

## Toward a Reconceptualization of the Law of Initial Value

Putai Jin  
La Trobe University  
Bundoora, Victoria, Australia

The traditional model of the law of initial value (LIV), “the higher the initial value, the smaller the response to function-raising, the larger the response to function-depressing stimuli” (Wilder, 1967, p. viii), is critically reviewed. Statistically, the usage of  $r_{DX}$ ,  $b_{DX}$ , and  $b_{YX}$  as the indices of LIV contains a spurious  $X(Y - X)$  effect. Moreover, defining initial value as a synonym of baseline is too narrow to cover an organism’s various states. The parameter of structural relationship  $\beta_x$  value and a null hypothesis test ( $\beta_x = 1$ ) are recommended to examine initial-value dependency for different levels of initial value and trends of change. Data suggest that LIV should be revised as follows: The higher the initial value, the greater the organism’s following reactivity, although a tendency to reversed responses may occur when the initial value reaches its upper extremity. Both phenomena are probably due to constitutional and homeostatic mechanisms, respectively.

Although many sciences in their early, developing stage have to a greater or lesser extent used models of physics for reference, psychophysiology differs in having only one “law,” the law of initial value (LIV), which appears to be in contrast with “the law of inertia” in classical physics. LIV, first named by Wilder in 1931 and used to estimate initial-value dependency (cf. Wilder, 1967, pp. 3–24), has been expressed as follows: “The higher the initial value, the smaller the response of function-raising, the larger the response to function-depressing stimuli” (Wilder, 1967, p. viii).

Extensive discussion and debate (e.g., Benjamin, 1963; Block & Bridger, 1962; Brandt, 1962; Bridger & Reiser, 1959; Campbell, 1981; Cumes-Rayner & Price, 1988; Graham & Jackson, 1970; Heath & Oken, 1962; Hord, Johnson, & Lubin, 1964; Hutt & Hutt, 1970; Julien & Over, 1981; J. Lacey, 1956; J. Lacey & Lacey, 1962; Levey, 1980; Libby, Lacey, & Lacey, 1973; Lovallo & Zeiner, 1975; Lykken, 1968; Malmstrom, 1968; Mock, 1962; Oken & Heath, 1963; Ray & Kimmel, 1979; Richards, 1980; Schmidt, Rose, & Bridger, 1974; Steinschneider & Lipton, 1965; Stratton, 1970; Surwillo & Arenberg, 1965; White, 1977; Wilder, 1957, 1958) followed Wilder’s proposal. Meanwhile, many relevant suggestions were made, for example, how to measure *base-free* changes (e.g., Cronbach & Furby, 1970; Lord, 1963; Lykken, Rose, Luther, & Maley, 1966; Oldham, 1962; Tucker, Damarin, & Messick, 1966) and how to deal with repeated measures (e.g., Bird & Hadzi-Pavlovic, 1983; Jennings, 1987; O’Brien & Kaiser, 1985; Vasey & Thayer, 1987). Nevertheless, since Benjamin (1967) presented a thorough review, it has been generally accepted that Wilder’s LIV is present if  $r_{DX}$ , the correlation between the initial value ( $X$ ) and the difference score ( $D = Y - X$ , where  $Y$  is the final value) is negative and significant. Two other indices of LIV in concordance with  $r_{DX}$

are the slopes of the best-fitted linear regression lines relating  $X$  to  $D$  ( $b_{DX}$ ) and relating  $X$  to  $Y$  ( $b_{YX}$ ): when  $r_{DX} < 0$ ,  $b_{DX} < 0$  and  $b_{YX} < 1$ .

To review LIV issues, I examined five of the main English outlets for publication of reports on human psychophysiology: *Psychophysiology*, *Biological Psychology*, *Psychosomatic Medicine*, *Journal of Psychosomatic Research*, and *Journal of Human Stress* (named *Behavioral Medicine* since 1988). During the period 1980–1989, there were only two articles (Myrtek & Foerster, 1986a, 1986b) that seriously questioned the justification of intuitively using  $r_{DX}$  as the key index of LIV. Instead, Myrtek and Foerster recommended using “the slope of the first principle-component axis in the factor analysis of the covariance matrix” and the related  $t$  test to examine the operation of Wilder’s LIV. They asserted that if researchers adopt the new methodology, originally from the work of Kendall and Stuart (1967) and introduced into psychology by Isaac (1970), “the problem of initial value may be finally resolved” (Myrtek & Foerster, 1986a, p. 237).

However, the recommendation by Myrtek and Foerster (1986a) has received limited attention; so far, there has been only one commentary on their work (Cleary, 1986) and only three reports using their proposal (Fahrenberg & Foerster, 1982; Fahrenberg, Walschburger, Foerster, Myrtek, & Müller, 1983; Myrtek & Foerster, 1986a). The most recent LIV-related articles (e.g., Emmons & Weidner, 1988; Houston, Smith, O’Connor, & Funk, 1988; Jamieson, 1987; Niaura, Wilson, & Westrick, 1988; Smith & Houston, 1987) still rely heavily on Benjamin’s methodology to examine the operation of Wilder’s LIV. Perhaps the convention of using the Wilder-Benjamin model is too strong to be replaced; alternatively, some issues in the new proposal need to be clarified and further elaborated.

More important, as pointed out by Wainer (1991) in an article based on Rubin’s model (Holland, 1986; Holland & Rubin, 1983; Rubin, 1974), the principal issues in adjustment for differences in initial values are first of all, epistemological: One has to make some assumptions before making causal inferences. This aspect, which deserves greater attention, has, on the whole, been neglected in the previous LIV literature. Further-

---

I gratefully acknowledge comments from Ray Over, George Singer, Geoff Cumming, Paul Yip, Philippa Barber, and three anonymous reviewers.

Correspondence concerning this article should be addressed to Putai Jin, Department of Psychology, La Trobe University, Bundoora 3083, Australia.

more, there has been the tendency to regard Wilder's LIV, in essence, as an inviolable "law" or proposition that reflects initial-value dependency (cf. Furedy & Scher, 1989). It is possible that under different conditions, an organismic regulation system would display different types of initial-value dependency. Hence, there is a real and urgent need to elaborate and establish an appropriate methodology for testing LIV, especially considering the many endeavors in the area of LIV during the past half century.

In this article, epistemological, statistical, and theoretical considerations on LIV are reviewed and new perspectives are delineated; then some data are presented to illustrate an appropriate test of initial-value dependency; finally, LIV is reconceptualized for future work. To differentiate the traditional LIV from the concept of LIV defined and discussed here, *Wilder's LIV* will be used to denote the former.

### Epistemological Considerations

When one is merely describing the change after treatment, it is entirely appropriate either to present the initial value  $X$  and final value  $Y$  or simply to calculate the difference score  $D$ . However, if one also wants to know to what extent the change is due to the treatment per se and what the "pure" influence of  $X$  is on  $Y$ , one becomes involved in a complicated process of causal inferences (Holland, 1986; Wainer, 1991).

In this process one asks, "What would be the true effect of  $X$  on  $Y$  if there were no treatment? Would it be positive, negative, or negligible?" To test these hypotheses, then one is immediately faced with a counterfactual such as "If kangaroos had no tails, they would topple over" (Lewis, 1973, p. 1). Here the fundamental problem is that the situation is subjunctive and thus unobservable: It concerns what the target variable following the treatment time would have been had the treatment not occurred (cf. Wainer, 1991). Because there are, perhaps, different possibilities, the tricky task is to decide which is "true in all possible worlds" (A. Lacey, 1982, p. 75). However, to avoid getting trapped in a dilemma such as that encountered by Buridan's ass who starved to death between two (or more!) tempting bundles of straw, one expects that the "possible worlds" could be arranged in a certain order according to whether they are more or less remote from the "real world" (cf. A. Lacey, 1982). In other words, unless one is willing and has good reasons to make additional assumptions about the ongoing status of the target variable (which, in this case, is supposed to be treatment-free), one cannot make any causal inference (Holland, 1986; Wainer, 1991). Therefore, extra information from other sources (the current state of knowledge, the designs chosen, etc.) is needed to reduce the degree of uncertainty.

In comparison with the traditional notation and natural language, the notation in Rubin's model (see Holland & Rubin, 1983; Wainer, 1991) allows a more precise definition and explanation of the variables discussed here. In the LIV setting one typically has (a) a prospective study (randomized or not), (b) a (large) population ( $i$ ) of experimental units of subjects, and

$Y_i$  = an outcome (i.e., a final value)

$X_i$  = an initial value

$S_i$  = a binary exposure

$$= \begin{cases} e: \text{if } i \text{ is exposed to causal agent of interest} \\ \quad \text{(treatment or hazard)} \\ c: \text{if } i \text{ is not exposed.} \end{cases}$$

When one tries to estimate the observed risk difference ( $\Delta$ ) adjusted for  $X$ ,

$$\Delta = E(Y|X, S = e) - E(Y|X, S = c),$$

one is instantly put in a difficult dilemma: It is not possible to impose  $e$  and  $c$  simultaneously on all units or subjects. Logically, one needs to separate two streams of outcomes: One is due to  $e$  and the other represents the consequence of  $c$ . In LIV research, for instance, in a study on activation, one normally chooses to observe or actually focus on  $X_e$  and  $Y_e$ . As such,  $X_e$  and  $Y_e$  are not directly observable from those units or subjects, given  $X_c$  and  $Y_c$ . Note that the traditional notation of observables  $X$ ,  $Y$ ,  $D$ ,  $b_{YX}$ ,  $b_{DX}$ , and  $r_{DX}$  mentioned previously is similar to the usage of  $X_e$ ,  $Y_e$ ,  $D_e$ ,  $b_{Y_e X_e}$ ,  $b_{D_e X_e}$ , and  $r_{D_e X_e}$ , respectively, in accordance with Rubin's model.

What kinds of assumptions relevant to the issue of initial-value dependency can be made? So far in LIV research the time interval between two measures has been fairly short and the same technique has been used on both occasions. On the basis of this extra information, one could assume that  $Y_c$  is identical to  $X_c$  and that the error variances of  $X_e$  and  $Y_e$  are very similar. These reasonable assumptions can facilitate further causal inferences (see following sections for details). However, this "short-term" paradigm of LIV research is only a special case of growth models (Bryk & Weisberg, 1977; Goldstein, 1979; Stemmler & Fahrenberg, 1989; Weisberg, 1979). Other assumptions about specific growth rates for different groups may be needed if, in any study, the time interval becomes considerably longer than that in the current LIV research. Moreover, information about the variation of the target variable under different experimental manipulations in other studies, and a thorough understanding of the specific features of research designs, can also be helpful in drawing reasonable assumptions. For example, if data have been obtained about the upper limit of the target variable and if one knows that the subjects have been randomly assigned to the experimental and control groups, the uncertainty in examining initial-value dependency can be markedly reduced (cf. Rubin, 1974; Weisberg, 1979).

These epistemological considerations are vitally important before researchers develop statistical models, because "rationalist questions about possibility" need to be "effectively translated into empirical questions about matters of fact" (White, 1990, p. 11).

### Statistical Considerations

#### *The $X(Y - X)$ Effect*

As J. Lacey (1956) pointed out, the correlation between the initial value ( $X_e$ ) and the change score ( $D_e = Y_e - X_e$ ), because of the fact that these two variables contain the same element  $X_e$ , can result in a spurious effect on real initial-value dependency. This problem was highlighted by Oldham (1962) through an extreme example: If  $X_e$  and  $Y_e$  are random numbers, the average difference ( $Y_e - X_e$ ) tends to be positive when  $X_e$  is small and will turn to negative when  $X_e$  is increased. This built-in tendency of change scores to be negatively correlated with initial

values has been noted by many other researchers (e.g., Campbell, 1981; Harris, 1985; Lykken, 1968; Plewis, 1985; Stemmler & Fahrenberg, 1989). Hence,  $r_{D,X_e}$ , a correlation including such a commonality in its two variables and thus being contaminated by the artificial  $X(Y - X)$  effect, cannot be an appropriate index of LIV.

### The Linear Structural Relation Between $X$ and $Y$

In previous literature, linear regression has been used to index LIV, for instance,  $b_{Y,X_e}$  to estimate  $Y_e$  from  $X_e$ . Strictly, here,  $X_e$  should be measured without error. However, this assumption is violated because there are often error variances in both  $X_e$  and  $Y_e$  (Isaac, 1970). This difficulty can be avoided by simply analyzing the linear structural relation between  $X_e$  and  $Y_e$ , where  $X_e$  and  $Y_e$  are allowed to have measurement errors. Thus, the question becomes how to find a single line for estimation of the true structural relationship between the two variables  $X_e$  and  $Y_e$  (Brown, 1957).

Following Rubin's work, we define

$\beta_e$  = structural relation between  $X_e$  and  $Y_e$

$\beta_c$  = structural relation between  $X_c$  and  $Y_c$ .

Using information obtained from other sources (such as matched controls, theory, and past experience), one can make some untestable assumptions about  $\beta_e$ ; this issue is discussed later. In this section, our discussion focuses on the estimation of  $\beta_e$ .

Kendall and Stuart (1967) listed four cases to obtain a slope  $\beta_e$ , which represents the structural relationship between  $X_e$  and  $Y_e$ : (a)  $S_{X_e}^2$ , known; (b)  $S_{Y_e}^2$ , known; (c)  $S_{X_e}^2/S_{Y_e}^2$ , known; and (d)  $S_{X_e}^2$  and  $S_{Y_e}^2$ , both known, where  $S_{X_e}^2$  and  $S_{Y_e}^2$  are the error variances of  $X_e$  and  $Y_e$ , respectively. Myrtek and Foerster (1986a) chose Case C to obtain  $\beta_e$ :

$$\beta_e = \{S_{Y_e}^2 - \lambda \cdot S_{X_e}^2 + [(S_{Y_e}^2 - \lambda \cdot S_{X_e}^2)^2 + 4\lambda \cdot S_{X_e Y_e} S_{Y_e}^2]^{1/2}\} / (2S_{X_e Y_e}), \quad (1)$$

where  $S_{X_e}^2$  and  $S_{Y_e}^2$  are the variances of  $X_e$  and  $Y_e$ , respectively,  $S_{X_e Y_e}$  is the covariance of  $X_e$  and  $Y_e$ , and  $\lambda$  is the ratio of the error variances  $S_{X_e}^2$  and  $S_{Y_e}^2$ .

For simplicity, let  $X_e$  and  $Y_e$  represent two repeated measures made with a short interval and using the same technique. Under such conditions, which are common in most LIV research, the error variances  $S_{X_e}^2$  and  $S_{Y_e}^2$  can be assumed to be equal, and so the value of  $\lambda$  is considered to be unity. Thus,  $\beta_e$  can be calculated from  $S_{X_e}^2$ ,  $S_{Y_e}^2$  and  $S_{X_e Y_e}$ . Formula 1 can be rewritten as

$$\beta_e = \{S_{Y_e}^2 - S_{X_e}^2 + [(S_{Y_e}^2 - S_{X_e}^2)^2 + 4(r_{X_e Y_e} \cdot S_{X_e} \cdot S_{Y_e})^2]^{1/2}\} / (2r_{X_e Y_e} \cdot S_{X_e} \cdot S_{Y_e}). \quad (2)$$

To elucidate the test on the  $\beta_e$  value, it is helpful to consider the following relations<sup>1</sup>:

1. Testing the null hypothesis,  $H_0: \beta_e = 0$  is identical with  $H_0: r_{X_e Y_e} = 0$ . Logically, if  $H_0: r_{X_e Y_e} = 0$  is accepted, then one does not need to test  $\beta_e = 0$ .

2. Testing the null hypothesis,  $H_0: \beta_e = 1$  is identical with  $H_0: r_{U_e V_e} = 0$ , where  $U_e$  and  $V_e$  are data axes rotated by  $45^\circ = \pi/4$ .

The null hypothesis  $\beta_e = 1$  can be tested by a  $t$  test if the sample is not too small:

$$t = \{(n-2) \cdot \sin^2 [2(\arctan \beta_e - \arctan 1)] [(1/4)(S_{X_e}^2 - S_{Y_e}^2)^2 + S_{X_e Y_e}^2] / (S_{X_e}^2 \cdot S_{Y_e}^2 - S_{X_e Y_e}^2)\}^{1/2}. \quad (3)$$

If  $H_0: \beta_e = 1$  is accepted, initial-value dependency is negligible; if  $\beta_e$  is significantly less than unity, negative initial-value dependency exists, and thus Wilder's LIV can be considered to operate; if  $\beta_e$  is significantly greater than unity, initial-value dependency is positive, a trend that is against Wilder's LIV.

Formula 3 can be re-expressed as

$$t = \{(n-2) \cdot \sin^2 [2(\arctan \beta_e - \arctan 1)] [(1/4)(S_{X_e}^2 - S_{Y_e}^2)^2 + (r_{X_e Y_e} \cdot S_{X_e} \cdot S_{Y_e})^2] / [S_{X_e}^2 \cdot S_{Y_e}^2 - (r_{X_e Y_e} \cdot S_{X_e} \cdot S_{Y_e})^2]\}^{1/2}. \quad (4)$$

I emphasize that the following two prerequisites are necessary to use this  $\beta_e$  value test: (a)  $r_{X_e Y_e}$  must be significant, and (b)  $D_e$  (i.e.,  $Y_e - X_e$ ) must be different from zero ( $H_0: D_e = 0$ ). This is because the initial-value dependency either does not actually exist or is negligible unless these two conditions are satisfied (Myrtek & Foerster, 1986a).

In sum, on the one hand, neither correlation ( $r_{D,X_e}$ ) nor slopes of regression lines ( $b_{D,X_e}$  and  $b_{Y,X_e}$ ) are suitable for testing LIV; on the other hand,  $\beta_e$  value, the parameter for the estimation of the linear structural relationship between initial value  $X_e$  and final value  $Y_e$ , stands out as the best estimation of initial-value dependency, especially when the error variances of  $X_e$  and  $Y_e$  are unknown and the ratio of these two error terms is assumed to be equal to unity.

### Theoretical Considerations

#### Different Conditions: Levels of Initial Value and Trends of Change

Wilder (1967) defined initial value as "something that is supposed to remain unchanged unless a stimulus intervenes" (p. 40) and used the term *basimetry* (measurement of the baseline) for "the study and the application of the law of initial value" (p. viii). It is clear that, in this instance, Wilder regarded initial value as a synonym for baseline. However, on another occasion Wilder (1967) emphasized that LIV, by analogy with the Weber-Fechner Law, "is valid within a certain range of initial values" (p. 39) and that "beyond a certain medium range of initial values, there is a tendency to paradoxical (reversed) responses, increasing with the extremeness of initial values" (p. viii). Obviously, there is confusion in the definition of initial value. Theoretically, as a "law," LIV should cover the effects of different levels of initial value on the organism's responses (Cumes-Rayner & Price, 1988; Myrtek & Foerster, 1986a). Basimetry is simply a special case of LIV when initial value equals baseline.

Another factor in LIV is the trend of change. Although Wilder (1967) mentioned two trends of change—function-raising and function-depressing—most previous LIV research concentrated solely on function-raising issues. Research either on function-depressing (e.g., pacification; see Oken & Heath,

<sup>1</sup> I appreciate a reviewer's advice on this issue.

1963) or on different initial levels (e.g., experimental manipulation of initial levels; see Goldwater, 1978) has been rare. Even the concept of function-raising is often replaced by *activation* (cf. Myrtek & Foerster, 1986a): Most of the parameters used in LIV research are those whose values increase from baseline to higher levels in activating processes. However, this can cause confusion when researchers adopt some parameters whose values decrease during activation. For example, in spite of the increase of heart rate and noradrenaline level, the cortisol level usually drops during moderate exercise. Therefore, the concept of "trends of change" is recommended to include function-raising (i.e., acceleration) and function-depressing (i.e., attenuation).

To summarize, the area of LIV research lacks an elaboration of different patterns of conditions. At least six patterns can be formed through a combination of different initial levels and change trends (see Table 1). LIV can be reconceptualized and tested in this contingency framework.

### *Constitutional Influence Versus Homeostatic Mechanism*

In addition to addressing LIV as a statistical law, Wilder (1967) also tried to link LIV to certain theories, of which the homeostatic theory seems to be the most important. LIV sounds meaningful in terms of Cannon's theory of homeostasis, as follows: It is the nature of an organism to actively maintain certain optimal levels of all its functions, which leads to a small or large magnitude of response to function-raising or function-depressing stimuli for a high initial value.

However, constitutional characteristics should not be ignored (Myrtek, 1984; Smith & O'Keeffe, 1988). It is now a common practice in psychophysiology and psychosomatic medicine to split the sample into high and low reactivity groups. It has been found that subjects with high initial values, possibly reflecting high levels of arousal, tend to have greater reactivity to various stimuli than those with low initial values (Myrtek, 1984). For instance, even Wilder (1967) admitted "greater rise with higher systolic pressure" when the initial value was within normal range (pp. 156, 201).

Taken together, these two points suggest that LIV can be regarded as a reflection of the organism's flexibility. On the one hand, within the medium range of initial values, constitutional characteristics (or arousal levels) can make the organism react to various stimuli in a positive initial-dependency way. On the other hand, when initial values are beyond the medium range, the upper and lower limitations of the organism's psychophysiological states can force the functions back to the norm (i.e.,

ceiling/floor effects), thus leading to negative initial-dependency responses. Furedy (1989) has mentioned that in the area of contemporary psychophysiology the two explanatory constructs of reactivity and Wilder's LIV need to be reconciled. Tests of initial-value dependency under different conditions with different initial levels may be helpful in this aspect.

### *Other Issues*

Scher, Furedy, and Heslegrave (1985) reported that the formulations of LIV could be different for within-subjects designs and between-subjects designs. In fact, these two approaches virtually do not differ with respect to initial-value dependency (cf. Myrtek & Foerster, 1986a; Wilder, 1967, p. 25). It is understandable that the operation of LIV may be more prominent under intraindividual conditions than under interindividual conditions, because the error variance in the former is usually less than in the latter and the underlying mechanisms may be different (e.g., probably in some circumstances homeostatic influence is critical in the former and constitutional influence is dominant in the latter). However, LIV should not be taken for granted in both instances. Rather, as recently pointed out by Furedy and Scher (1989), an investigative approach should be adopted to scrutinize the operation of LIV under different conditions.

Similar to some researchers at the beginning of this century who asked whether the Weber-Fechner Law could apply to physiological data (e.g., Lyon, 1923), one may ask whether LIV can apply to psychological data as well. Wilder (1967) believed that "the LIV introduces a number of new concepts into the dynamics of the psyche: . . . auto-regulation, psychic and somatic" (p. 303). In fact, Thorndike (1924) noticed that "when the individuals in a varying group are measured twice in respect to any ability by an imperfect measure, . . . individuals who are above the mean of the group in the first measurement will tend by error to be less far above it in the second" (p. 225). This "regression to the mean" statement concerning psychological variables is similar to the classical LIV. Simons and Birkimer (1988) reported that those subjects who were initially most mood-disturbed showed most improvement in mood. It would be interesting to examine initial-value dependency at least in relation to some state measures, for example, mood states.

### *Empirical Tests of LIV*

Using a set of variables (cardiovascular-respiratory parameter, skin conductance, electromyogram, eye-blink activity, etc.) and under four baseline-stress conditions (cold pressor test, breath holding, reaction time measurement, and digit series test), Myrtek and Foerster (1986a) tested LIV by calculating the corresponding  $\beta_e$  values in 125 male subjects. They reported 16 anti-Wilder's LIV outcomes<sup>2</sup> and only one pro-Wilder's LIV result in 25 cases (the remaining cases did not display significant initial-value dependency), implying that Wilder's LIV is a rare exception. This is sharply in contrast with the conclusion

Table 1  
*Different Patterns of Conditions*

Pattern	$X_e \rightarrow Y_e$	Example
I	basal $\rightarrow$ high	Activation
II	basal $\rightarrow$ low	Relaxation
III	high $\rightarrow$ basal	Pacification
IV	low $\rightarrow$ basal	Recovery
V	high $\rightarrow$ higher	Intensive stress
VI	low $\rightarrow$ lower	Deep inhibition

Note.  $X_e$  = the initial value;  $Y_e$  = the final value.

<sup>2</sup> In the table reported by Myrtek and Foerster (1986a, p. 234), the sign in the column of LIV for SCR should be + instead of 0. According to my calculation using Formula 4 in this article,  $t(123) = 2.67$ ,  $p < .01$ .

Table 2  
Summary of Tests of Initial-Value Dependency, Expressed in Number of Cases

Pattern	Physiological variables					Psychological variables				
	New method			Old method		New method			Old method	
	–	0	+	$r_{DX} < 0$	$r_{DX} > 0$	–	0	+	$r_{DX} < 0$	$r_{DX} > 0$
I		12	15	13	14		6		5	1
II	1	1		2		5	3		8	
III	21	9		30		49	14		61	2
IV							5		5	
V	1	6	11	9	9					
VI						1			1	
Total	23	28	26	54	23	54	29		80	3

Note. The negative symbol denotes significant negative initial-value dependency ( $\beta_e < 1$ ); zero denotes no significant initial-value dependency ( $\beta_e = 1$ ); the positive symbol denotes significant positive initial-value dependency ( $\beta_e > 1$ );  $r_{DX}$  is the correlation between change score and initial value (when  $r_{DX} < 0$ ,  $b_{DX} < 0$  and  $b_{YX} < 1$ ).

that would have been reached if  $r_{DX}$  had been used as the determinant index of LIV in their report; in that case, Wilder's LIV would have been confirmed because 13 of 14 correlation coefficients significant at the  $p < .05$  level were negative (in the other 11 cases,  $r_{DX}$  was not significant). I have classified the  $\beta_e$  values reported by Myrtek and Foerster into Pattern I and Pattern II as defined earlier in this article. Of the 16 cases of Pattern I, 14 were anti-Wilder's LIV (+), 2 indicated no significant initial-value dependency (0), and none was consistent with Wilder's LIV (–); in the 9 cases in Pattern II, the results were 2, 6, and 1, for positive, zero, and negative, respectively. On another occasion, Myrtek (1984) and his research team reported that positive initial-value dependency occurred in 13.5% of all intraindividual cases and in 42.9% of the interindividual cases. The validity of Wilder's LIV is thus seriously challenged.

However, the scope of the research by Myrtek and Foerster (1986a) is still too narrow to cover the six patterns conceptualized in this article. To further illustrate the new methodology for testing LIV, some data from a project of stress-management techniques (see Jin, 1989, 1990, for details) were reanalyzed by calculating  $\beta_e$  values and conducting related  $t$  tests. There were two studies in this stress-management research project. In the first study, 66 subjects (36 men and 30 women) were recruited in a procedure consisting of 3 sessions: 0.5 hr of baseline → 1 hr of Tai Chi Chuan exercise<sup>3</sup> → 1 hr of recovery period. In the second study, 96 subjects (48 men and 48 women) were repeatedly tested under the following two conditions: (a) baseline → 1 hr of mental stress (mental arithmetic tests and bogus IQ tests in a noisy setting under high time pressure) → 1 hr of post-stress treatment (either physical exercise or relaxation without physical activity); (b) baseline → 1 hr of emotional stress (watching a stressful film) → 1 hr of post-stress treatment (either physical exercise or relaxation without physical activity). Physiological dependent variables included heart rate (mean, variability, peak, and lowest heart rate), blood pressure (systolic/diastolic), immunological globulin-A (Ig-A) concentration in saliva, salivary cortisol, urinary catecholamines (noradrenaline, adrenaline, and dopamine), and urinary serotonin (5-HT). Psychological responses were tension, depression, anger, vigor, fatigue,

confusion, total mood disturbance (TMD), state anxiety, cognitive anxiety, somatic anxiety, and perceived physical or mental workload.

Two-tailed  $t$  tests revealed that 49 of 209 cases had no significant change from initial to final value; thus, the initial-value dependency in these cases was negligible. However, according to the traditional indices of LIV (i.e.,  $r_{DX}$ ,  $b_{DX}$ , and  $b_{YX}$ ), 48 of these 49 cases would have had a pro-Wilder's LIV effect. Table 2 is a summary of LIV testing of the remaining 160 cases in which the change from initial to final value was significant ( $p < .05$ , two-tailed). Under the two preconditions (i.e.,  $D_e$  and  $r_{DX}$  are significant at the level of  $p < .05$ ), the criterion for negative initial-value dependency is  $\beta_e < 1$  ( $p < .05$ ), and the criterion for positive initial-value dependency is  $\beta_e > 1$  ( $p < .05$ ). Once again, the conclusion drawn from the new LIV methodology is significantly different from that obtained through the old LIV methodology for both physiological variables,  $\chi^2(2, N = 77) = 48.86$ ,  $p < .000001$ , and psychological variables,  $\chi^2(1, N = 83) = 5.80$ ,  $p < .02$ , Yate's correction,  $\chi^2(1, N = 83) = 3.21$ ,  $p < .08$ .

Further scrutiny of the data revealed that (a) for physiological variables, positive initial-value dependency was obvious in Patterns I and V, whereas negative initial-value dependency was displayed in Patterns II and III (the negative initial-value dependency in one case of Pattern V was probably due to a ceiling effect); (b) for psychological variables, negative initial-value dependency was displayed in Patterns II and III. Note that  $D_e$  was positive in Patterns I and V, and negative in Patterns II and III. Both the positive initial-value dependency shown in Patterns I and V and the negative initial-value dependency in Patterns II and III imply greater reactivity for subjects with high initial values. The operation of LIV in the remaining psychophysiological patterns, however, was not clear because of insufficient data.

<sup>3</sup> Tai Chi Chuan (usually called Tai Chi) is a popular Chinese fitness exercise that is now widely practiced in many countries. It is a system of meditation with smooth movements that has been reported as a health improvement regimen (cf. Jin, 1989; Zhou, Shephard, Phyley, & Davis, 1984).

## Conclusion and Recommendations

### *An Appropriate Test of Initial-Value Dependency*

It is statistically appropriate to adopt the parameter of structural relationship  $\beta_e$  value (using Formula 1 or 2) as an index of initial-value dependency. The traditional LIV indices ( $b_{D,X_e}$ ,  $b_{D,X_e}$ , and  $b_{Y,X_e}$ ) either contain the spurious  $X(Y - X)$  effect or violate the assumption that  $X_e$  should be error-free in the linear regression; hence, these indices should be abandoned in future research on LIV testing. Initial-value dependency can be further tested on the basis of the null hypothesis  $\beta_e = 1$  (using Formula 3 or 4). The preconditions of this initial-value dependency test are that (a) the change from initial to final result must be significant, (b) the correlation between the initial value and the final value must be significant, and (c) the sample size should not be too small.

### *Reconceptualizing LIV*

Although more data are needed to test initial-value dependency under different conditions, the available data suggest that LIV could be reconceptualized as follows: Given the initial value within a certain medium range, the higher the initial value, the greater the organism's following reactivity; moreover, a tendency to reversed responses may occur when the initial value reaches its upper extremity. The reactivity effect is probably a feature of constitutional forces and individual differences, whereas the reversed response effect may be due to psychophysiological limitations and homeostatic mechanisms. Because the situation in which the initial value is lower than the basal level is uncommon, the initial-value dependency when the initial value reaches its lower extremity remains undemonstrated.

Understanding the initial-value dependency in this context can be of important practical use, especially in clinical applications. In interindividual cases, one can classify patients into groups with different initial levels of certain functions and then treat them according to their different reactivity levels (e.g., Johansson & Frankenhauser, 1973); in addition, one may find some links between initial levels and Type A or B behavior. In intraindividual cases, one can partially predict an individual's responses under different conditions and cyclic changes (such as activation, relaxation, pacification, recovery, intensive stress, and deep inhibition); in addition, one may find the threshold of a function for a person in whom a paradoxical response is likely to occur (cf. Haynes, Falkin, & Sexton-Radek, 1989).

### *An Expanded Framework of LIV*

Although this review has to some extent broadened the scope of the traditional LIV, this is only the tip of the iceberg: LIV research thus far based on the assumption of  $S_{X_e}^2 = S_{Y_e}^2$  is but a special category of general growth models (Goldstein, 1979). From the developmental perspective, there are probably various natural growth models that may reflect the dynamics of different populations' growth rates. Moreover, the appropriate choice of a measurement unit and an equation of transfer function (defining raw scores as a function of response measures) for a variable should rely heavily on effective theories and on our knowledge of the growth model related to this target variable

(Jamieson, 1988; Levey, 1980; Lykken, 1968; Plewis, 1985; Stemmler, 1987; Stemmler & Fahrenberg, 1989; Stratton, 1970). Linking the existing laboratory data on LIV to the findings on some developmental issues may give some insights into the issue of initial-value dependency.

The investigation into initial-value dependency can also be regarded as a kind of time-series analysis (Cleary, 1986). If the stimulation is repeated, habituation would probably play an important role in the determination of the organism's responses (Levey, 1980; Ray, Cole, & Raczyński, 1983; Stratton, 1970). Thus, a multiple-time-point methodology and the concatenation rule need to be considered. Moreover, a variety of stimuli with a large scope of intensities and durations should be used in future LIV research (Goldwater, 1988; Stratton, 1970).

It might be beneficial to examine LIV from the perspective of biocybernetics. In an efficient system, the Yin-Yang dichotomous dynamics (Capra, 1982; Hu, 1963), as expressed in the continuous strife between stability and instability, are the essential means by which the system survives or achieves longevity (Andrew, 1982; Wilder, 1967). Thus, any healthy living system must possess two complementary functions: positive feedback and negative feedback. The former tends to enhance instability, which in a sense denotes constitutional characteristics and therefore results in "the higher the initial value, the higher the reactivity." On the other hand, the latter is conducive to stability, which could be regarded as homeostatic forces maintaining the variable's level within the medium range. The thresholds of both feedback loops are in general determined by the state of the living system (i.e., the critical initial value) and the input (i.e., the effective stimulus). In this way, in order for the living system to respond effectively to the changing internal and external environment, it manages to go into oscillation by small departures from smoothness.

### For Non-LIV Researchers: How to Deal With a Possible LIV Effect

Very often, researchers have regarded initial-value dependency as a nuisance in their work and have tried to nullify it. For example, a therapist is perhaps much more interested in the "pure" effect of a special treatment rather than in any operation of LIV in clients. This is, however, not always the case. Another therapist may decide to accept the initial differences and further try to maximize the therapeutic effects under different conditions. This is an alternative formulation that identifies the contribution of initial level without discarding it (cf. Levey, 1980). It is interesting that in my review of five journals from 1980 to 1989 I found that researchers have adopted various strategies (often using a combination of several strategies in the same statistical processes) to struggle out of the shadow of LIV. For example, analysis of covariance (ANCOVA; covariate = baseline) on difference scores or poststimulus scores, residualized scores (Cronbach & Furby, 1970), autonomic lability score (ALS; J. Lacey, 1956), the distance from the first principal-component axis (AHA; see Fahrenberg et al., 1983; Myrtek, 1985; Myrtek & Foerster, 1986a; Myrtek, Foerster, & Wittmann, 1977), analysis of variance (ANOVA) on difference scores (after ascertaining that no basal differences exist between groups), percentage scores, and multivariate analyses of

variance (MANOVA) and covariance (MANCOVA). Because the scope and the purpose of this article limit detailed discussion on this topic, only a few guidelines are listed here.

First, researchers should always keep in mind the old principle that there is no substitute for randomization (Bock, 1975; Bock & Haggard, 1968). Although randomization does not improve "the closeness of the calculated experimental minus control difference to the typical causal effect for the two trials" (Rubin, 1974, p. 691), this manipulation is conducive to an "unbiased" estimate of the desired typical causal effect. When subjects are randomly assigned to different groups, systematic differences in initial value across groups are generally not expected. If the questions asked in such a randomized design allow the experimenter to deal with initial-value dependency as an error source or a statistical "noise," then the researcher is certainly justified in using either an ANOVA for repeated measures with Greenhouse-Geisser or Huynh-Feldt adjustment of degree of freedom (cf. Jennings, 1987; Maxwell & Bray, 1986; Vasey & Thayer, 1987) or a simultaneous test procedure with a Bonferroni or Scheffé-type method (cf. Bird, 1975; Bird & Hadzi-Pavlovic, 1983; O'Brien & Kaiser, 1985; Vasey & Thayer, 1987).

Second, if researchers go further and use ANCOVA or MANCOVA with the baseline as a covariate in a randomized experiment, then the question they are asking is totally different from that in the first case. They are now asking, "What would the results be if the subjects were at the same basal level?" However, sometimes this is an unrealistic question (e.g., in a weight-loss program). In addition, the assumptions for ANCOVA (cf. Elashoff, 1969; Huitema, 1980; Winer, 1971) should be satisfied—this is an issue often neglected in reports. An alternative is to use AHA scores (cf. Fahrenberg et al., 1983; Myrtek & Foerster, 1986a) to eliminate the  $X(Y - \bar{Y})$  effect:  $AHA = (Y_e - \beta_e \cdot X_e) / (1 + \beta_e^2)^{1/2}$ . In both cases, researchers may be able to shrink the within-group variance and thus have a more delicate test.

Third, when randomization is impossible, or when the sample consists of several groups with different levels of initial value, the data analysis will be much more difficult than in the earlier two cases (Bryk & Weisberg, 1977; Cook & Campbell, 1979; Rubin, 1974). This circumstance is in some instances known as Lord's Paradox (Lord, 1967, 1969, 1975; Holland & Rubin, 1983; Wainer, 1991). A feasible solution for this is largely dependent on the inferential issues raised in the study and on the researcher's expectation (Wainer, 1991). The decision-making process on statistical strategies initially is contingent on how a researcher makes an assumption about  $\beta_e$ , which is untestable. On the basis of other resources, such as intuition, theory, information accumulated in previous studies, current experimental design, or data obtained from a matched intact group, the researcher may believe that after a period the variable in a study would have been at the same rate if no intervention had been introduced. This assumption means that  $X_e = Y_e$ , so that  $\beta_e = 1$ . In such circumstances, it is reasonable to test difference scores. In a different study, the same researcher with the knowledge of a particular growth model may prefer to make the assumption that  $\beta_e \neq 1$ . Furthermore, the researcher may consider that initial-value dependency is a critical factor in the question they are trying to answer and also find that its impact is not negligible (i.e., the null hypothesis  $\beta_e = 1$  is rejected); therefore,

(while using caution in interpreting outcomes) researchers can use AHA (Myrtek & Foerster, 1986a), ALS (J. Lacey, 1956), covariance analysis (Porter & Raudenbush, 1987; Rubin, 1977), or a multiple-time-point approach (Bryk & Raudenbush, 1987) in their statistical processes.

However, as some researchers have warned (e.g., Fahrenberg, Schneider, & Safian, 1987; Myrtek & Foerster, 1986a), the major disadvantages of these "adjusting" methods are that (a) the "corrected" scores are dependent on a specific sample and therefore are no longer comparable with the scores derived from other samples, and (b) some outliers can seriously distort the entire range of "corrected" results. Under some circumstances, especially in nonequivalent group studies, ANCOVA may either overadjust or underadjust (cf. Huitema, 1980; Kenny, 1975; Weisberg, 1979). Hence, if the sample size is not large enough to represent the population, if the questions in the study are not too much concerned with initial-value dependency, or if one has some reason to assume that the target variable would have been unchanged had there been no stimulation (often, in the case in which the initial value equals the base-rate), one may simply use difference scores or a repeated-measures ANOVA to examine whether any Group  $\times$  Treatment interaction exists (cf. Huck & McLean, 1975; Wainer, 1991).

### Summary

The initial-value dependency can better be examined and understood under different conditions that represent various combinations of initial levels and trends of change rather than in the traditional way. As a result of the joint effect of constitutional drives and homeostatic mechanisms, an organism achieves flexibility, which demonstrates that (a) within the middle range of the initial state, the higher the initial value the greater the organism's reactivity, and (b) a tendency to reversed responses may occur when the initial value reaches its upper limit. Before researchers adopt any special statistical techniques to deal with groups having differential initial levels, more knowledge about the questions specified in their study, the features of the design, the underlying processes, and the extent to which the target variables have been found to vary in previous empirical research is needed to make reasonable assumptions. It is hoped that this article will attract researchers to adopt a new methodology as well as new perspectives to re-evaluate the almost 60-year-old LIV issue.

### References

- Andrew, A. M. (1982). Cybernetics and system concepts in the natural sciences. *Kybernetes*, 11, 9–13.
- Benjamin, L. S. (1963). Statistical treatment of the law of initial values (LIV) in autonomic research: A review and recommendation. *Psychosomatic Medicine*, 25, 556–566.
- Benjamin, L. S. (1967). Facts and artifacts in using analysis of covariance to "undo" the law of initial values. *Psychophysiology*, 4, 187–206.
- Bird, K. D. (1975). Simultaneous contrast testing procedures for multivariate experiments. *Multivariate Behavioral Research*, 10, 343–352.
- Bird, K. D., & Hadzi-Pavlovic, D. (1983). Simultaneous test procedures and the choice of a test statistic in MANOVA. *Psychological Bulletin*, 93, 167–178.

- Block, J. D., & Bridger, W. H. (1962). The law of initial value in psychophysiology: A reformation in terms of experimental and theoretical considerations. *Annals of the New York Academy of Sciences*, 98, 1229-1241.
- Bock, R. D. (1975). *Multivariate statistical methods in behavioral research*. New York: McGraw-Hill.
- Bock, R. D., & Haggard, E. A. (1968). The use of multivariate analysis of variance in behavioral research. In D. K. Whitla (Ed.), *Handbook of measurement and assessment in behavioral sciences* (pp. 100-142). Reading, MA: Addison-Wesley.
- Brandt, E. N., Jr. (1962). Gastric secretion and the law of initial value. *Annals of the New York Academy of Sciences*, 98, 1291-1295.
- Bridger, W. H., & Reiser, M. F. (1959). Psychophysiological studies of the neonate: An approach toward the methodological and theoretical problems involved. *Psychosomatic Medicine*, 21, 265-276.
- Brown, R. L. (1957). Bivariate structural relation. *Biometrika*, 44, 84-96.
- Bryk, A. S., & Raudenbush, S. W. (1987). Application of hierarchical linear models to assessing change. *Psychological Bulletin*, 84, 950-962.
- Bryk, A. S., & Weisberg, H. I. (1977). Use of nonequivalent control group design when subjects are growing. *Psychological Bulletin*, 84, 950-962.
- Campbell, M. E. (1981). Statistical procedures with the law of initial values. *Journal of Psychology*, 108, 85-101.
- Capra, F. (1982). *The turning point: Science, society and the rising culture*. London: Wildwood House.
- Cleary, P. J. (1986). L.I.V. R.I.P.: Comments on Myrtek and Foerster's "The law of initial value: A rare exception." *Biological Psychology*, 22, 279-284.
- Cook, T. D., & Campbell, D. T. (1979). *Quasi-experimentation*. Chicago: Rand McNally.
- Cronbach, L. J., & Furby, L. (1970). How we should measure "change"—or should we? *Psychological Bulletin*, 74, 68-80.
- Cumes-Rayner, D. P., & Price, J. (1988). Blood pressure reactivity: Pitfalls in methodology. *Journal of Psychosomatic Research*, 32, 181-190.
- Elashoff, J. D. (1969). Analysis of covariance: A delicate instrument. *American Educational Research Journal*, 6, 383-401.
- Emmons, K. M., & Weidner, G. (1988). The effects of cognitive and physical stress on cardiovascular reactivity among smokers and oral contraceptive users. *Psychophysiology*, 25, 166-171.
- Fahrenberg, J., & Foerster, F. (1982). Covariation and consistency of activation parameters. *Biological Psychology*, 15, 151-169.
- Fahrenberg, J., Schneider, H. J., & Safian, P. (1987). Psychophysiological assessments in a repeated-measurement design extending over a one-year interval: Trends and stability. *Biological Psychology*, 24, 49-66.
- Fahrenberg, J., Walschburger, P., Foerster, F., Myrtek, M., & Müller, W. (1983). An evaluation of trait, state and reaction aspects of activation processes. *Psychophysiology*, 20, 188-195.
- Furedy, J. J. (1989). On approaches to explaining cardiovascular reactivity: Toward explanations that explain. *Psychophysiology*, 26, 482-484.
- Furedy, J. J., & Scher, H. (1989). The law of initial values: Differentiated testing as an empirical generalization versus enshrinement as a methodological rule. *Psychophysiology*, 26, 120-122.
- Goldstein, H. (1979). *The design and analysis of longitudinal studies*. San Diego, CA: Academic Press.
- Goldwater, B. C. (1978). Effects of physical activity on initial level and response magnitude: An experimental study of the LIV. *Biological Psychology*, 7, 125-138.
- Goldwater, B. C. (1988). Experimental evaluation of the LIV. *Psychophysiology*, 25, 432.
- Graham, F. K., & Jackson, J. C. (1970). Arousal systems and infant heart rate responses. In H. W. Reese & L. P. Lipsitt (Eds.), *Advances in child development and behavior* (Vol. 5, pp. 59-117). San Diego, CA: Academic Press.
- Harris, R. J. (1985). *A primer of multivariate statistics* (2nd ed.). San Diego, CA: Academic Press.
- Haynes, S. N., Falkin, S., & Sexton-Radek, K. (1989). Psychophysiological assessment in behaviour therapy. In G. Turpin (Ed.), *Handbook of clinical psychophysiology* (pp. 175-214). New York: Wiley.
- Heath, H. A., & Oken, D. (1962). Change scores as related to initial and final values. *Annals of the New York Academy of Sciences*, 98, 1242-1256.
- Holland, P. W. (1986). Statistics and causal inference. *Journal of the American Statistical Association*, 81, 945-970.
- Holland, P. W., & Rubin, D. B. (1983). On Lord's paradox. In H. Wainer and S. Messick (Eds.), *Principals of modern psychological measurement* (pp. 3-25). Hillsdale, NJ: Lawrence Erlbaum Associates.
- Hord, D., Johnson, L. C., & Lubin, A. (1964). Differential effect of the law of initial value (LIV) on autonomic variables. *Psychophysiology*, 1, 79-87.
- Houston, B. K., Smith, M. A., O'Connor, L., & Funk, S. C. (1988). Interviewer style, Type A behavior, and cardiovascular response. *Behavioral Medicine*, 14, 90-95.
- Hu, Y. Z. (1963). *Qigong and setting-up exercises*. Beijing: People's Hygiene Press.
- Huck, S. W., & McLean, R. A. (1975). Using a repeated measures ANOVA to analyze the data from a pretest-posttest design: A potentially confusing task. *Psychological Bulletin*, 82, 511-518.
- Huitema, B. E. (1980). *The analysis of covariance and alternatives*. New York: Wiley.
- Hutt, C., & Hutt, S. J. (1970). The neonatal evoked heart rate response and the law of initial value. *Psychophysiology*, 6, 661-668.
- Issac, P. D. (1970). Linear regression, structural relations and measurement error. *Psychological Bulletin*, 74, 213-218.
- Jamieson, J. (1987). Bilateral finger temperature and the law of initial values. *Psychophysiology*, 24, 666-669.
- Jamieson, J. (1988). The Law of Initial Values: Influences of unreliability and skewness. *Psychophysiology*, 25, 432.
- Jennings, J. R. (1987). Editorial policy on analyses of variance with repeated measures. *Psychophysiology*, 24, 474-475.
- Jin, P. (1989). Changes in heart rate, noradrenaline, cortisol and mood during Tai Chi. *Journal of Psychosomatic Research*, 33, 197-206.
- Jin, P. (1990). *Test of the law of initial value: Using a new methodology under various conditions*. Manuscript submitted for publication.
- Johansson, G., & Frankenhaeuser, M. (1973). Temporal factors in sympatho-adrenomedullary activity following acute behavioral activation. *Biological Psychology*, 1, 63-73.
- Julien, E., & Over, R. (1981). Male sexual arousal and the law of initial value. *Psychophysiology*, 18, 709-711.
- Kendall, M. G., & Stuart, A. (1967). *The advanced theory of statistics* (2nd ed.): Vol. 2. *Inference and relationship*. London: Charles Griffin.
- Kenny, D. A. (1975). A quasi-experimental approach to assessing treatment effects in the nonequivalent control group design. *Psychological Bulletin*, 82, 345-362.
- Lacey, A. R. (1982). *Modern philosophy*. Boston: Routledge & Kegan Paul.
- Lacey, J. I. (1956). The evaluation of autonomic responses: Toward a general solution. *Annals of the New York Academy of Sciences*, 67, 123-163.
- Lacey, J. I., & Lacey, B. C. (1962). The law of initial value in the longitudinal study of autonomic constitution: Reproducibility of autonomic responses and response patterns over a four-year interval. *Annals of the New York Academy of Sciences*, 98, 1257-1290.
- Levey, A. B. (1980). Measurement units in psychophysiology. In I. Martin & P. H. Venables (Eds.), *Techniques in psychophysiology* (pp. 597-628). New York: Wiley.
- Lewis, D. (1973). *Counterfactuals*. Cambridge, MA: Harvard University Press.



- Libby, W. L., Lacey, B. C., & Lacey, J. I. (1973). Pupillary and cardiac activity during visual attention. *Psychophysiology*, 10, 270-294.
- Lord, F. M. (1963). Elementary models for measuring change. In C. W. Harris (Ed.), *Problems in measuring change* (pp. 21-38). Madison: University of Wisconsin Press.
- Lord, F. M. (1967). A paradox in the interpretation of group comparison. *Psychological Bulletin*, 68, 304-305.
- Lord, F. M. (1969). Statistical adjustments when comparing preexisting groups. *Psychological Bulletin*, 72, 336-337.
- Lord, F. M. (1975). Lord's paradox. In S. B. Anderson, S. Ball, & R. T. Murphy (Eds.), *Encyclopedia of educational evaluation* (pp. 232-236). San Francisco, CA: Jossey-Bass.
- Lovaglio, W., & Zeiner, A. R. (1975). Some factors influencing the vasomotor response to cold pressor stimulation. *Psychophysiology*, 12, 499-505.
- Lykken, D. T. (1968). Neuropsychology and psychophysiology in personality research. In E. F. Borgatta and W. W. Lambert (Eds.), *Handbook of personality theory and research* (pp. 413-509). Chicago: Rand McNally.
- Lykken, D. T., Rose, R., Luther, B., & Maley, M. (1966). Correcting psychophysiological measures for individual differences in range. *Psychological Bulletin*, 66, 481-484.
- Lyon, D. M. (1923). Does the reaction to adrenalin obey Weber's law? *Journal of Pharmacology and Experimental Therapeutics*, 21, 229-235.
- Malmstrom, E. J. (1968). The effect of prestimulus variability upon physiological reactivity scores. *Psychophysiology*, 5, 149-165.
- Maxwell, S. E., & Bray, J. H. (1986). Robustness of the quasi *F* statistic to violations of sphericity. *Psychological Bulletin*, 99, 416-421.
- Mock, D. C., Jr. (1962). The effects of the law of initial value on drug-induced diuresis. *Annals of the New York Academy of Sciences*, 98, 1296-1301.
- Myrtek, M. (1984). *Constitutional psychophysiology: Research in review*. San Diego, CA: Academic Press.
- Myrtek, M. (1985). Adaptation effects and the stability of physiological responses to repeated testing. In A. Steptoe, H. Ruddle, & H. Neus (Eds.), *Clinical and methodological issues in cardiovascular psychophysiology* (pp. 93-106). New York: Springer-Verlag.
- Myrtek, M., & Foerster, F. (1986a). The law of initial value: A rare exception. *Biological Psychology*, 22, 227-237.
- Myrtek, M., & Foerster, F. (1986b). Rejoinder to Cleary's "Comments on Myrtek and Foerster's 'The law of initial value: A rare exception.'" *Biological Psychology*, 22, 285-287.
- Myrtek, M., Foerster, F., & Wittmann, W. (1977). Das Ausgangswertproblem: Theoretische Überlegungen und empirische Untersuchungen [The problem of evaluation: Theoretical considerations and empirical investigation]. *Zeitschrift für Experimentelle und Angewandte Psychologie*, 24, 463-491.
- Niaura, R., Wilson, T., & Westrick, E. (1988). Self-awareness, alcohol consumption, and reduced cardiovascular activity. *Psychosomatic Medicine*, 50, 360-380.
- O'Brien, R. G., & Kaiser, M. K. (1985). MANOVA method for analyzing repeated measures designs: An extensive primer. *Psychological Bulletin*, 97, 316-333.
- Oken, D., & Heath, H. A. (1963). The law of initial values: Some further considerations. *Psychosomatic Medicine*, 25, 3-12.
- Oldham, P. D. (1962). A note on the analysis of repeated measurements of the same subjects. *Journal of Chronical Disease*, 15, 969-977.
- Plewes, I. (1985). *Analyzing change*. New York: Wiley.
- Porter, A. C., & Raudenbush, S. W. (1987). Analysis of covariance: Its model and use in psychological research. *Journal of Counseling Psychology*, 34, 383-392.
- Ray, R. L., & Kimmel, H. D. (1979). Utilization of psychophysiological indices in behavioral assessment: Some methodological issues. *Journal of Behavioral Assessment*, 1, 107-122.
- Ray, W. J., Cole, H. W., & Raczynski, J. M. (1983). Psychophysiological assessment. In M. Hersen, A. E. Kazdin, & A. S. Bellack (Eds.), *The clinical psychology handbook* (pp. 427-453). New York: Pergamon Press.
- Richards, J. E. (1980). The statistical analysis of heart rate: A review emphasizing infancy data. *Psychophysiology*, 17, 153-166.
- Rubin, D. B. (1974). Estimating causal effects of treatments in randomized and nonrandomized studies. *Journal of Educational Psychology*, 66, 688-701.
- Rubin, D. B. (1977). Assignment to treatment group on the basis of a covariate. *Journal of Educational Statistics*, 2, 1-26.
- Scher, H., Furedy, J. J., & Heslegrave, R. J. (1985). Individual differences in phasic cardiac reactivity to psychological stress and the law of initial value. *Psychophysiology*, 22, 345-348.
- Schmidt, K., Rose, S. A., & Bridger, W. H. (1974). The law of initial value and neonatal sleep states. *Psychophysiology*, 11, 44-52.
- Simons, C. W., & Birkimer, J. C. (1988). An exploration of factors predicting the effects of aerobic conditioning on mood state. *Journal of Psychosomatic Research*, 32, 63-75.
- Smith, M. A., & Houston, B. K. (1987). Hostility, anger expression, cardiovascular responsivity, and social support. *Biological Psychology*, 24, 39-48.
- Smith, T. W., & O'Keefe, J. L. (1988). Cross-situational consistency of cardiovascular reactivity. *Biological Psychology*, 27, 237-243.
- Steinschneider, A., & Lipton, E. L. (1965). Individual differences in autonomic responsivity. *Psychosomatic Medicine*, 27, 446-456.
- Stemmler, G. (1987). Standardization within subjects: A critique of Ben-Shakhars's conclusions. *Psychophysiology*, 24, 243-246.
- Stemmler, G., & Fahrenberg, J. (1989). Psychophysiological assessment: Conceptual, psychometric, and statistical issues. In G. Turpin (Ed.), *Handbook of clinical psychophysiology* (pp. 71-104). New York: Wiley.
- Stratton, P. M. (1970). The use of heart rate for the study of habituation in the neonate. *Psychophysiology*, 7, 44-56.
- Surwillo, W., & Arenberg, O. (1965). On the law of initial value and the measurement of change. *Psychophysiology*, 1, 368-370.
- Thorndike, E. L. (1924). The influence of chance imperfections of measures upon the relation of initial score to gain or loss. *Journal of Experimental Psychology*, 7, 225-232.
- Tucker, L., Damarin, R., & Messick, S. (1966). A base free measure of change. *Psychometrika*, 31, 457-473.
- Vasey, M. W., & Thayer, J. F. (1987). The continuing problem of false positives in repeated measures ANOVA in psychophysiology: A multivariate solution. *Psychophysiology*, 24, 479-486.
- Wainer, H. (1991). Adjusting for differential base rates: Lord's Paradox again. *Psychological Bulletin*, 109, 147-151.
- Weisberg, H. I. (1979). Statistical adjustment and uncontrolled studies. *Psychological Bulletin*, 86, 1149-1164.
- White, K. D. (1977). Salivation and the law of initial values. *Psychophysiology*, 14, 560-562.
- White, P. A. (1990). Ideas about causation in philosophy and psychology. *Psychological Bulletin*, 108, 3-18.
- Wilder, J. (1957). Adrenalin and the law of initial value: A critical survey. *Experimental Medicine and Surgery*, 15, 47-67.
- Wilder, J. (1958). Modern psychophysiology and the law of initial value. *American Journal of Psychotherapy*, 12, 199-211.
- Wilder, J. (1967). *Stimulus and response: The law of initial value*. Bristol, England: Wright.
- Winer, B. J. (1971). *Statistical principles in experimental design* (2nd ed.). New York: McGraw-Hill.
- Zhuo, D., Shephard, R. J., Phyley, M. J., & Davis, G. M. (1984). Cardio-respiratory and metabolic responses during Tai Chi Chuan exercise. *Canadian Journal of Sport Science*, 9, 7-10.

Received May 7, 1990

Revision received April 15, 1991

Accepted August 2, 1991 ■