1 Part 3: Sleep Study Research Question

1.1 Goal

Compare SomnoPose (phone app) against Embletta (clinical device) for measuring sleeping position, with emphasis on whether SomnoPose is sufficient to study side-dependent eye pressure risk (which depends on *which side* the subject mostly sleeps on over long horizons, not on sub-second movement detail).

1.2 Alignment of Sampling rates

- Embletta records at 10 Hz (10 samples/sec). SomnoPose records one sample every 2 seconds.
- For turn-by-turn kinematics, 10 Hz would be preferable; but our scientific question is *time spent on left/right/back etc*, which evolves on minutes/hours. Therefore SomnoPose's frequency of recording is sufficient.

1.3 Pre-processing

- **Angle convention.** Raw angles were wrapped to $[-180^\circ, 180^\circ]$ via

$$w(\theta) = ((\theta + 180) \bmod 360) - 180.$$

  For the second subject (nights 5–6), the devices were mounted with opposite sign; we therefore used the flipped convention $\theta' = -\,w(\theta)$ for Embletta on those nights.

- **Cadence matching.** Embletta ($\sim$10 Hz) was downsampled to the same 2-second grid as SomnoPose by taking the median within each 2s bin (robust to spikes/artifacts).
- **Timestamps and local time.** The SomnoPose CSV provides a numeric `timestamp` in seconds since 2001-01-01 00:00:00 UTC (Apple/ CFAbsoluteTime). We convert these to actual timestamps in UTC with POSIXct then render in Eastern Time (ET) to get the local time. Checking the resulting timestamps and dates we find that they align with the folder names of the data (November 2011) as well as the times of the recording during the night according to the README files. Embletta has no absolute clock; its time is kept as seconds since device start and is subsequently aligned to the SomnoPose clock by estimating a lag via cross-correlation.

1.4 Alignment of recording timeframe using cross-correlation

Let x_t be the 2 s SomnoPose series over the night window and y_t the 2 s Embletta series (after the sign convention above). We estimate a lag $k^\star$ (in 2 s samples) by maximizing the sample cross-correlation over a larger search window, but only among lags that yield at least 2 hours of overlapping pairs using the R function ccf(). We then align Embletta by shifting its time axis *forward* by $k^\star \cdot 2$ seconds so both traces share the same local-time x-axis. As can be seen in the title of the plots below, this data-driven approach shifts the Embletta data by about 15 seconds for subject one (days 1-4). For subject two part of the Embletta data seems to be missing, on day 5 roughly 2.5h of data (8880 sec) and on day 6 roughly 1.5h of data. The shift based on maximised cross-correlation corrects for that.

1.5 Recommendation for the Study Question

Note first that the Embletta records at 10Hz whereas SomnoPose records roughly once every 2 seconds. This lower cadence is sufficient for the research question of which side the subject is mostly sleeping on, but would not suffice for other studies examining e.g. rotations during the sleep closely.
We would expected a single small constant vertical shift between the angles of the devices, given they could never be perfectly placed similarly on a round torso. Inspecting the data we find that the offset varies by pose (e.g., on Day 2/Figure 2 the curves have an offset of about 60 degrees near 00:00 yet diverge by only 20 degrees at 00:30 when the subject rotated in their sleep). This pose-dependent bias is plausible: the devices were not perfectly co-located and, on a rounded torso, small lateral separations produce different effective rotations when the subject lies on the side; minor strap slippage could have added to this. We also find that for our test subjects, none of the nights shows sustained "tummy" sleep, angles cluster around back (0°) and left/right (±90°). For the eye-pressure question, where we mainly care about *which of the four canonical poses* (back, left, right, tummy) the subject is in, this might be acceptable: even with a modest bias (often on the order of 20–30 degrees), mapping each sample to the "nearest target angle" (0, +90, 90, ±180) would likely yield stable pose labels.
In short, SomnoPose remains adequate for side-occupancy summaries, while closer assesment of exact sleeping angle or studies investigating how the subject turns would still require the Embletta.

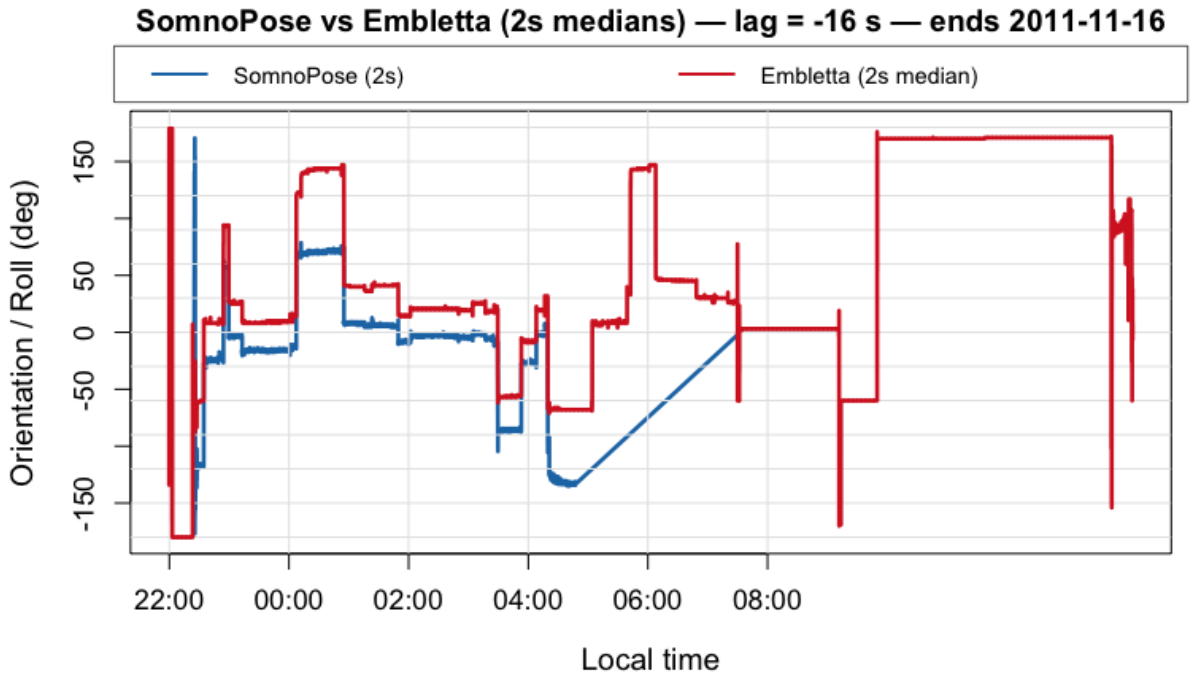

Figure 1: Night 1: SomnoPose vs. Embletta (aligned).

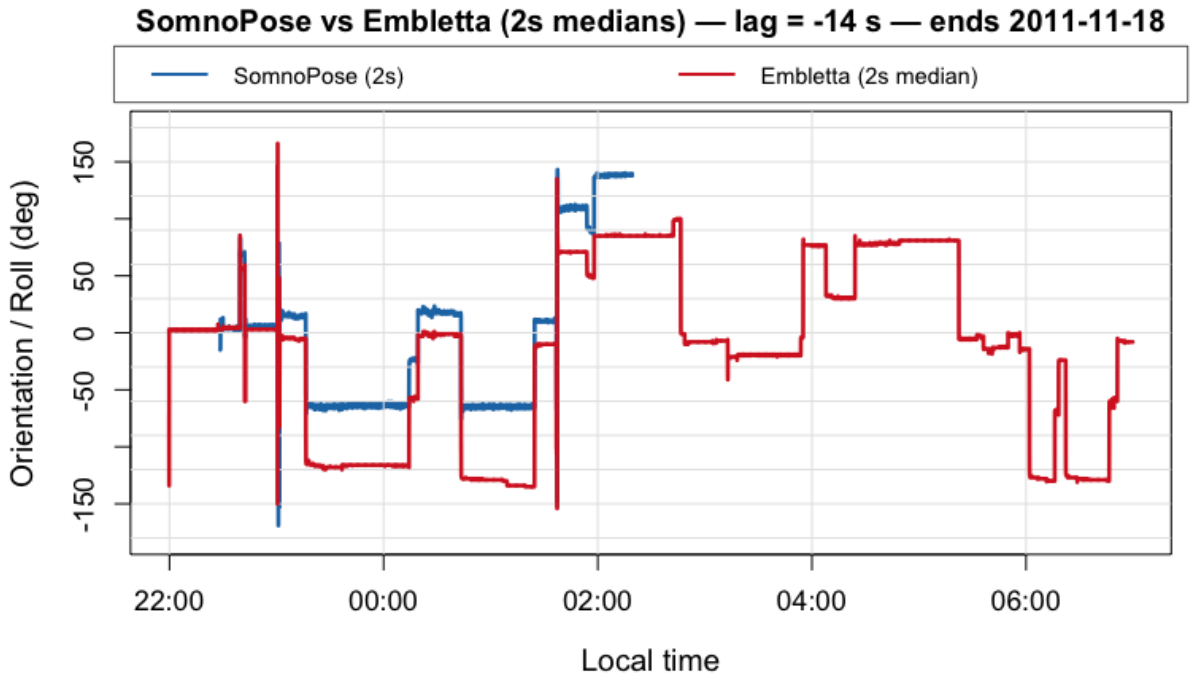

Figure 2: Night 2: SomnoPose vs. Embletta (aligned).

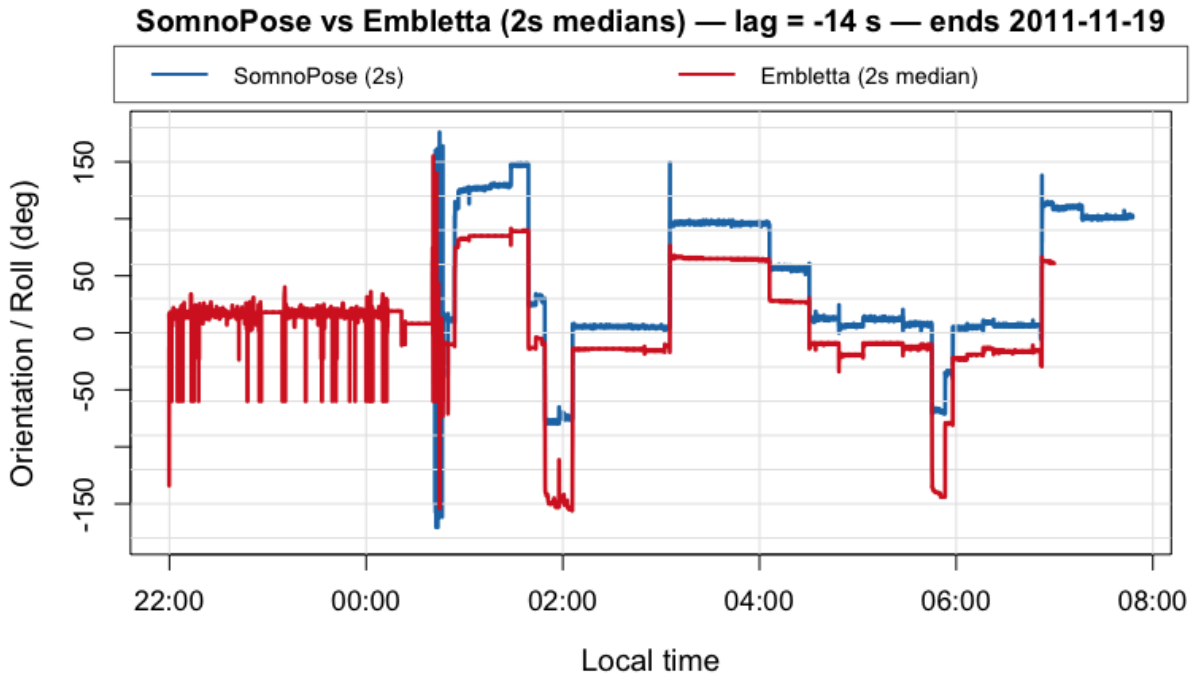

Figure 3: Night 3: SomnoPose vs. Embletta (aligned).

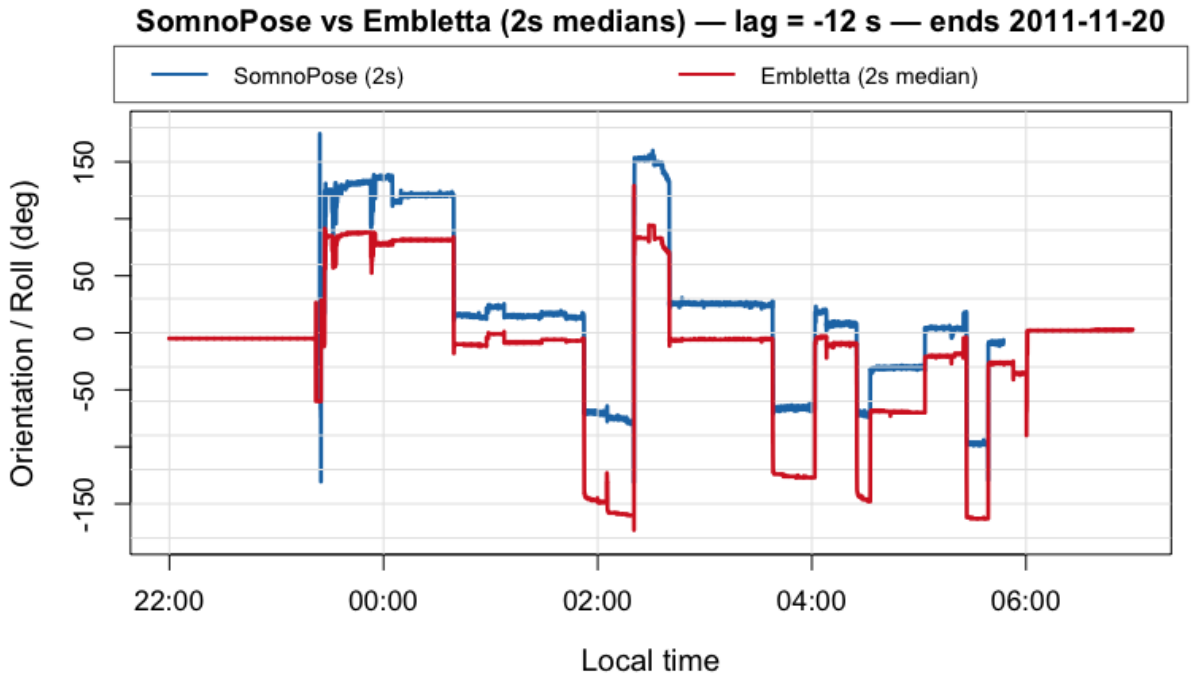

Figure 4: Night 4: SomnoPose vs. Embletta (aligned).

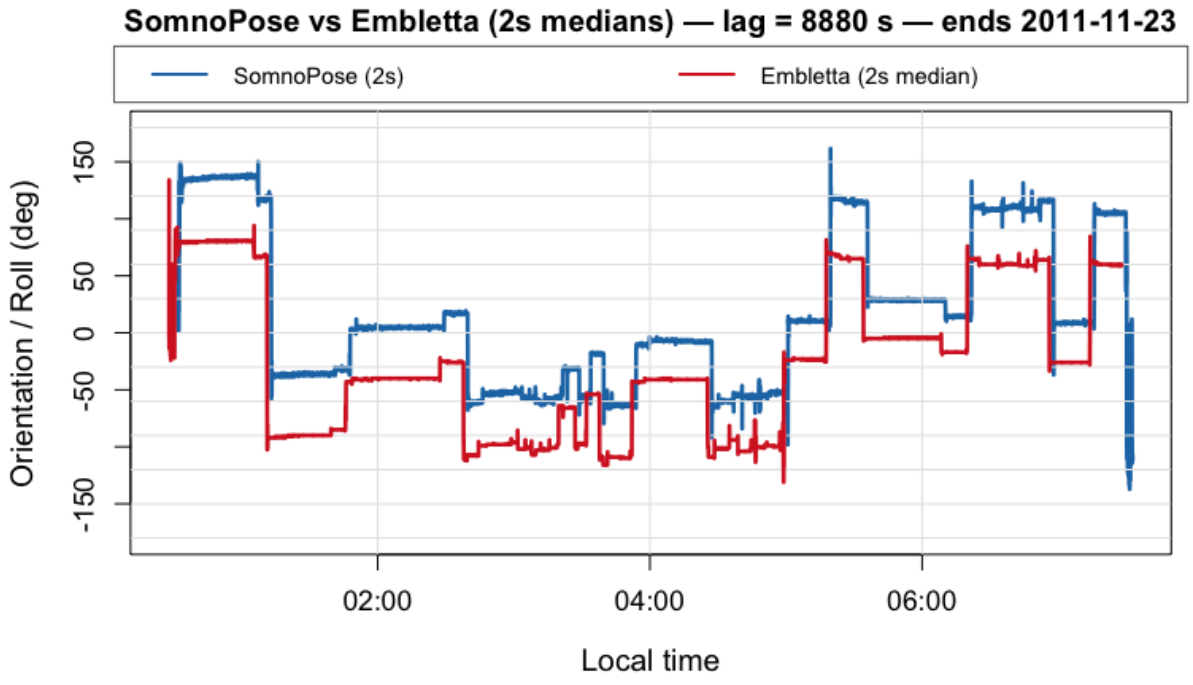

Figure 5: Night 5: SomnoPose vs. Embletta (aligned; Embletta sign flipped; overlap constrained ≥ 2 h).

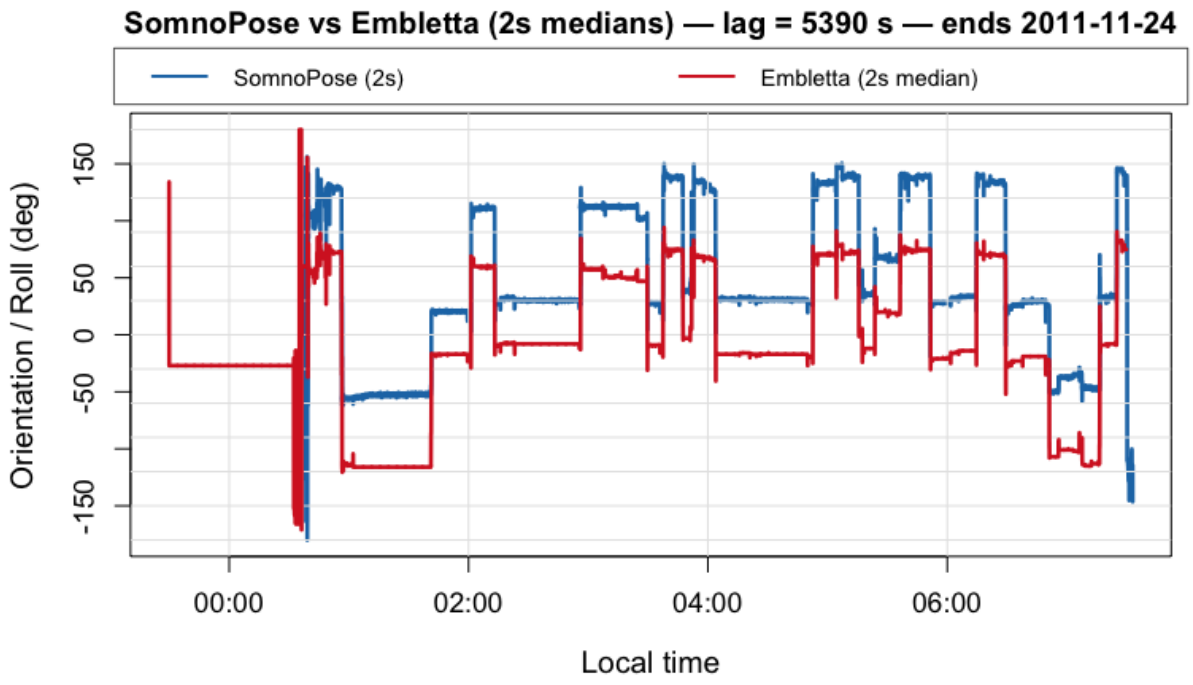

Figure 6: Night 6: SomnoPose vs. Embletta (aligned; Embletta sign flipped; overlap constrained $\geq$ 2 h).