Research Article

MEASUREMENT OF STRESS: Scaling the Magnitudes of Life Changes

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Abstract—*This paper evaluates models and measurements of the stress induced by life changes to determine whether a single scale can explain several different phenomena, including judgments of "ratios" and "differences" as well as "combinations." Judgments of "ratios" and "differences" were found to be approximately monotonically related, suggesting that these judgments should not be taken at face value, but instead that the same comparison operation governs both tasks. Judgments of "combinations" of stressful events were not simply the sums of their separate events; instead, they showed two systematic departures from additivity. First, the effect of a given event was less when it was the least stressful event in a combination than when it was the most, as if the most stressful event carries extra configural weight. Second, each additional stressor had diminishing marginal effect on the overall judgment. All three sets of data could be explained with a single scale using the theory that "ratios" and "differences" are both governed by subtraction and that "combination" judgments are a configurally weighted combination of the same scale values. This unified scale of stress seems preferable to the previous scale that was based on magnitude estimation.*

INTRODUCTION

Holmes and Rahe (1967) asked subjects to estimate the social readjustment induced by life changes. The scale that they generated has become an important instrument for the quantification of stress and it has been used in many studies of health and stress. It has achieved the distinction of being reproduced in virtually every new introductory psychology book. It also makes for convenient discussion at cocktail parties, because one can answer the question "how are you?" with a numerical response.

Some examples of the Holmes and Rahe (1967) scale are listed below:

Event	Value
Death of spouse	100
Jail term	63
Fired at work	47
Death of a close friend	37
Child leaving home	29
Change in eating habits	15
Vacation	13

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This scale has been used to study the correlation between stress and health. The sum of life changes in a certain interval can be correlated with health changes following that interval. Although such correlations may or may not be due to causal effects of stress on health, the predictive possibilities alone stimulate great interest in the measures. These scales and empirical correlations have been discussed from different viewpoints by a number of authors (Cleary, 1981; Cohen & Williamson, 1991; Cox, 1985; Grant, Sweetwood, Gerst, & Yager, 1978; Holmes & Masuda, 1974; Kamarck & Jennings, 1991; Lei & Skinner, 1980; Paykel, 1983; Paykel, Prusoff & Uhlenhuth, 1971; Rowlison & Felner, 1988; Zimmerman, 1983).

The focus of the present research is not on the health correlates of the events, but on more basic questions concerning the measurement properties of the scale. The numbers assigned to the events in Holmes and Rahe (1967) were obtained using magnitude estimation, a method which yields values that are nonlinearly related to measures based on other methods. For example, magnitude estimations are nonlinearly related to scale values that reproduce the rank order of judgments of "ratios" and "differences" between stimuli (Birnbaum, 1978, 1982).[1] The Holmes and Rahe scale should therefore be interpreted with caution, until its measurement properties have been demonstrated.

To illustrate the concept of a scale of measurement, consider the consequences of monotonic transformation of the values listed for the events. For example, suppose person A has had the following life changes: Vacation, Change in eating habits, and Child leaving home. Suppose person B has had the following life changes: Death of close friend. According to the Holmes and Rahe scale, the total stress for person A is 57, which is more than person B, who has a score of 37. However, if the numbers were squared before adding, person A would have a total of 1,235, which now would be less than the corresponding value of 1,369 for person B. This example illustrates that the rank order of combinations (the rank order of stress of the people) can change when the values are monotonically transformed. Similarly, subtracting 13 from all the values would also reverse the rank order of persons A and B. In order to compute the combine stress of several events so that the total stress will be rank invariant, we desire a ratio scale of subjective value (Krantz, Luce, Suppes, & Tversky, 1971).

In the additive model, it is assumed that the effect of any stressor should be independent of the events and stresses al-

1. Quotation marks are used to distinguish judgments of "ratios," "differences," and "combinations" from numerical or theoretical ratios, differences, and totals. These distinctions are needed because "ratio" judgments, for example, might not fit a ratio model.

ready experienced by the individual (N.H. Anderson, 1974; T. Anderson & Birnbaum, 1976; Krantz et al., 1971). In this example, Fired at work (or any other event) should produce as much stress when added to individual A as it would when added to B. Intuitively, however, such independence assumptions seem implausible. As Ben Franklin remarked, "People who have nothing to worry about, worry about nothing." Beyond intuition, there is evidence in other judgment domains that the additive model needs revision (Birnbaum, 1982).

The purpose of this paper is to investigate three intertwined problems: scaling the stress of life changes; testing models of judgments of "ratios," "differences," and "combinations" of stress; and exploring whether or not scales defined by these models converge. Model testing and measurement go hand in hand, because models can be tested by asking whether measurements can be constructed to reproduce the data (Anderson, 1974; Birnbaum, 1974b; Krantz et al., 1971). Scale convergence is analogous to the idea of converging operations. Investigations of scale convergence ask whether a single measurement scale can be used in a system of theories to account for several empirical phenomena (Birnbaum, 1974a, 1990).

"Ratio" and "Difference" Scaling

Birnbaum (1978, 1980, 1982, 1990) concluded that for a number of continua, judgments of "ratios" and "differences" are monotonically related, consistent with the theory that subjects compare stimuli by subtraction, despite the instructions. This one-operation theory can be written as follows:

$$R_{ij} = J_R(s_j - s_i); \tag{1}$$

$$D_{ij} = J_D(s_j - s_i); \tag{2}$$

where R_{ij} and D_{ij} are the judgments of "ratios" and "differences" between stimuli with scale values, s_j and s_i; J_R and J_D are strictly monotonic judgment functions; and the comparison operation is subtraction in both cases. If there is one scale and one comparison operation, the judgments of "ratios" and "differences" will be monotonically related because both are strictly monotonically related to the same difference, $R_{ij} = J_R[J_D^{-1}(D_{ij})]$.

However, if subjects used both ratio and difference operations as instructed, judged "ratios" would not be monotonically related to "differences" because the ratio model would replace Equation 1 as follows:

$$R_{ij} = J_R(s_j/s_i). \tag{3}$$

In this case, "ratios" and "differences" would have different rank orders. For example, assuming the Holmes and Rahe (1967) values, Equations 2 and 3 imply that the judged "difference" between Death of spouse and Jail term should exceed the "difference" between Child leaving home and Vacation (because $100 - 63 > 29 - 13$), but the judged "ratios" should have the opposite rank order ($100/63 < 29/13$). For a constant difference, true ratios approach one as the values are moved up the scale (e.g., $2 - 1 = 3 - 2 = 4 - 3$, but $2/1 > 3/2 > 4/3$). For a given ratio, differences grow more extreme as the values are moved up the scale (e.g., $2/1 = 4/2 = 8/4$, however, $2 - 1 < 4 - 2 < 8 - 4$).

If such changes in rank order were observed, they would rule out the one-operation theory (Eqs. 1 and 2) in favor of the two-operation theory (Eqs. 2 and 3). In principle, two-operations would permit the estimation of a ratio scale of subjective value (Birnbaum, 1980; Krantz et al., 1971; Miyamoto, 1983). In a ratio scale, all of the values can be multiplied by a positive constant, and the new values would continue to reproduce the rank orders of both judgments, but scales produced by adding a constant or by nonlinear transformations would not have that property.

A ratio scale of subjective value would provide measures that would produce an invariant order of additive totals. Similarly, if judgments of "combinations" were additive, the data could be used to generate a scale of subjective value that could be compared with the scales fit to "ratios" and "differences."

Models of Combination

The additive model can be written:

$$C = J_C[\Sigma s_i], \tag{4}$$

where C is the judged "combination" of life events; s_i is the scale value of event i; J_C is the strictly monotonic judgment function for "combination" judgments; and the summation runs over all life changes experienced.

Previous tests of additive and parallel averaging models of evaluative and moral judgment led to evidence against additive models in favor of configural weighting (Birnbaum, 1972, 1973b, 1974a, 1982, 1983; Birnbaum & Jou, 1990; Birnbaum & Mellers, 1983; Birnbaum & Stegner, 1979, 1981; Birnbaum & Sutton, in press; Riskey & Birnbaum, 1974). Configural weight models allow the weight of each item to depend on its rank among the stimuli to be combined, and are closely related to dual bilinear and rank-dependent utility theory (Luce & Narens, 1985; Wakker, 1990).

If the highest and lowest stimuli receive greater or less weight, and the other stimuli receive weights that are independent of their values, a simple range model may describe the configural weighting (Birnbaum, 1974a, 1982; Birnbaum, Parducci, & Gifford, 1971; Birnbaum & Stegner, 1979) as follows:

$$C = J_C[\Sigma w_i s_i + \omega(s_{\mathrm{MAX}} - s_{\mathrm{MIN}})] \tag{5}$$

where w_i and s_i are the weights and scale values of the events; and ω is the configural weight taken from the lowest valued stimulus in that combination (s_{MIN}) and given to the highest stimulus (s_{MAX}). Note that s_{MAX} and s_{MIN} change from trial to trial, depending on the stimuli to be combined. When the weights are constant and $\omega = 0$, the model reduces to the additive model. When the weights are independent of their scale values and sum to a constant and $\omega = 0$, the model reduces to a parallel averaging model. However, when the configural weight is not zero, then weight is transferred from the highest stimulus to the lowest, or vice versa, depending on the sign of ω. In extreme cases, the highest or lowest stimulus could receive zero weight. When there are exactly two stimuli, Equation 5 becomes a dual bilinear representation, which defines scale values to an interval scale (Luce & Narens, 1985).

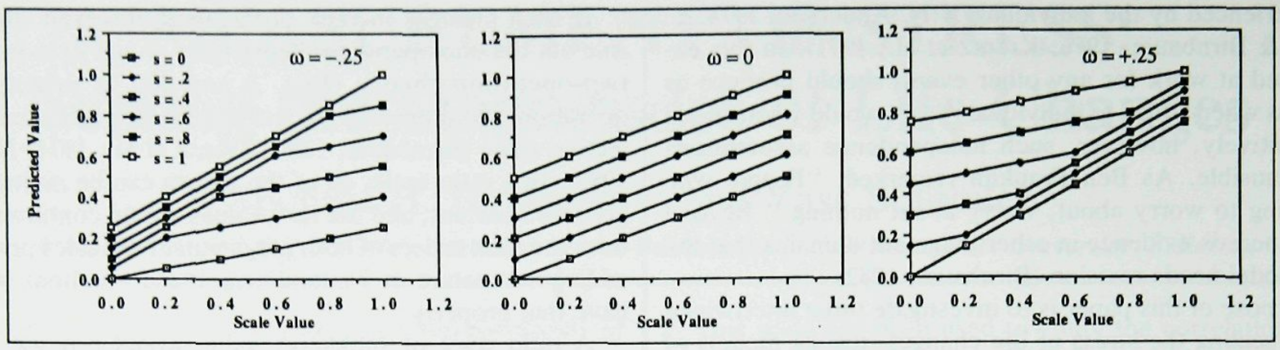

Fig. 1. Predictions of configural weight theory for combinations of two life events. Separate panels show predictions for different values of the configural weight parameter, ω.

Figure 1 illustrates predictions of Equation 5 for combinations of two life events, to illustrate configural weighting. Predictions were calculated using scale values between 0 and 1, and $w_1 = w_2 = .5$. Within each panel, separate curves are shown for $s = 0$, .2, .4, .6, .8, and 1.0. In separate panels, the configural weight was set to either −.25, 0, or .25; when the configural weight is zero (middle panel), the curves are parallel; however, when ω is negative (left panel) or positive (right panel), the curves diverge or converge to the right, respectively.

METHOD

Stimuli

The 15 life change events, selected from Holmes and Rahe (1967), are abbreviated in Table 1. They were placed in two sets, A and B, for construction of the combinations.

Instructions

For the "ratio" task, the subjects were to compare events and judge the "ratio" of the stresses. The response was to be 100 times the subjective ratio of the first event, relative to the second in each pair. Seven examples illustrated "ratios" of 1/8, 1/4, 1/2, 1, 2, 4, and 8 (see Hardin & Birnbaum, 1990).

For the "difference" task, the scale ranged from −100 to 100, where 0 represents no difference between the two events, 100 = first event is very very much more stressful than the second, and −100 = second event is very, very much more stressful than the first.

For the "combination" task, the scale ranged from 0 = no stress at all; 20 = slightly stressful; 40 = stressful; 60 = very stressful; 80 = very, very stressful; and 100 = maximal stress.

Designs

For the "ratio" and "difference" tasks, the pairs were formed by a 7 × 15 factorial design. This design was actually the union of a 7 × 7, A × A factorial design in which all items from set A were paired with each other, combined with a 7 × 8, A × B factorial design, which paired each item from set A with every B item.

For the "combination" task, there were three subdesigns:

Table 1. *Life stress events and scale values*

Event (abbreviated)	Holmes & Rahe	"Diffs" (Eq. 2)	"Ratios" (Eq. 1)	Additive Combos	Unified Scale
Set A					
Christmas	12	−1.14	−1.18	.08	1.00
Change in family get-togethers	15	−1.07	−1.10	.01	1.06
Child leaving home	29	−.20	−.08	.24	2.00
New family member	39	−.50	−.60	.04	1.54
Marriage	50	−.05	−.03	.13	2.00
Divorce	73	1.06	1.00	1.15	3.11
Death of spouse	100	1.99	2.02	3.31	4.06
Set B					
Change in eating habits	15	−1.09	−1.06	.02	1.05
New school	20	−.49	−.68	.08	1.56
Moving (change in residence)	20	−.52	−.45	.10	1.71
Outstanding achievement	28	−1.08	−1.12	0.00	.98
Death of close friend	37	1.53	1.63	1.99	3.67
Fired at work	47	.49	.42	.84	2.70
Injury or illness	53	.06	.20	.32	2.24
Jail term	63	1.01	1.04	1.04	3.00

Each event was presented alone (A, B alone), in a pair (7 × 8, A × B), and the seven A events were combined with four pairs of events to form triples (7 × 4, A × BB pairs). The four BB pairs were as follows: Vacation and Change in eating habits; Moving and New school; Death of a close friend and Fired at work; and Injury and Jail term. The family-related items were assigned to set A to prevent combinations such as Divorce and Death of spouse, which create unusual but interpretable scenarios.

Procedure and Subjects

For each task, booklets contained instructions, warm-up trials, and the experimental trials in random order. The order of the three tasks was counterbalanced across subjects, who were 95 undergraduates at California State University, Fullerton, participating for extra credit in Introductory Psychology.

RESULTS

"Ratio" and "Difference" Judgments

Figure 2 plots mean "ratio" judgments as a function of mean "difference" judgments, with a separate type of symbol for each value of the second life change. According to the two-operation theory (Eqs. 2 and 3), the data should form a set of intersecting curves with different slopes for different levels of the second life change (Birnbaum, 1980). (When actual ratios are plotted against differences, each curve represents x/c vs. $x - c$ for a different value of c; for positive x and c, these curves would be straight lines that cross when $x = c$ with an intercept of one and slopes that are inversely proportional to c.) Instead, the data in Figure 2 appear more consistent with one-operation theory (Eqs. 1 and 2), which implies that the points should fall on a single monotonic function, $R_{ij} = J_R[J_D^{-1}(D_{ij})]$, except for error.

One-operation theory implies specific patterns in Figures 3 and 4, which show mean judgments of "ratios" and "differences" as a function of the marginal mean for the first stimulus ($R_{.j} = \Sigma R_{ij}/7$ and $D_{.j} = \Sigma D_{ij}/7$, respectively), with a separate curve for each level of the second life change. According to one-operation, subtractive theory (if J_R in Eq. 1 is exponential, as theorized by Birnbaum, 1978), the data in Figure 3 should form a divergent fan of straight lines that intersect at a common point (see also Birnbaum, 1980; Hardin & Birnbaum, 1990). Similarly, if J_D in Equation 2 is linear, the curves in Figure 4 should form a set of parallel, straight lines (Birnbaum, 1978). The data appear to be roughly consistent with the predicted patterns, but there are some deviations, such as a wider spread of the curves for "differences" near zero, that may be attributable to the judgment functions.

To correct for any nonlinearity in the judgment functions and to test whether one-operation theory leads to consistent scales for both tasks, Equations 1 and 2 were fit to "ratios" and "differences" separately by means of the computer program

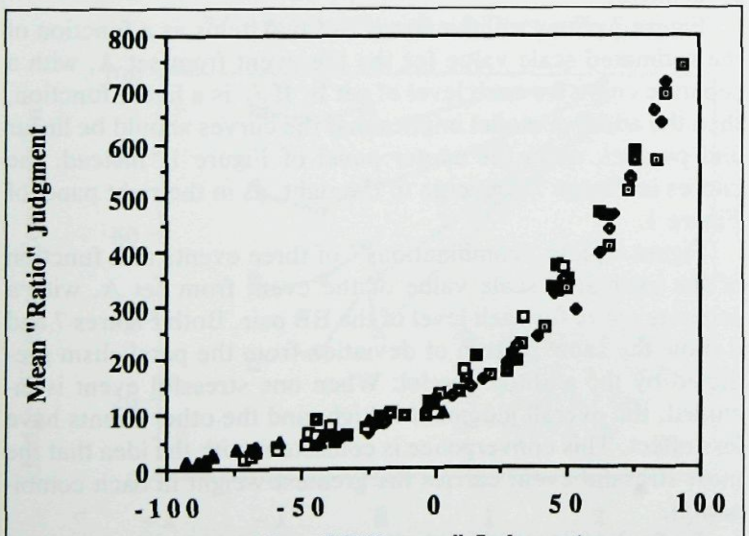

Fig. 2. "Ratio" judgments of each pair plotted against corresponding "difference" judgments. Different symbols correspond to levels of second event, from set A.

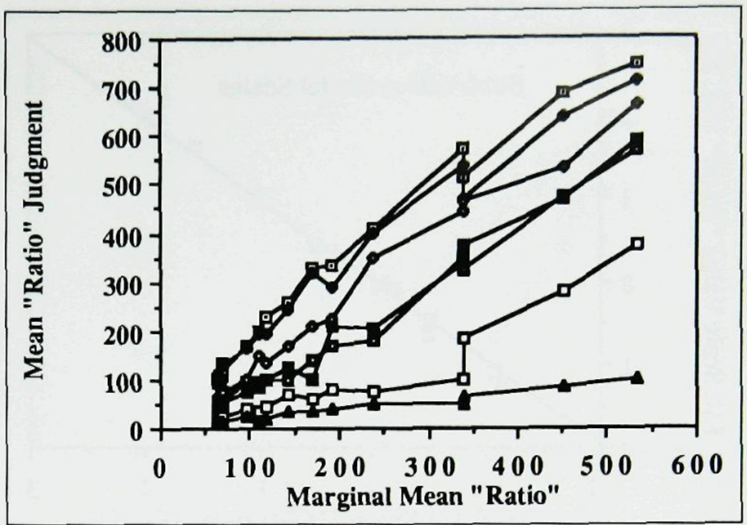

Fig. 3. Mean judgments of "ratios" as a function of marginal means for the first event with a separate curve (and symbol) for each level of the second event; symbols correspond to Figures 2 and 4.

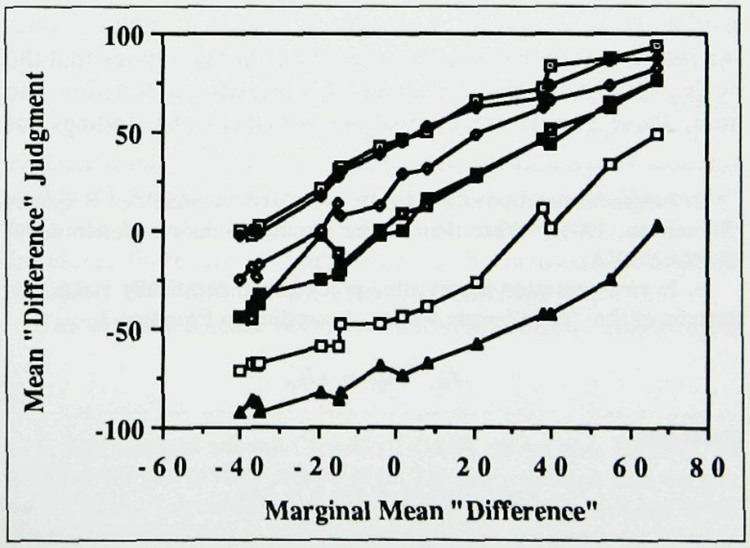

Fig. 4. Mean judgments of "differences," plotted as in Figure 3.

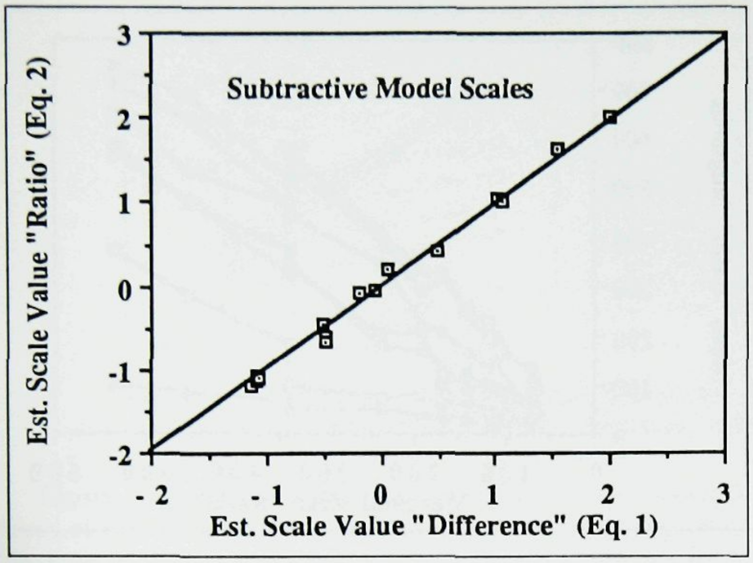

Fig. 5. Scale values estimated from one-operation, subtractive theory fit to "ratio" task plotted against corresponding estimates from "difference" task. One-operation theory implies that this relationship should be linear, whereas two-operation theory implies that it should be logarithmic.

MONANOVA (Kruskal & Carmone, 1969), which transforms the data as follows:

$$r_{ij} = J_R^{-1}[R_{ij}]; \quad (6)$$

$$d_{ij} = J_D^{-1}[D_{ij}]; \quad (7)$$

where J_R^{-1} and J_D^{-1} are strictly monotonic transformations; and r_{ij} and d_{ij} are transformed "ratio" and "difference" judgments, which are fit to subtractive models.[2] Scale values estimated from this procedure are listed in Table 1, and they are plotted against one another in Figure 5.

Figure 5 tests whether one-operation theory can describe both "ratios" and "differences" with the same scale values (a test of scale convergence). Figure 5 shows that the scale values estimated from "ratios" and "differences" are virtually identical when both sets of data are separately fit to subtractive models (Eqs. 1 and 2). Linearity in Figure 5 supports one-operation theory because two-operation theory implies that the scales should be related instead by a logarithmic function.[3] In sum, these results are compatible with previous findings for other continua (Birnbaum, 1978, 1980, 1982; Hardin & Birnbaum, 1990), consistent with the theory that "ratios" and "differences" can be represented by subtraction on a single scale.

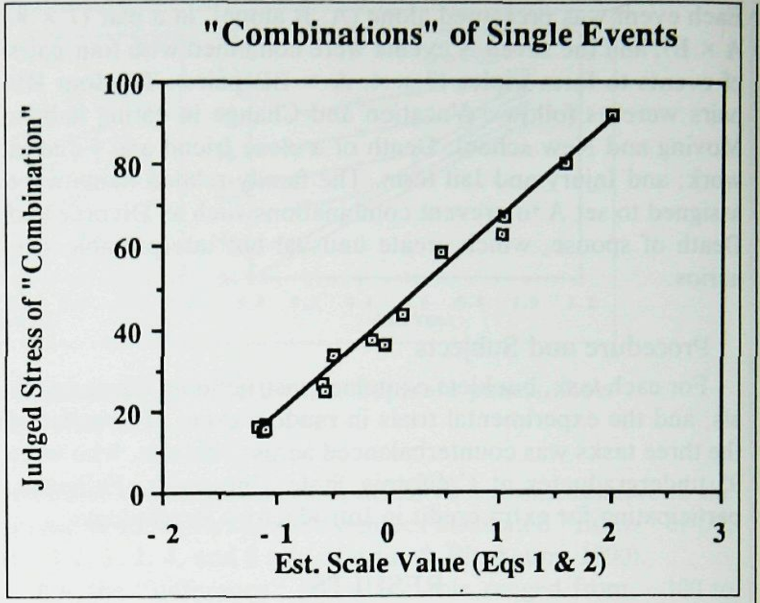

Fig. 6. Mean judgments of stress of single items, plotted as a function of scale values estimated from one-operation, subtractive theory fit to "ratios" and "differences."

"Combinations"

Figure 6 plots the mean "combination" ratings of single items against the average of the scale values estimated from the subtractive model applied to "ratios" and "differences." According to either additive or configural weight models (Eqs. 4 or 5), the stress of a single item is a function of s_i. Therefore, assuming scale values are the same for all tasks, the function J_C can be estimated from Figure 6, which appears to indicate that J_C is linear.

Figure 7 plots "combinations" of two items as a function of the estimated scale value for the life event from set A, with a separate curve for each level of set B. If J_C is a linear function, then the additive model implies that the curves should be linear and parallel, as in the center panel of Figure 1. Instead, the curves in Figure 7 converge to the right, as in the right panel of Figure 1.

Figure 8 plots "combinations" of three events as a function of the estimated scale value of the event from set A, with a separate curve for each level of the BB pair. Both Figures 7 and 8 show the same pattern of deviation from the parallelism predicted by the additive model: When one stressful event is included, the overall judgment is high, and the other events have less effect. This convergence is consistent with the idea that the most stressful event carries the greatest weight in each combination.

To further investigate the additive model, "combinations" were transformed to fit the additive model (Eq. 4) by means of MONANOVA. The estimated scale values from the additive model are not a linear function of the scale values estimated from "ratios" and "differences." The best-fit additive scale

2. Judgment functions can also be estimated as integrated B-splines (Stevenson, 1986), rather than as the strictly monotonic functions of MONANOVA.

3. In two-operation theory, this procedure theoretically yields logarithms of the "ratio" scale values. According to Equation 3,

$$J_R^{-1}(R_{ij}) = s_j/s_i;$$

therefore,

$$\log[J_{R^{-1}}(R_{ij})] = \log s_j - \log s_i;$$

consequently, scales estimated from "ratio" judgments should be related to scales from "difference" judgments by a logarithmic function, according to Equations 2 and 3, contrary to the linearity in Figure 5.

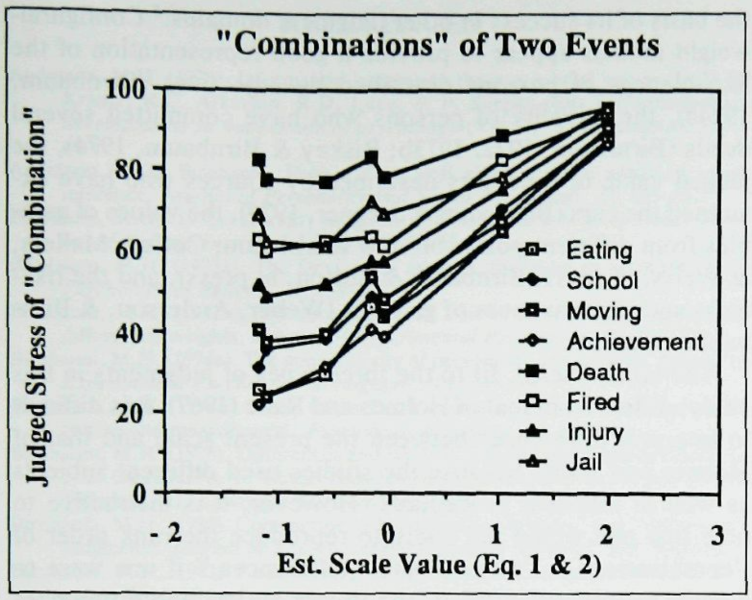

Fig. 7. Mean judgments of "combinations" of two events, plotted as a function of the estimated scale value of the event from set A, with a separate curve for each event from set B.

values are listed in Table 1, and they are plotted against the average of "ratio" and "difference" model scale values in Figure 9. The best-fit J_C function inferred from the additive model was negatively accelerated, contrary to Figure 6. In sum, the nonlinear relationship in Figure 9, the linear one in Figure 6, and the nonparallel curves in Figures 7 and 8 suggest that the additive model should be rejected in favor of the theory that the most stressful item receives more weight than the least stressful item in each combination.

Scale Convergence and Configural Weighting

Although the additive model failed to yield scales that are compatible with the subtractive model of "ratios" and

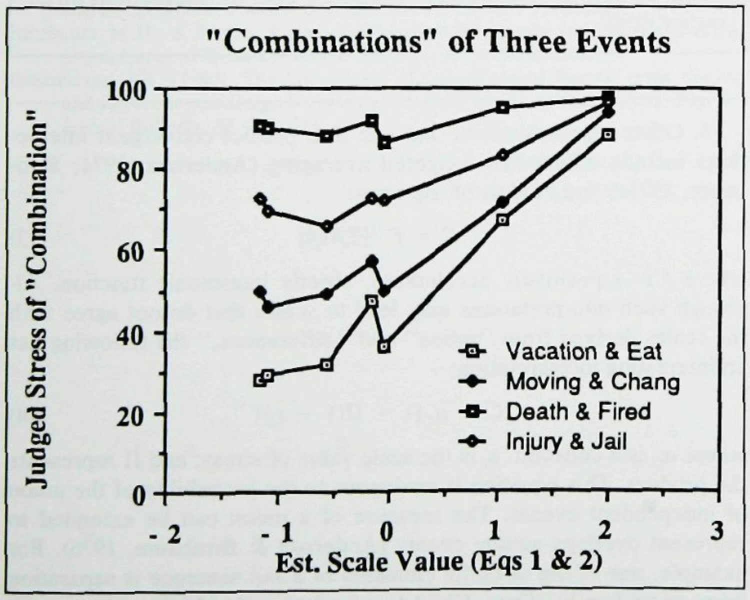

Fig. 8. Mean judgments of "combinations" of three events, as in Figure 7, with a separate curve for each pair of added events from set BB.

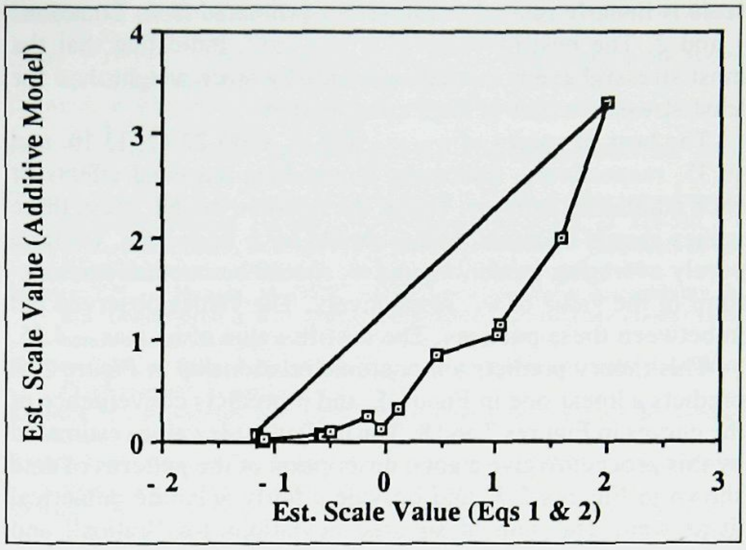

Fig. 9. Additive model scale values plotted against scale values estimated from Equations 1 and 2 fit to "ratios" and "differences." Nonlinear function indicates that if scale values are assumed to be the same, then either the additive model of "combinations" or subtractive theory should be revised.

"differences," configural weighting theory may be able to describe "combinations" using the same scale, and also account for the empirical patterns of the data. Therefore, to test scale convergence for the configural weight theory, a computer program was written to fit "ratios," "differences," and "combinations" with a unified scale for the life changes.[4] The equations were as follows:

$$r_{ij} = s_j - s_i \quad (8)$$

$$d_{ij} = s_j - s_i \quad (9)$$

$$C_i = w_1(s_i) + b_C \quad (10)$$

$$C_{ij} = w_2(s_i + s_j + \omega \mid s_i - s_j \mid) + b_C \quad (11)$$

$$C_{ijk} = w_3(s_i + s_j + s_k + \omega \mid s_{MAX} - s_{MIN} \mid) + b_C \quad (12)$$

where r_{ij} and d_{ij} are the transformed "ratios" and "differences" from Equations 6 and 7; C_i, C_{ij}, and C_{ijk} are stress judgments of "combinations" of one, two, and three events, respectively; the coefficients, w_1, w_2, w_3, and b_C, are constants; and ω is the configural weight parameter. In addition to these 5 constants, there are 14 scale values (s_i) to be estimated (s_1 is set to 1); therefore, there are 19 parameters to be estimated from 105 "ratios," 105 "differences," and 99 "combinations."

The estimated scale values are listed in Table 1. This unified

4. The program utilized Chandler's (1969) subroutine, STEPIT, to minimize the sum of three indices of fit. The index for each task was the sum of squared deviations between the predicted and obtained mean judgments divided by the sum of squared deviations about the mean in that array (see Birnbaum, 1980). This approach implicitly treats errors as additive terms that follow judgment functions in Equations 1, 2, 10, 11, and 12 (see also Busemeyer, 1980).

scale is linearly related to the scales estimated from Equations 1 and 2. The best-fit value of ω was .637, indicating that the most stressful event carried substantially more weight than the least stressful event in each combination.

The best-fit values of w_1, w_2, and w_3 were 22.42, 13.10, and 10.35, respectively, indicating diminishing marginal effects of each additional stressor. Under the additive model, these three values should be equal, and ω should have been zero. Under a purely averaging model, w_2 and w_3 should be one-half and one-third of the value of w_1, respectively. The values observed fall in between these patterns. The best-fit value of b_C was -4.55.

This theory predicts a monotonic relationship in Figure 2, it predicts a linear one in Figure 5, and it predicts convergence of the curves in Figures 7 and 8. The unified scale values estimated by this procedure give a good description of the patterns of data shown in Figures 2–8, and provide a fairly accurate numerical fit as well. The sum of squared deviations for "ratios" and "differences" were 1.05% and 0.38% of the systematic variance in their tasks, respectively; for the three subdesigns of "combination" judgments, this sum was 2.68% of the systematic variance. (Correlations between theory and data are thus .998, .995, and .987, for the data in Figs. 2, 3, and 6–8, respectively.)

DISCUSSION

The present results indicate that judgments of "ratios" and "differences" of stress are approximately monotonically related. This finding is consistent with the hypothesis that the same operation underlies both types of judgments. If subtraction underlies both tasks, as suggested by other evidence (Birnbaum, 1978, 1980, 1982, 1990; Birnbaum, Anderson, & Hynan, 1989; Hardin & Birnbaum, 1990), then the scale derived from "ratios" and "differences" is unique to an interval scale.

Ratings of the stress of single life changes are linearly related to the scale derived from "ratios" and "differences" (Fig. 6). However, "combinations" of two and three events show two systematic deviations from the additive model. First, the most stressful event in each combination has a greater effect on the judgment than the least stressful event. Second, the data show subadditivity: There is a diminishing marginal effect of each additional life change. A third stressor of equal value appears to contribute less than half as much as the first one. A similar pattern of subadditivity was reported by Shanteau and Phelps (1975).

With the requirement that the same scale explain several types of judgments, the present data permit rejection of the additive model in favor of the theory that the most stressful event outweighs the others. Configural weighting explains the convergence (deviations from parallelism) in Figures 7 and 8; it explains the particular nonlinear relationship in Figure 9; it can account for the diminishing effects of additional stressors; and it can also fit the "combination" judgments using the same scale of stress that describes "ratios" and "differences."

Although certain formulations can also describe a convergent interaction as in Figures 7 and 8, the configurally weighted model can be favored over them because of its success in fitting several types of judgments with the same scale values, and on the basis of its success in other judgment domains.[5] Configural-weight models appear to provide a good representation of the likeableness of persons described by adjectives (Birnbaum, 1974a), the morality of persons who have committed several deeds (Birnbaum, 1972, 1973b; Riskey & Birnbaum, 1974), the judged value of used cars described by sources who have examined the cars (Birnbaum & Stegner, 1979), the values of gambles from different points of view (Birnbaum, Coffey, Mellers, & Weiss, in press; Birnbaum & Sutton, in press), and the riskiness and attractiveness of gambles (Weber, Anderson, & Birnbaum, in press).

The unified scale, fit to the three types of judgments in this study, differs from that of Holmes and Rahe (1967). It is difficult to interpret differences between the present scale and that of Holmes and Rahe, because the studies used different subjects as well as different procedures. However, it is instructive to note that one would fail badly to reproduce the rank order of "combinations," "ratios," and "differences," if one were to naively try to predict them from totals, ratios, and differences of Holmes and Rahe (1967) values. There would be three major problems: First, "combination" judgments do not satisfy the additive model. Second, "ratios" and "differences" are monotonically related, unlike calculated ratios and differences. Third, Holmes and Rahe values are not even monotonically related to the unified scale, so the Holmes and Rahe values fail to predict the rank order of any of these tasks.

The unified scale predicts the rank order of all three types of judgments and therefore represents a theoretically more tractable scale of human judgment. The present scale may also provide better predictions of actual health states, when used in association with configural theory of combinations.

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5. Other representations that can also predict convergent interactions include differential weighted averaging (Anderson, 1974; Birnbaum, 1973a) and models of the form:

$$C = f^{-1}[\Sigma f(s_i)] \tag{13}$$

where f is a positively accelerated, strictly monotonic function. Although such interpretations may lead to scales that do not agree with the scales derived from "ratios" and "differences," the following has an interesting interpretation:

$$C = a_C[1 - \Pi(1 - s_i)] \tag{14}$$

where a_C is a constant, s_i is the scale value of stress; and Π represents the product. This equation is analogous to the probability of the union of independent events. The measure of a union can be extended to represent overlaps among events (Anderson & Birnbaum, 1976). For example, one of the stressful elements of a Jail sentence is separation from one's family. Thus, Child leaving home shouldn't add as much unique stress to a person in jail as it might to a person in other circumstances. It is interesting that the present data can be well approximated without such complications.

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