

The Elusory Upward Spiral: A Reanalysis of Kok et al. (2013)

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Received 12/2/14; Accepted 1/25/15

Kok et al. (2013a) claimed to have demonstrated that practicing loving-kindness meditation (LKM) generates an “upward spiral” of mutual enhancement among positive emotions, social connectedness, and physical health, the latter being indexed by vagal nerve tone (VNT). They concluded that “advice about how people might improve their physical health . . . can now be expanded to include self-generating positive emotions” (p. 1131). Close examination of their study, however, suggests that this claim and conclusion are unwarranted for three reasons.

No Effect of Experimental Condition on VNT

Kok et al. hypothesized that participants in the LKM group would show greater increases in positive emotions than those in the control group, and that this effect would be moderated by initial (Week 1) high-frequency heart rate variability (HF-HRV). They further hypothesized that increased positive emotions would lead to increased perceptions of social connections, which in turn would lead to increased end-point (Week 9) HF-HRV, a series of effects that they described as an “upward spiral.” These hypotheses were represented by what Kok et al. described as a “variant of a mediational, parallel-process, latent-curve model” (p. 1127), which can be considered a mediated moderation model with positive emotions and social connectedness as mediators. Experts in the analysis of such models disagree on whether a significant main effect of the predictor variable on the criterion variable must be demonstrated before testing for the significance of a hypothesized mediator of that effect (e.g., MacKinnon, 2008, pp. 6–11, 67–75). But any demonstration of the existence of an upward spiral set in motion by LKM training clearly requires that there be a significant increase in

HF-HRV over time for the LKM group (i.e., a significant positive main effect of LKM on change in VNT).

Kok et al. did not report any such main effect in their article, but in their Supplemental Material (Kok et al., 2013b, p. 3) they did report an investigation of whether experimental condition predicted change in HF-HRV between time points. To do so, they (a) dropped from their analysis any participant who did not have HF-HRV data at both Week 1 and Week 9 (reducing N from 65 to 52¹), (b) applied a square-root transformation to the HF-HRV values at both time points, (c) standardized the resulting transformed values, (d) assessed change in HF-HRV by calculating the residuals from a regression of Week 9 HF-HRV on Week 1 HF-HRV, and (e) entered those residuals into a t test with experimental condition as the independent variable. This analysis yielded a near-significant main effect, $t(36) = -1.93$, $p = .06$, two-tailed, leading Kok et al. to conclude that LKM resulted in an increase in HF-HRV. In an alternative model, which they later discarded, Kok et al. (see p. 9 of their Supplemental Material) obtained a similar result that just attained significance ($z = 1.97$, $p = .05$).

However, Kok et al. failed to note that both of these purported main effects were partly due to an unexpected and unexplained negative change in HF-HRV in the control group, a change that was of similar size to the positive change in the LKM group. The mean square-root-transformed Week 1 and Week 9 HF-HRV values for the LKM group equaled 0.0350 and 0.0399, whereas the corresponding values for the control group equaled 0.0393 and 0.0345, respectively. When the t test is corrected for

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the negative change in HF-HRV in the control group, the main effect of experimental condition on change in HF-HRV is clearly not significant, $t = -0.89$, $df = 35$ with unequal variances, $p = .37$. Hence, LKM cannot be said to predict an increase in HF-HRV (or a concomitant improvement in physical health).

Furthermore, the choice of a square-root transformation of HF-HRV to correct for skewness is problematic. HF-HRV values typically exhibit substantial skew, which is nearly always handled with a logarithmic (rather than a square-root) transformation (Kuo et al., 1999). The quantile-quantile plots of the application of these two transformations to the data obtained by Kok et al., shown in Figure 1, clearly demonstrate the superiority of the logarithmic transformation in this case. However, when the analysis is repeated using the more appropriate logarithmically transformed HF-HRV data, the result is again clearly nonsignificant, $t = 1.06$, $df = 43$ with unequal variances, $p = .30$.

Use of a Nonvalidated Surrogate for Physical Health

Kok et al. relied on HF-HRV as a proxy for VNT, which they in turn interpreted as a surrogate measure for physical health. However, many researchers have cautioned against using VNT as an index of physical health because of its complexity and ambiguous clinical significance (e.g., Berntson, Cacioppo, & Grossman, 2007). At least three elements cast doubt on the validity of using VNT (whether measured with HF-HRV or any other proxy) in this role.

First, it conflates tonic VNT with the *modulation* of VNT by respiratory sinus arrhythmia (e.g., Hedman, Hartikainen, Tahvanainen, & Hakumäki, 1995). Second, increased VNT is far from consistently correlated with “improved physical health”; on an experimental level, an array of unconstrained methodological changes can affect measurement (e.g., Grossman & Taylor, 2007). Third, meditative traditions, including LKM, very often include components focused on altering the only aspect of human behavior that exhibits volitional control over the autonomic nervous system, namely, breathing. Consequently, meditative or relaxation exercises alter breathing speed, regularity, and tidal volume, all of which are capable of distorting measures of baseline VNT (Brown, Beightol, Koh, & Eckberg, 1993). It is well established that respiratory sinus arrhythmia increases dramatically when breathing slows below around 0.15 Hz, regardless of the level of autonomic regulation (Angelone & Coulter, 1964; Hirsch & Bishop, 1981). This is the most likely explanation for the fact that several participants in the study’s sample had implausibly high (above 10,000 ms^2/Hz) HF-HRV values; such participants would be in the 90th percentile for unfatigued elite athletes during supine rest (Schmitt et al., 2013) if their respiration was

controlled. Moreover, 1 participant recorded a baseline HF-HRV value of 239 ms^2/Hz before an end-point value of 10,600 ms^2/Hz ; this enormous increase is almost certainly evidence of an altered respiratory pattern, rather than increased vagal tone, across the study. Note that the problem of slower respiratory frequencies distorting baseline HF-HRV has been observed, in studies not involving meditation, when participants alter their breathing after being told to relax during baseline measurement (Quintana & Heathers, 2014). Although there is some debate over whether respiratory monitoring is necessary during HF-HRV measurement (Denver, Reed, & Porges, 2007), choosing not to monitor respiration assumes that it will remain within normative frequencies without distortion. In the study by Kok et al., however, it seems very likely that this was not the case.

No Measurement of Participants’ Practice of LKM

Kok et al. indicated that participants reported the number of minutes they spent in “meditation, prayer, or solo spiritual activity” (p. 1126 in their main article). However, this information, which would seem to be essential for an understanding of how these activities might influence the biological and psychological variables under study, is not reported anywhere in the article or the Supplemental Material, and was not included in the data set the authors provided to us. It is unclear how Kok et al. reached their conclusions about the impact of meditation practice without including a measure of the extent of that practice in their analysis. In effect, the only independent variable in their study is the assignment of experimental condition to each participant.

Conclusion

It is imperative that extraordinary scientific claims be supported with solid evidence, especially when they carry health-related messages that are likely to be widely reported by the popular media (e.g., “Don’t Bother With the Gym Today,” 2013; “Think Yourself Well,” 2012). Close examination of the article and Supplemental Material by Kok et al., as well as their data set, reveals that this evidence is missing because (a) their claim to have found a significant positive main effect of LKM on change in VNT was based on a misinterpretation of the data; (b) the validity of using VNT as an objective proxy for physical health, and of measuring VNT as HF-HRV, is questionable; and (c) the extent to which participants in the LKM group actually practiced what they had been taught in their LKM training was not considered. Without a significant positive main effect of LKM on change in HF-HRV, the principal claim that positive emotions enhance physical health and

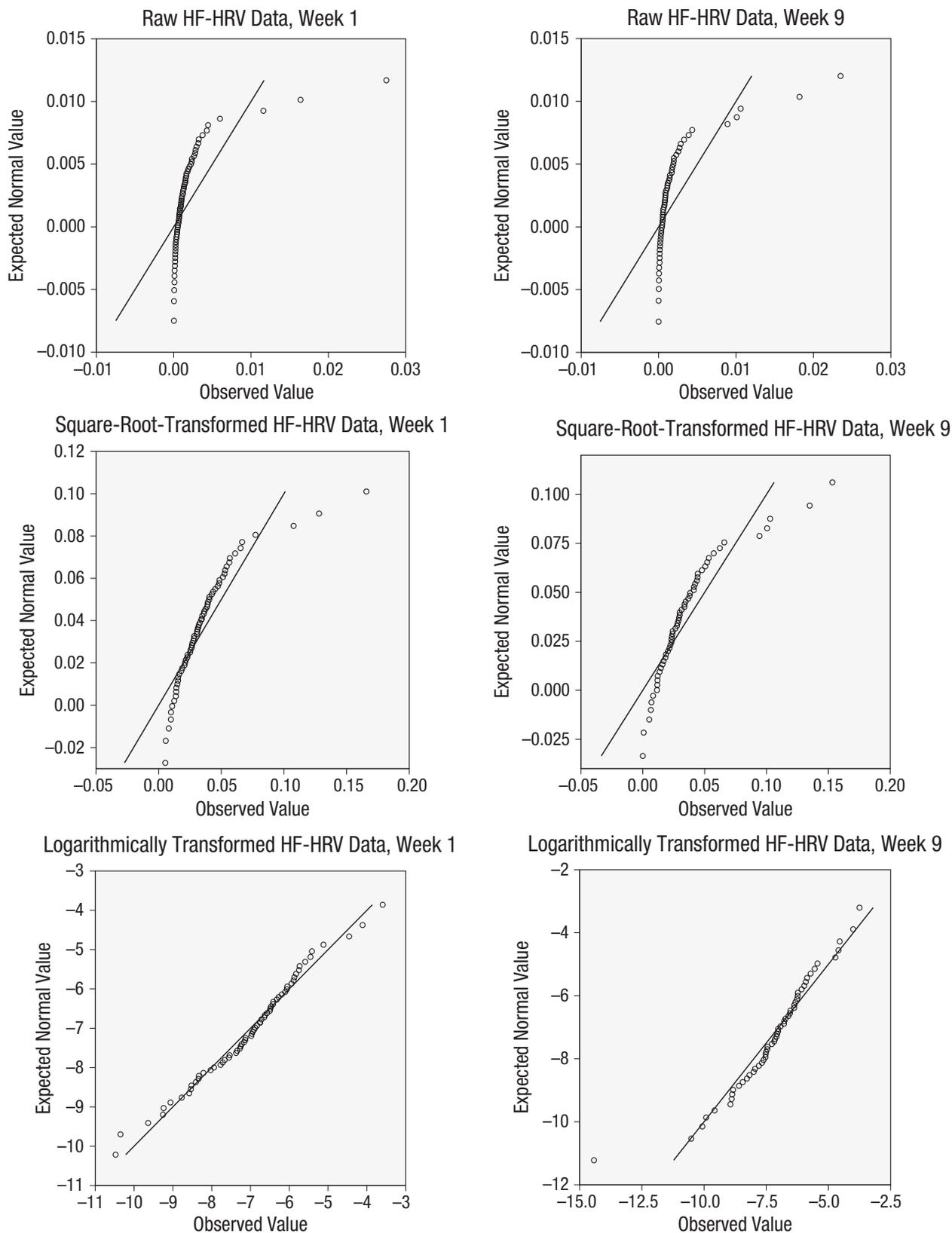


Fig. 1. Quantile-quantile plots showing the relationship between observed and expected normal high-frequency heart rate variability (HF-HRV) at the start (left) and end (right) of the study by Kok et al. Results are shown separately for raw (top), square-root-transformed (middle), and logarithmically transformed (bottom) data.

the bold assertion that perceived positive social connections account for an upward spiral between positive emotions and VNT are unsupported by our reanalysis: There appears to be no upward spiral to be explained.

Author Contributions

J. A. J. Heathers and N. J. L. Brown performed the analysis of the data set. All authors participated in drafting the manuscript, provided critical revisions, and approved the final version of the manuscript for submission.

Acknowledgments

We thank Bethany Kok for kindly providing us with the data set from the original study.

Declaration of Conflicting Interests

The authors declared that they had no conflicts of interest with respect to their authorship or the publication of this article.

Note

1. Arguably, 2 participants (#557004 and #557033) with biologically impossible Week 9 HF-HRV values of 0 and 0.54 ms²/Hz, respectively, should also have been removed.

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