Evidence for the Upward Spiral Stands Steady:A Response to Heathers, Brown, Coyne, & Friedman

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Evidence for the Upward Spiral Stands Steady:

A Response to Heathers, Brown, Coyne, & Friedman

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In 2013, we reported in *Psychological Science* on a longitudinal field experiment in which we randomized participants to receive positive-emotions training (or not) to illuminate the pathways by which positive emotions might build physical health (Kok et al., 2013). The commentary offered by Heathers, Brown, Coyne and Friedman claims to overturn the conclusions that we and our co-authors drew in that original report. Here we rebut their claims and illustrate how our substantive conclusions in fact stand steady.

Conceptually, Heathers and colleagues contend that cardiac vagal tone is not a valid proxy for physical health, and even if it were, that HF-HRV is a flawed measure of cardiac vagal tone. It is true that scientists continue to debate the proper measurement and interpretation of cardiac vagal tone. It is also true, as we noted in our original report (pp. 8-9), that future research should include additional objective health-related markers to complement the findings that we reported in this particular article. However, other claims by Heathers and colleagues are based on misrepresentations of our original report and misrepresentations of the extant research literature. For example, our conclusions do not hinge on the unique properties of a single measurement approach because we found support for our hypothesized model using both frequency-domain (HF-HRV) and time-domain (RSA) measures of cardiac vagal tone, the latter of which entails direct measurement of respiration using pneumatic bellows that encircle each participant's ribcage. Although we clearly conveyed this dual measurement strategy in our report (p. 4), Heathers and colleagues failed to mention this fact and indeed implied that we did not measure respiration (p. 8). These authors also implied that our post-workshop assessments of HF-HRV were obtained while participants meditated, which would presumably slow their breathing. This was not the case, however. As indicated in our original report (p. 4), both baseline and post-workshop measures of cardiac vagal tone were carried out under identical instructions, at rest, without constraints or suggestions regarding respiration. To test whether respiratory changes were indeed confounded with experimental treatment, and thereby might offer an alternative explanation for our reported findings, here we report the results of a repeated-measure ANOVA that compares baseline and post-workshop values for respiratory period (seconds per breath cycle). Table 1 reports descriptive statistics by experimental treatment group and Table 2 provides analysis results. No statistically significant main effects for, or interaction of, treatment condition and time emerged for respiratory period. Thus, contrary to the claims made by Heathers and colleagues, changes in respiration cannot account for the observed changes in HF-HRV reported in Kok et al., 2013.

Table 1

Descriptive statistics for respiratory period by experimental treatment group

	Experimental group		Waitlist control	
	Baseline	Post-workshop	Baseline	Post-workshop
Respiratory Period	5.17 [4.51,5.91]	5.45 [4.80,6.19]	4.97 [4.36,5.66]	5.00 [4.42,5.65]

Note: Values were log-transformed to correct for skewness. Descriptive statistics, represented in the format "mean [95% CI]" were calculated then back-transformed for inclusion in the table.

Table 2

F-values for Direct Effects and Interaction of Treatment and Time on Respiratory Period in Repeated-measures ANOVA

Treatment	0.564	ns
Time	0.676	ns
Treatment x Time	0.444	ns

Note: Degrees of freedom are 1, 56. With these *df*, *F*-values greater than 4.0129 are required for an effect to be significant at $p < .05$. Three participants were not included in these analyses due to missing respiratory data.

Regarding the validity of cardiac vagal tone as a health-relevant biological indicator, ample evidence across 36 studies using a variety of measurement techniques, including HF-HRV, has shown cardiac vagal tone to be associated with all-cause mortality and cardiovascular disease (for a review, see Thayer & Lane, 2007). In prospective studies, decreased vagal function precedes the development of hypertension (Schroeder et al., 2003) and diabetes (Carnethon, Golden, Folsom, Haskell, & Liao, 2003). As such, cardiac vagal tone is a useful index of physical health and mortality risk.

Statistically, Heathers and colleagues make two primary claims. First, they claim that a significant main effect of experimental condition on cardiac vagal tone is required for demonstration of an upward spiral. We note here that modern mediation analyses are not predicated on tests of direct effects being significant (MacKinnon & Fairchild, 2009; Zhao, Lynch, & Chen, 2010). Indeed, a direct effect of LKM on HF-HRV is not required to test our primary hypothesis (depicted in Figure 1 in our original report), which stated that the well-known link between positive emotions and health (Pressman & Cohen, 2005) might be explained by related changes in social closeness. To test our hypothesis, we randomized participants to a 6-week meditation workshop centered on loving-kindness meditation (LKM) as a training technique to experimentally manipulate positive emotions over time; such randomization is necessary for making causal assertions about subsequently observed physiological changes relative to any changes observed in the control group. As noted in the online supplementary material for our original report (p. 2), we observed a linear increase in positive emotions for participants in the meditation training group. This result indicates that the experimental manipulation was successful. Moreover, our complete latent growth model (pg. 5-6) clearly demonstrated experimental group differences in changes in cardiac vagal tone: Experimental

Condition and baseline HF-HRV combined to predict increases in positive emotions, which in turn predicted increases in social closeness, which in turn predicted increased HF-HRV over the 9-week span of the study. Our focus was to demonstrate an upward spiral through these interrelationships. Our findings allow the conclusion that, relative to those in a waitlist control group, those who practice LKM may increase HF-HRV if, and only if, LKM increases positive emotions and, in turn, perceived positive social connections.

These authors' second statistical claim is that a logarithmic transformation is preferable to the square-root transformation as a means to normalize the skew in the raw HF-HRV data. What these authors fail to mention is that when their preferred transformation is used to test our hypothesized model (Figure 2 in our original report), the same pattern of significance emerges. Table 3 compares the model results based on square-root transformation (as reported in our original report, pp. 5-6) to those based on logarithmic transformation. In reanalyzing our data for this rebuttal, we also considered Heathers and colleagues concerns about "biologically impossible" and "implausibly high" values for HF-HRV. Specifically, for each of the six participants whose HF-HRV values these authors called into question, we shared the corresponding raw data files with James Long, an outside expert in the measurement and interpretation of autonomic physiological data, who was unaware of experimental condition. After a detailed examination of these data files, he concluded that data from two of the identified six participants should indeed be excluded from analyses (557004 at t2 and 557027 at t2). Results in Table 3 reflect the omission of these two participants. Regardless of whether these participants are included or not, and whether raw data are transformed by square-root or by logarithm, substantively identical results emerge (cf., paths d, e, g, h, and k in Table 3).

Table 3

Mediational Parallel-Process Latent Growth Model Results Using Square-Root and Logarithmic Transformations of HF_HRV

Path in Figure 2 of Kok et al., 2013	Square-root (Kok et al., 2013)	Logarithmic[1]
Condition to PE Intercept, *a*	-.03	-.03
T1 HF_HRV x Condition to PE Intercept, *b*	.12	.17
T1 HF_HRV to PE Intercept, *c*	.05	.01
Condition to PE Slope, *d*	.05***	.05**
T1 HF_HRV x Condition to PE Slope, *e*	.04**	.03*
T1 HF_HRV to PE slope, *f*	-.01	-.01
PE Intercept to SC Intercept, *g*	1.11***	1.10***
PE Slope to SC Slope, *h*	1.04***	1.03***
PE Intercept to T2 HF_HRV[2]	-.22	-.17
SC Intercept to T2 HF_HRV, *j*	.07	.04
SC Slope to T2 HF_HRV, *k*	4.90*	3.42*
Selected Model Fit Statistics		
RMSEA	0.078	0.078
CFI	0.95	0.95

Note. PE: Positive emotions; SC: Social connections; HF_HRV: High-frequency heart rate variability; ***p<.0001, **p<.01, *p<.05; all p-values are two-tailed.

[1]In re-fitting the original model with the logged transformation of HF_HRV, the first-order derivative product matrix was non-positive definite. We resolved this problem by utilizing T2 HF_HRV as the final dependent variable rather than the HF_HRV residualized change score used in Kok et al. (2013), and including an additional path from T1 HF_HRV to T2 HF_HRV.

[2] For clarity of presentation, the path from PE Intercept to T2 HF_HRV was not shown in Figure 2 of Kok et al., 2013 and thus does not have an alphabetic path designation.

In sum, none of the critiques offered by Heathers and colleagues change the fact that the data we reported in Kok et al. (2013) support an upward spiral model of positive emotions as they relate to cardiac vagal tone.

Author Contributions

B.E. Kok drafted the manuscript, and B. L. Fredrickson provided critical revisions. Both authors approved the final version of the manuscript for submission.

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