Supplementary Figures and Tables

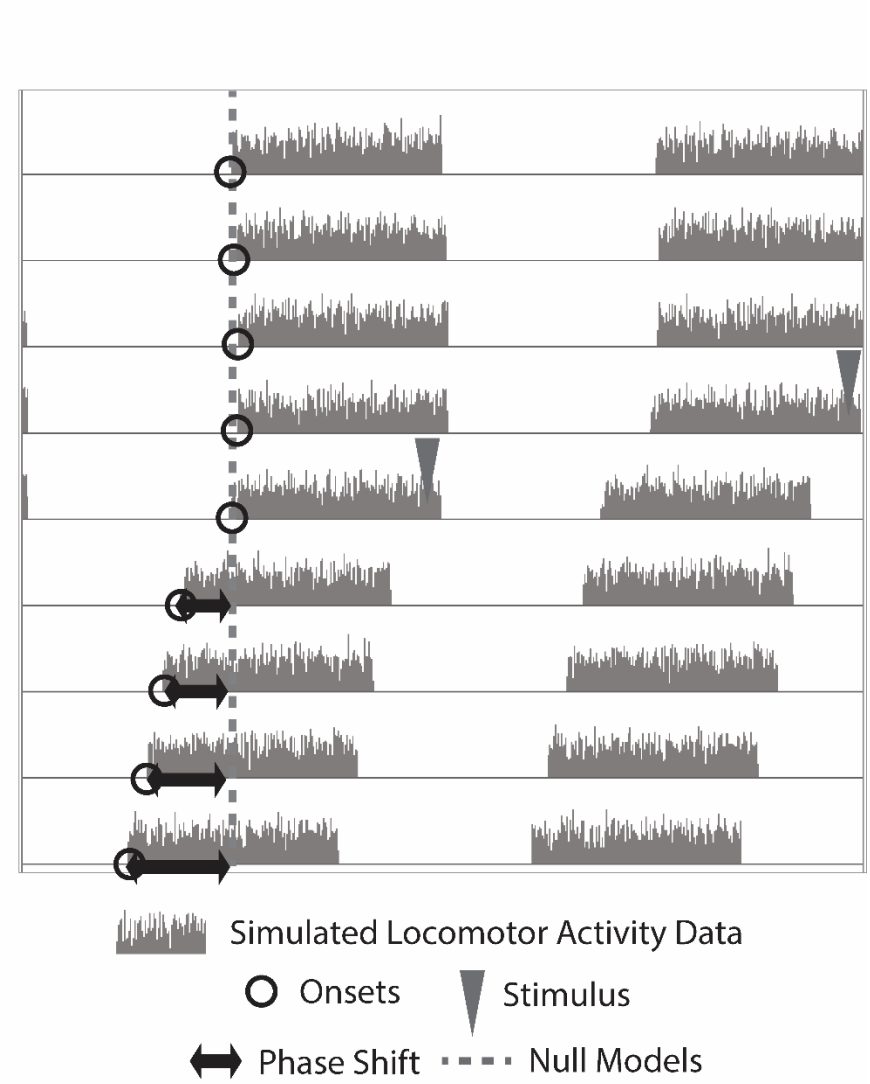

Figure S1. Period changes have effects on phase shift estimation. When the period changes between pre- and post-stimulus epochs, the comparison of the phase reference points (open circles) to the pre-stimulus null model (dashed grey line) can produce widening or narrowing estimates of phase shift (black arrows).

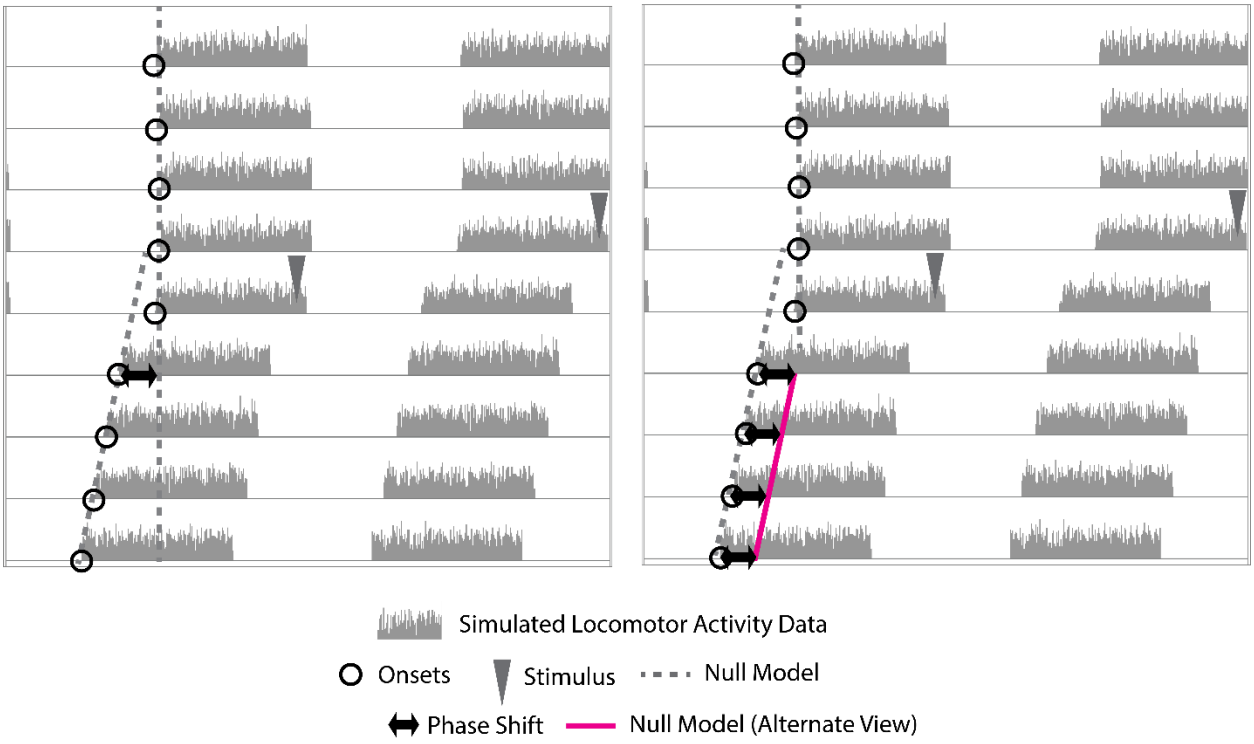

Figure S2. The basis of the actogram approach is the anchoring of a null model to the pre-stimulus model. The actogram approach can be replotted by anchoring the post-stimulus null model to the projection of the pre-stimulus null model on the first post-stimulus cycle. This produces an equivalent estimation of phase shift, because the underlying null hypothesis remains the same: that the stimulus is inducing a known period change, but no phase shift. Because this replotted null model (magenta line) has the same slope as the post-stimulus null model passing through the post-stimulus phase reference points (grey dashed line), the phase relationship between the two lines is stable and the comparison between them can be made on each cycle.

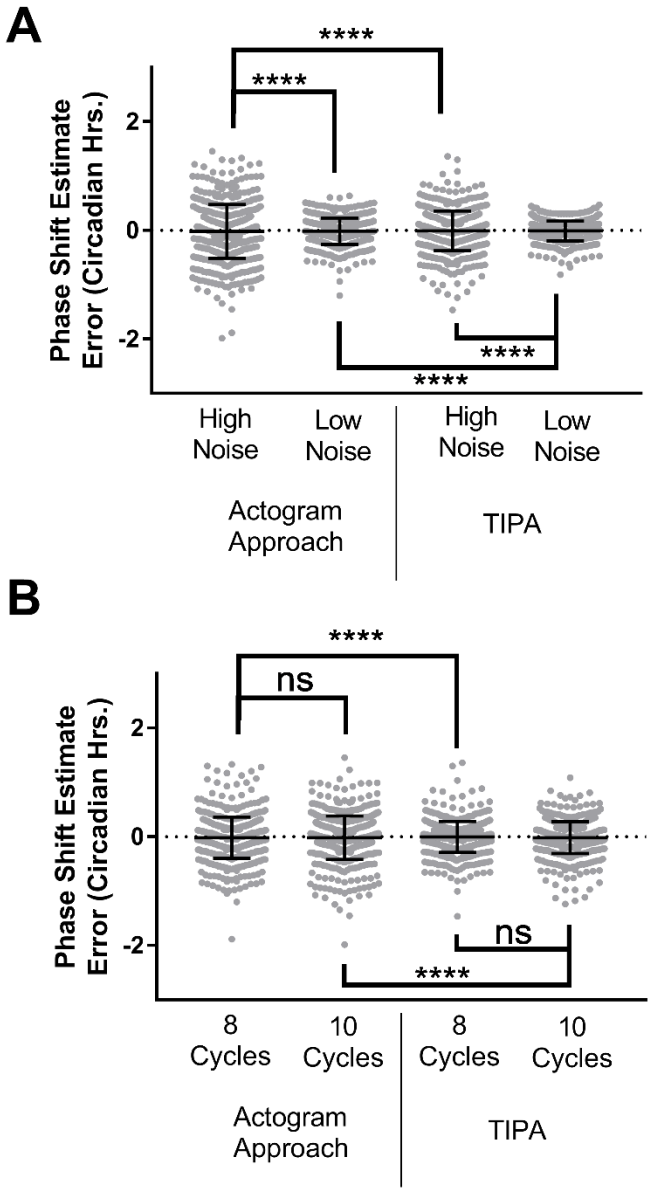

Figure S3. TIPA remains more precise despite noise level and cycle number. A, comparison of TIPA and the actogram approach in simulation groups that had high and low noise levels. For both methods, precision is higher (variance is lower) in the low-noise simulations. For both high and low noise simulations, TIPA has a higher precision (lower variance) than the corresponding actogram approach. B, comparison of TIPA and the actogram approach in simulation groups that had 8 (4 cycles pre- and post-stimulus) or 10 (5 cycles pre- and post-stimulus). Both methods had equivalent precision across each cycle number. TIPA had a higher precision than the actogram approach for both cycle numbers. Brown-Forsythe test for unequal variances, (****) corresponds to $p < 0.0001$, **ns** corresponds to $p > 0.05$.

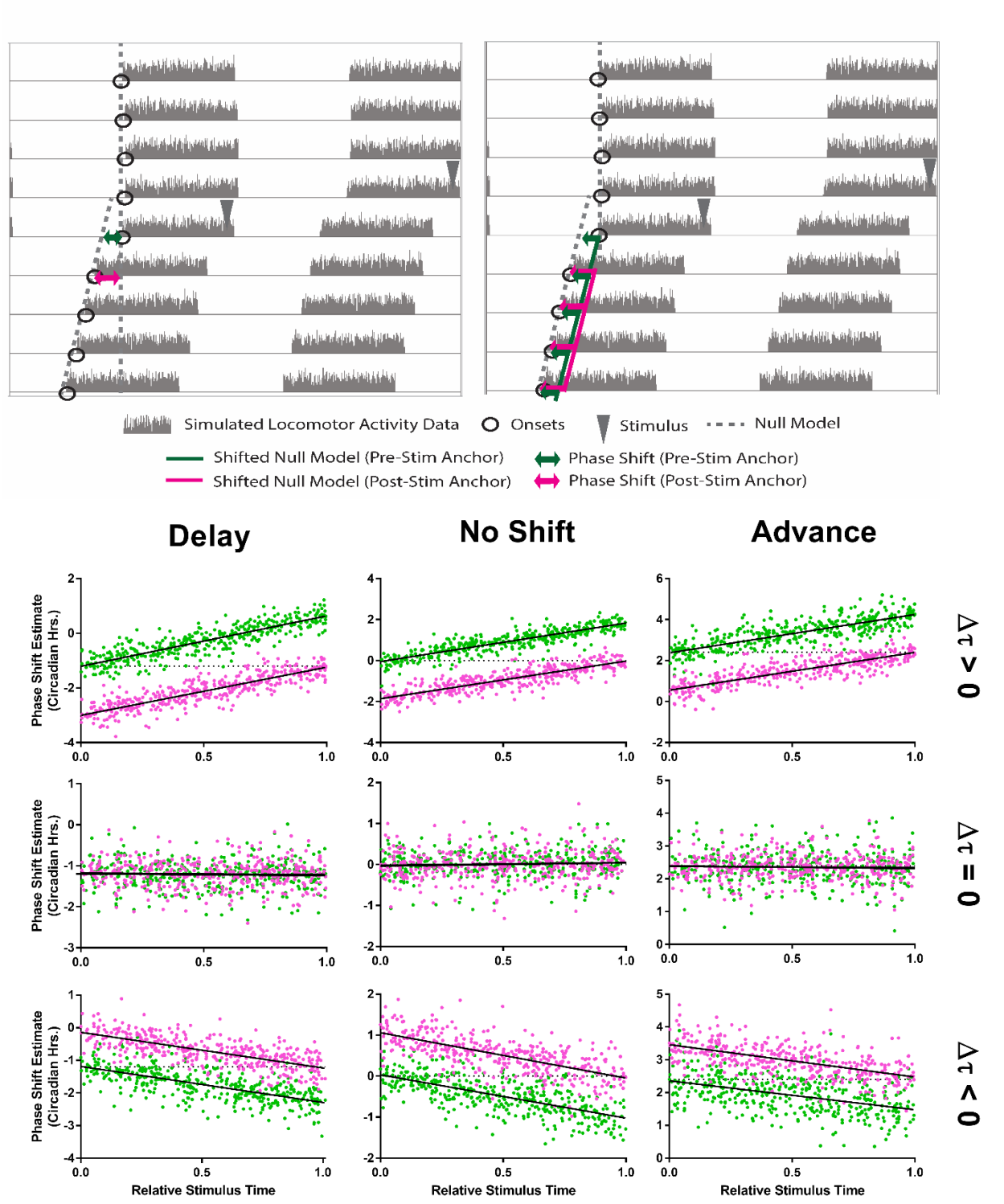

Figure S4. Anchoring the actogram approach to the last pre-stimulus phase reference point produces a complementary error in the phase shift estimate. Phase shifts can be calculated by anchoring the null model to the last pre-stimulus phase reference point (green) or the first phase reference point projected by the null (magenta, see Figure 2). This can be visualized using the traditional actogram approach (top, left) or the alternate anchor-based plotting (top, right). The phase shift estimate using each

anchor is dependent on the relative stimulus time (bottom array of 9 panels, see Figures 5 and 7). The pre-stimulus anchor (green) is most accurate when the stimulus occurs near the last pre-stimulus phase reference point, and the post-stimulus anchor (magenta) is most accurate when the stimulus occurs near the first post-stimulus phase reference point as projected by the pre-stimulus null model.

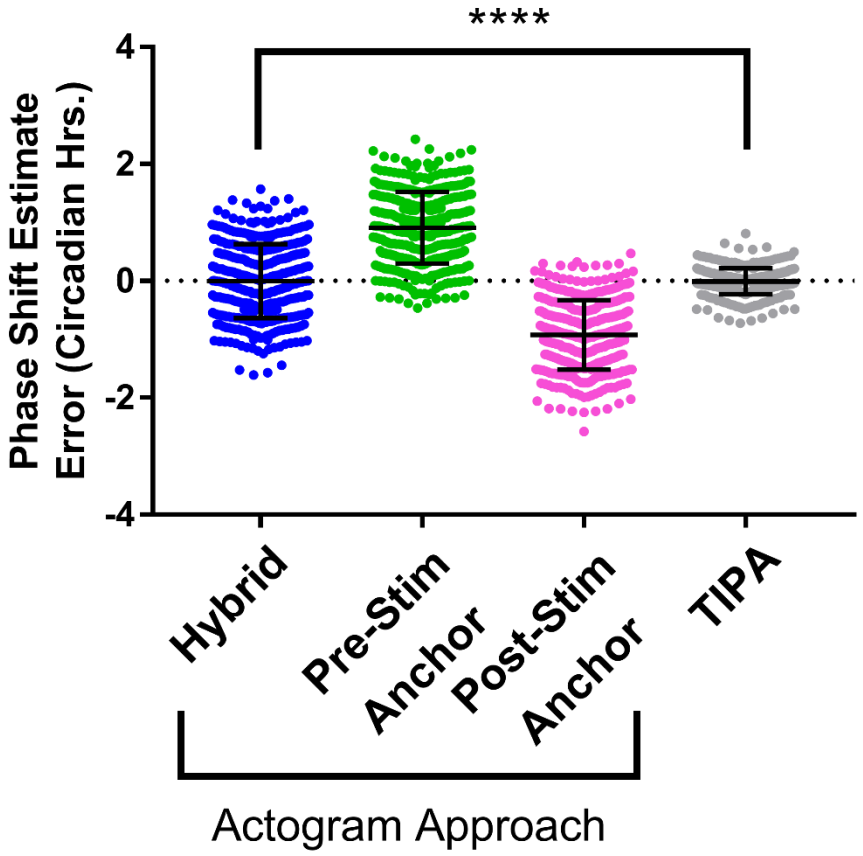

Figure S5. An example of the two actogram approach anchor points, and their hybrid, estimating the phase shift of a phase delay, lengthened period simulation group. Though the hybrid actogram approach (blue) has an error that surrounds 0, its variance is higher than that of TIPA (grey). This is because the hybrid approach is averaging the over-estimation error of the post-stimulus anchor (magenta) and the pre-stimulus anchor (green) versions. Brown-Forsythe test for unequal variances compared between TIPA and Actogram Approach Hybrid, (****) corresponds to $p < 0.0001$.

Group	*$\Delta\phi$*	*$\Delta\tau$*	*Noise*	*Total Cycles*
1	Delayed	Shortened	High	8
2				10
3			Low	8
4				10
5		Not Changed	High	8
6				10
7			Low	8
8				10
9		Lengthened	High	8
10				10
11			Low	8
12				10
13	Not Shifted	Shortened	High	8
14				10
15			Low	8
16				10
17		Not Changed	High	8
18				10
19			Low	8
20				10
21		Lengthened	High	8
22				10
23			Low	8
24				10
25	Advanced	Shortened	High	8
26				10
27			Low	8

28			10
29	Not Changed	High	8
30			10
31		Low	8
32			10
33	Lengthened	High	8
34			10
35		Low	8
36			10

Table S1. Description of parameters for each simulation group. 3,600 simulations were generated, divided into 36 groups of 100. Each group consisted of each combination of phase advance, delay, and no phase change; period lengthening, shortening, and no period change; high or low noise; and 8 or 10 total cycles generated. High and low noise correspond to 0.5 and 0.25 standard deviations of the Gaussian distribution used for the phase reference point interval generation.