excitement, depression, relaxation), which represent extremes located at the corners of the grid. These extra labels "do not form extra dimensions, but help to define the quadrants of the grid" (Russell, 1980, p. 1163). In the participant instructions (see the Appendix in Russell, *et al.*, 1989), more subtle examples are given. For example, if a person feels "mildly surprised" (Fig. 2), then she should mark an X slightly left and above the centre point (score = 7, 7).

The Affect Grid has been used by many researchers in a variety of topics (for examples, see Campbell, Chew, & Scratchley, 1991; Eich, Macauley, & Ryan, 1994; Rotton & Shats, 1996; Roesch, 1999; Deaver, Miltenberger, Smyth, Meidinger, & Crosby, 2003; Mead & Ball, 2007), sometimes with slight modifications (e.g., changing labels, altering the scale

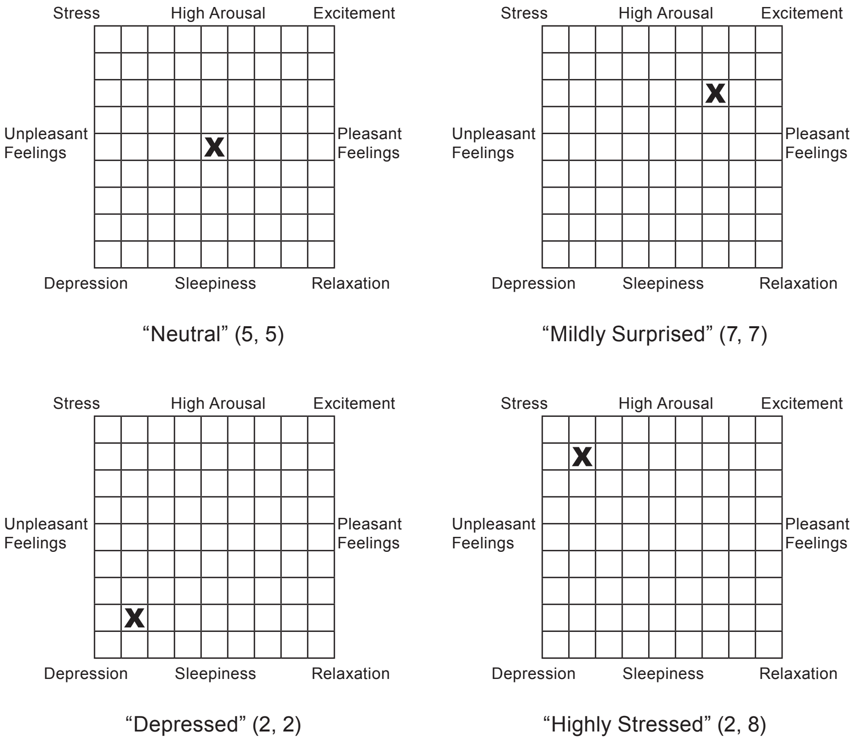

Fig. 2. Examples of Affect Grid responses

numbers, etc.). Although the grid was primarily designed to record single events, some of the studies cited above required that participants fill out the Affect Grid multiple times. For example, Campbell, *et al*. (1991), in their study of mood and self-esteem, asked participants to fill out the Affect Grid five times per day for two weeks. Similarly, Eich, *et al*. (1994), in their study of mood-dependent memory, asked participants to indicate their mood on the Affect Grid repeatedly after listening to various pieces of music. Also, Deaver, *et al*. (2003), in their study of mood and binge eating, asked participants to fill out the Affect Grid before, during, and after meals. Also, a recent study by the current authors (Russell, Gobet, & Whitehouse, 2011) also required that each participant use the Affect Grid multiple times (a total of four). Here, after the data were collected, a problem became apparent. Some participants habitually chose more extreme options than others. Fig. 3 illustrates the problem using actual data from that study. Both grids show a sequence of four ratings (originally made on separate grids). As shown, one participant "travelled further" than the

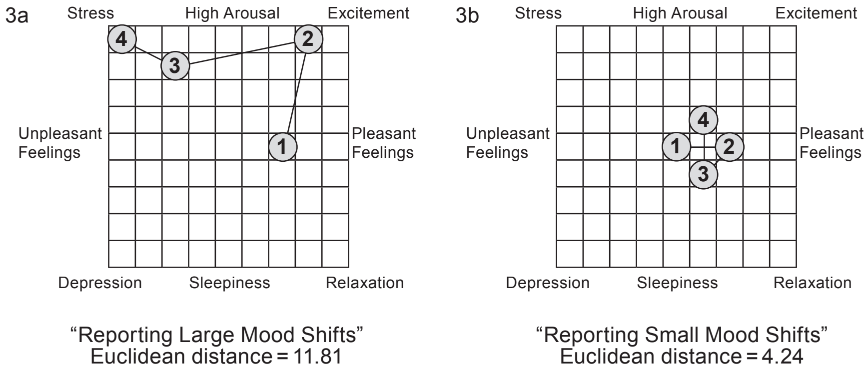

FIG. 3. Two examples of sequential mood reporting differs between individuals on Euclidean distance

other, i.e., his scores changed more over the measurements. The "distances travelled" can be measured as Euclidean distance (Fig. 3).

There are three possible explanations of this phenomenon. (a) Some people have higher mood variability than others and reported genuine mood swings (cf. Campbell, *et al.*, 1991). (b) Participants recognised the experiment as a mood study, and hence, felt some social obligation to over-report mood shifts. (c) Participants differentially construed the magnitude of the scale, and therefore some regarded a movement of one square as an insignificant shift, whereas others regarded it as a large shift. The final two possibilities are examples of what psychologists call "response set" (Cronbach, 1950), an example of individual test-taking habits which interfere with the validity of the test. In this paper, a methodology is proposed for correcting Affect Grid mood shifts based on *overall movement* and tendency to *meander*. "Meandering" is defined as directed spatial behaviour that deviates from the shortest path between Point A and Point B. The method proposed in this paper is useable for studies where mood was measured multiple times, but where a researcher is interested in evaluating individual steps in the chain.

METHOD

The purpose of this procedure was to render an assessment of changes from an earlier (s_i) to a later score (s_j) on the Affect Grid. In accordance with the scoring system of Russell, *et al.* (1989), the horizontal and vertical dimensions were analyzed separately. For example, in Fig. 3a, one might want to assess the horizontal score between Point 1 and Point 2 ($1 \rightarrow 2$). It can be seen that $s_i = 6$ and $s_j = 8$. The difference is therefore $s_j - s_i = 2$. In Fig. 3b, the same difference ($s_j - s_i = 2$) is obtained for the same step. As shown, the participant in Fig. 3a appeared to be introducing two "response set" confounds: (a) excessive meandering on the 9 × 9 grid and (b) excessive distance travelled. In order to correct for response set, the following equation is proposed (Eq. 1). It is a correction to the difference score (s_j- s_i), which incorporates a measure of sinuosity.

$$s_{mod} = \left(\frac{s_j - s_i}{\text{CL} + 1/\text{AL} + 1} \right) \Big/ \text{CL (if } CL > 0) \qquad [1]$$

The denominator (CL + 1/AL + 1) in Eq. [1] was adapted from the "sinuosity" measure, a geographical measure that quantifies how much a river is meandering (Mueller, 1968). It is based on two variables. The first is air length (AL), which refers to the shortest distance between the beginning and end of the measured river. This is a straight line regardless of how much the river might meander. The other variable is channel length (CL), which refers to the actual length of the river. If the river is completely straight, then AL and CL will be equal. The basic sinuosity measure is CL divided by AL (CL/AL). A measure of 1 indicates a completely straight path, and a measure larger than 1 indicates some sinuosity (meandering). For the Affect Grid, the above sinuosity measure must be modified because individuals could theoretically respond in the same square in the last measure as in the first (AL = 0), so that the denominator would have been zero. Thus, adding 1 to both numerator and denominator (CL + 1/AL + 1) prevents such a singularity. This modified sinuosity score reduces the magnitude of the numerator over the denominator (e.g., 3/2 becomes 4/3, etc.).

To obtain sinuosity on the plane, one could use *Euclidean distance* in a two-dimensional space. Euclidean distance, in its standard measurement, is represented by the following equation:

$$\text{d (p, q)} = \sqrt{\sum_{i=1}^{n} (p_i - q_i)^2} \; . \qquad [2]$$

As shown in Eq. [2], Euclidean distance involves the measurement of a line between two coordinate points (p, q) on a Cartesian plane. Because the measure is in two dimensions, only p1 minus q1 and p2 minus q2 are calculated. For example, in Fig. 3, one can calculate the distances in the first step (1 → 2), second step (2 → 3), and third step (3 → 4). In Fig. 3a, these distances are 4.472, 5.099, and 2.236, respectively. In Fig. 3b, these distances are 2.000, 1.414, and 2.000, respectively. To calculate CL, these three segments are added. As shown, the CL is 11.807 in Fig. 3a, and 5.414 in Fig. 3b. To calculate AL, the Euclidean distance between Points 1 and

4 is calculated, ignoring the points in between. In Fig. 3a, the AL is 6.403. In Fig. 3b, the AL is 1.414. Using the modified measure (CL + 1/AL + 1), the scores are 1.730 in Fig. 3a and 2.657 in Fig. 3b. In Eq. [1], the sinuosity is divided by CL because the sinuosity score is independent of actual line length (this was obvious when applied to Fig. 3). Thus, the score is reduced in inverse proportion to the total amount of distance travelled. In effect, Eq. [2] is a double transform, reducing first for sinuosity, and then for distance. The final step in applying Eq. [2] is to decide on which segment ($s_i - s_j$) to transform. This is entirely the choice of the investigator.

Suppose that one wishes to transform only the first step ($1 \rightarrow 2$) on the horizontal dimension. As noted above, the movement would be recorded as +2 for each participant prior to transformation. After the transformation (Eq. 2), the new score would be +0.098 for the first participant (Fig. 3a) and +0.217 for the second participant (Fig. 3b). The underlying assumption is that moving two squares was more meaningful for the second participant than the first, because the second participant generally tended to move around less.

Application

Russell, *et al*. (2011) studied the effect of mood on the ability to transfer learned rules from one puzzle game to another. Their methods and results will be partially summarized here as an example of the application of the sinuosity transform. Russell, *et al.* (2011) was part of a psychology of religion project involving the relevance of mood to the learning and application of ritual-like tasks. There were two independent variables (expertise and mood), each with two levels. Here, the sinuosity transform will be applied to a subsample of 42 participants (who had been randomly assigned to each condition and paid £10GBP for their participation). In expert conditions, participants learned to play the Tower of Hanoi game (Simon, 1975). They were subsequently asked to play a second game—a Tower of Hanoi *isomorph*—which had identical rules to the Tower of Hanoi game, but with a radically different presentation (cf. Kotovsky, Hayes, & Simon, 1985). The participants were not told that the isomorph had the same rules as the Tower of Hanoi game. In the non-expert conditions, the participants played a different game prior to playing the isomorph task. The mood conditions were either euphoric (happy) or dysphoric (unhappy). The participants' mood was manipulated in advance of the games by having them watch an ostensibly unrelated 10-minute video clip that was taken either from a comedy (euphoric condition) or harrowing drama (dysphoric condition). In this study, the Affect Grid was used four times: (a) prior to the video clip, (b) after the video clip, (c) after the first game, and (d) after the second game. The mood shift of interest was *only* between the first and second measure (i.e., before and after watching the video clip), because it was a manipulation check for the mood induction. The manipulation check was not significant for the vertical dimension. For the horizontal dimension, there was an apparent difference (see Fig. 4a), but it was not significant.

The lack of significant difference was possibly attributable to response set (Cronbach, 1950). The sinuosity transform was not used in the Russell, *et al*. (2011) study, but it will be used here to transform the horizontal score. Fig. 4 shows the horizontal score before and after applying the equation. The y-axis shows the difference between the first horizontal mood measure and the second horizontal mood measure. A positive score indicates an improvement in mood. A negative score indicates a worsening of mood. The x-axis shows whether the video was euphoric or dysphoric. Prior to transformation (Fig. 4a), the mean difference after the euphoric video was 0.00 ($SD = 2.52$) and the mean difference after the dysphoric video was −1.00 ($SD = 2.14$). There was no significant difference between conditions ($t_{39} = 1.36$, $p = .18$; Cohen's $d = 0.43$). After transformation (Fig. 4b), the mean difference after the euphoric video was 0.55 ($SD = 0.12$) and the mean difference after the dysphoric video was −0.48 ($SD = 0.09$). There was a significant difference between conditions ($t_{39} = 3.07$, $p = .004$; Cohen's $d = 9.71$).

To clarify how the transform has improved the scoring, a further analysis was conducted using the same data as above (Russell, *et al*., 2011). The sinuosity transform was run on all conceivable single segments within that study (i.e., the first numerator is different each time, but the other elements stay the same). There were six altogether, comprising segments [1 → 2], [2 → 3], and [3 → 4] on both horizontal and vertical dimensions (these segments represent the difference between the first and second

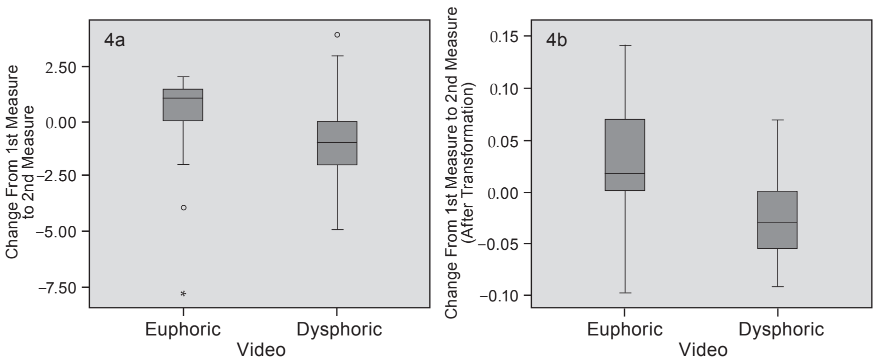

Fig. 4. Mood manipulation data before and after transformation (horizontal dimension) based on previous study ($n = 42$). Note the differences in the y-axis range.

measure, second and third, etc.). Each of these segments is construed as a data point in the analysis below. As shown in Eq. [1], the transformation has two stages, the first being a correction for meandering, and the second a correction for varying distance. Fig. 5 displays the two-stage results for all possible segments ($n=6$) using five descriptive statistics (means, standard deviations, ranges, skewness, and kurtosis). The three stages on the x-axis are pre-transform (raw scores), mid-transform (after the first transformation), and post-transform (after both transforms). Using a Kruskal-Wallis H test across the three stages, there were significant differences between stages for range [$\chi^2(2, N=18)=15.17, p=.001$] and standard deviation [$\chi^2(2, N=18)=15.16, p=.001$], showing an apparent reduction after the first transform and then again after the second transform. There were no differences among stages for mean [$\chi^2(2, N=18)=0.89, p=.64$], skewness [$\chi^2(2, N=18)=0.22, p=.90$], or kurtosis [$\chi^2(2, N=18)=0.98, p=.61$).

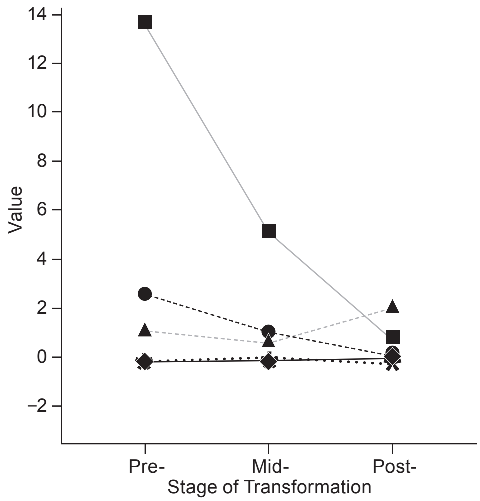

FIG. 5. Transformations in descriptive statistics before, during, and after sinuosity transformation. Range (■); Mean (◆); Standard deviation (●); Skewness (✱); Kurtosis (▲).

DISCUSSION

A simple and flexible new equation was proposed to correct for response set distortion (Cronbach, 1950) in using the Affect Grid (Russell, *et al.*, 1989). The new equation incorporated the sinuosity measure (Mueller, 1968), used in surface-water hydrology to measure the meandering of rivers, based on the assumption that some participants exaggerated their mood shifts either because of a desire to please the experimenter, or else because they misperceived the importance of the increments in the scale. This potential problem had been mentioned multiple times by previous researchers who used the Affect Grid (e.g., Deaver, *et al.*, 2003, p. 596), but there has been no standard methodology for correcting the scores. The equation simultaneously corrects for excessive "distance travelled" (magnitude of change in scores over multiple measurements) and excessive "meandering" around the grid (changes in response over multiple measurements). The equation was tested on actual Affect Grid data (Russell, *et al.*, 2011); the transformation altered the reported difference between the two conditions ("euphoric" and "dysphoric"). In the next analysis, it was shown that the mechanism behind this improvement entailed successive reductions in range and standard deviation, but no significant shifts in mean, skewness, or kurtosis. It is true that the data from Russell, *et al.* (2011) are from a small sample in a single study. Future applications of the sinuosity transform can make assessments of larger data sets. The value of the sinuosity transform is that it directly addresses the "meandering" of scores over multiple measurements.

Emerson and Stoto (1983) outline the various reasons for data transformation. Among the many reasons cited, one is relevant here: transforming for stable spread, i.e., equalizing the spread between different data sets. Excessive meandering and distance contribute to outliers in the distributions. The sinuosity transform dampens the influence of those outliers. Of course, use of the sinuosity transform is not mandatory, but is an additional tool for users of the Affect Grid. As mentioned earlier, excessive meandering can be attributed to at least three causes (true variability, social obligation, undervaluing the intervals). It is possible that some people are inherently moodier and that they are recording their mood shifts accurately. However, it is unlikely that every participant has an identical construal of the intervals in the scale. Also, it is unlikely that every participant feels an identical extent of obligation to the experimenter. The transform is meant to mitigate against the latter two variables (social obligation, differential understanding of intervals) whilst preserving the effect of mood variability. It can be used in future studies where the Affect Grid is used for repeated measurements, to correct for differences in how people report their mood shifts.

The sinuosity transform might have wider applicability beyond the Affect Grid. It could be applied to any visually based task involving a grid or for studies of spatial behaviour (e.g., Mackett, Gong, Kitazawa, & Paskins, 2007). Another novel application might be for questionnaires that have multiple questions rated on the same scale. The transform can be n-dimensional (imagine a participant filling out the same multi-item questionnaire repeatedly, allowing analysis within and between individual test sessions). All that is required for adapting the sinuosity measure are multiple steps and two orthogonal response dimensions.

It should be noted that sinuosity might be quite useful in psychology, but the word "sinuosity" itself is rarely used. Some examples of its application are in studies of spatial movement in animals (e.g., Sanuy & Bovet, 1997) and humans (e.g., Mackett, *et al.*, 2007), analyses of methodological distortion in sensory magnitude estimation by individuals (Teghtsoonian, Teghtsoonian, & Baird, 1995), and as a variable in studies of haptic distance estimation (Lederman, Klatzky, & Barber, 1985). Other studies use the word "meandering" (similar but not synonymous to the sinuosity measure). For example, Miles, Karpinska, Lumsden, and Macrae (2010) apply the word to describe daydreams in an experiment about the relation between mental time travel and spatial direction. In this context, it becomes more difficult to operationally define "meandering" because it is outside the context of a spatial study. Instead, meandering refers to a kind of conceptual *free association* (lacking a pre-planned logical pathway between the first and final thoughts of the daydreaming sequence). This non-spatial definition of "meandering" might justifiably be utilized in the study of emotion. A longstanding issue in emotion and mood research is the relationship between *trait mood* (a person's typical patterns of emotion over the long term) and *state mood* (temporary periods of mood, which may be situational; Magnusson, 1976; Williams, 1981; Zelenski & Larsen, 2000). In the short term, the Affect Grid measures a state mood; but if the measurements continue long enough, the Affect Grid could be capturing trait-based tendencies (cf. Zelenski & Larsen, 2000). Indeed, long-term studies may provide interesting data on "meandering," comparing short-term fluctuations (state mood) versus more stable long-term patterns (trait mood). Quantitative distinctions between long-term and short-term mood changes should emerge from such a long-term analysis.

The sinuosity transform (as a corrective procedure) is completely agnostic toward the issue of distinguishing between true mood variability and response set confounds. The Affect Grid may measure genuine fluctuations and some people may have more extreme mood shifts than others. Yet, this explanation should not be presumed any more than the other possibilities (response set, social obligation). This question touches on validity (Hood, 2009): does a measurement tool allow us to make an assertion that data are actually caused by the phenomenon that it was designed to measure, assuming that the defined phenomenon even exists in the first place? In philosophy, the debate is about whether validity is a property of the test itself, or a judgement made by a scientist who views the data (Hood, 2009). In psychology, the validity question can be addressed empirically by comparing different scales measuring the same variables in the same individuals. A psychologist who wishes to find the "true" mood variability of participants could make parallel evaluations using different scales (cf. Zelenski & Larsen, 2000). Furthermore, additional testing would be needed to tease apart real mood variability from social obligation and response set. In the absence of such parallel analyses, the sinuosity transform is the next-best option. Ultimately, it is a statistical procedure, not a theory-based manipulation.

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