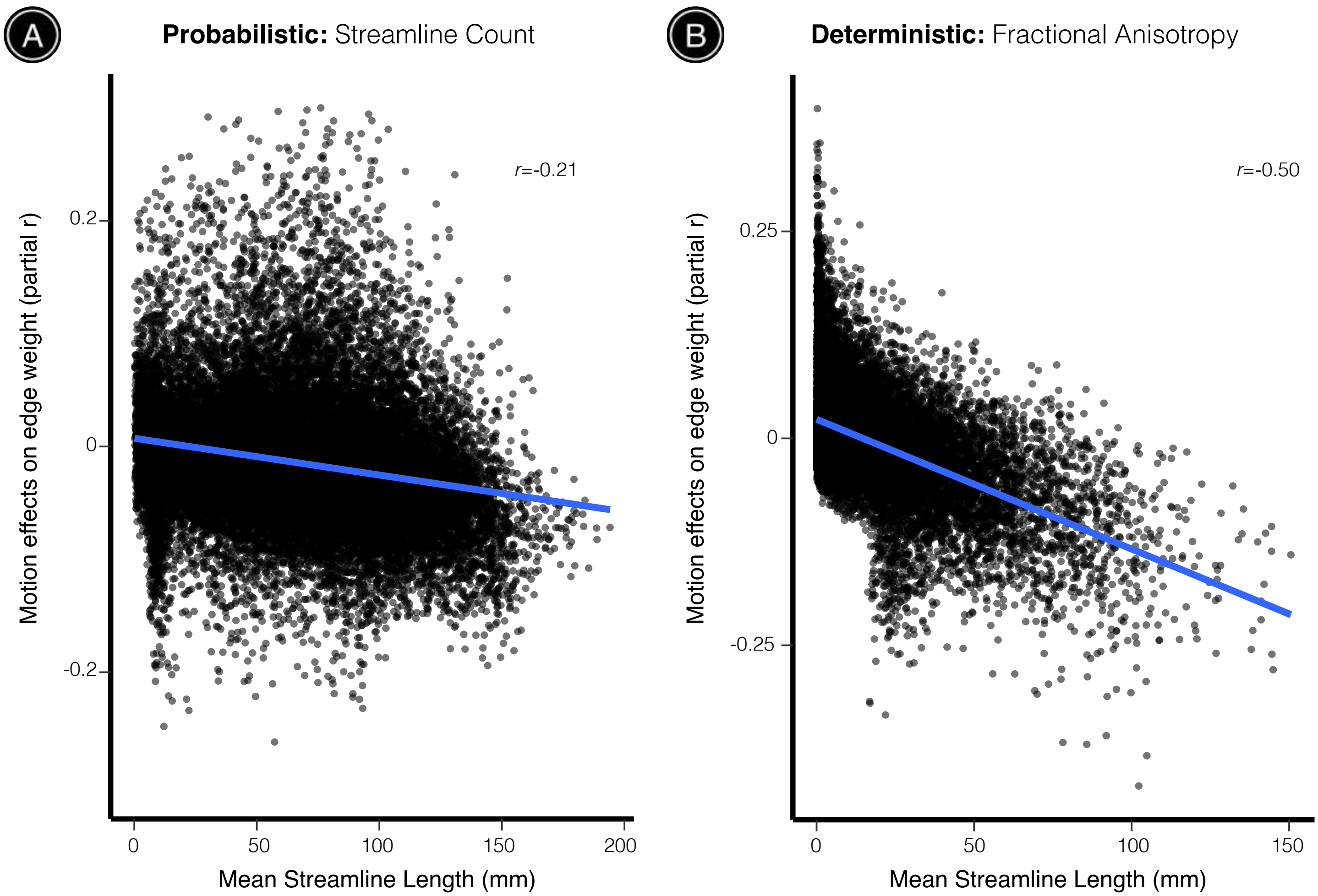
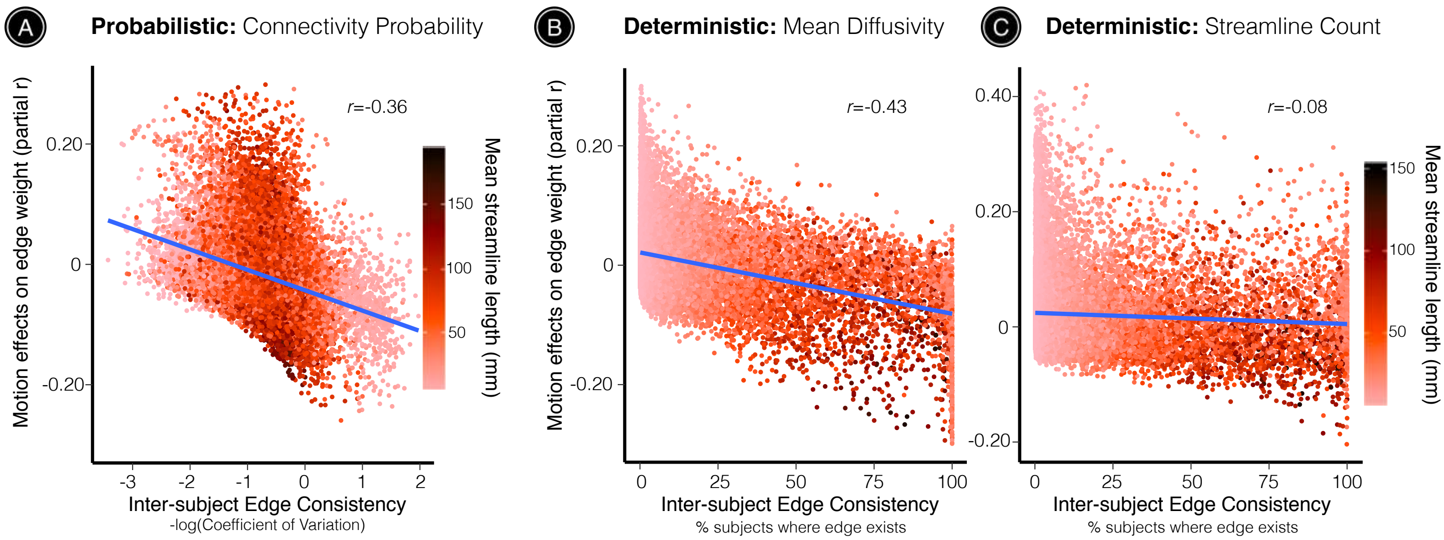
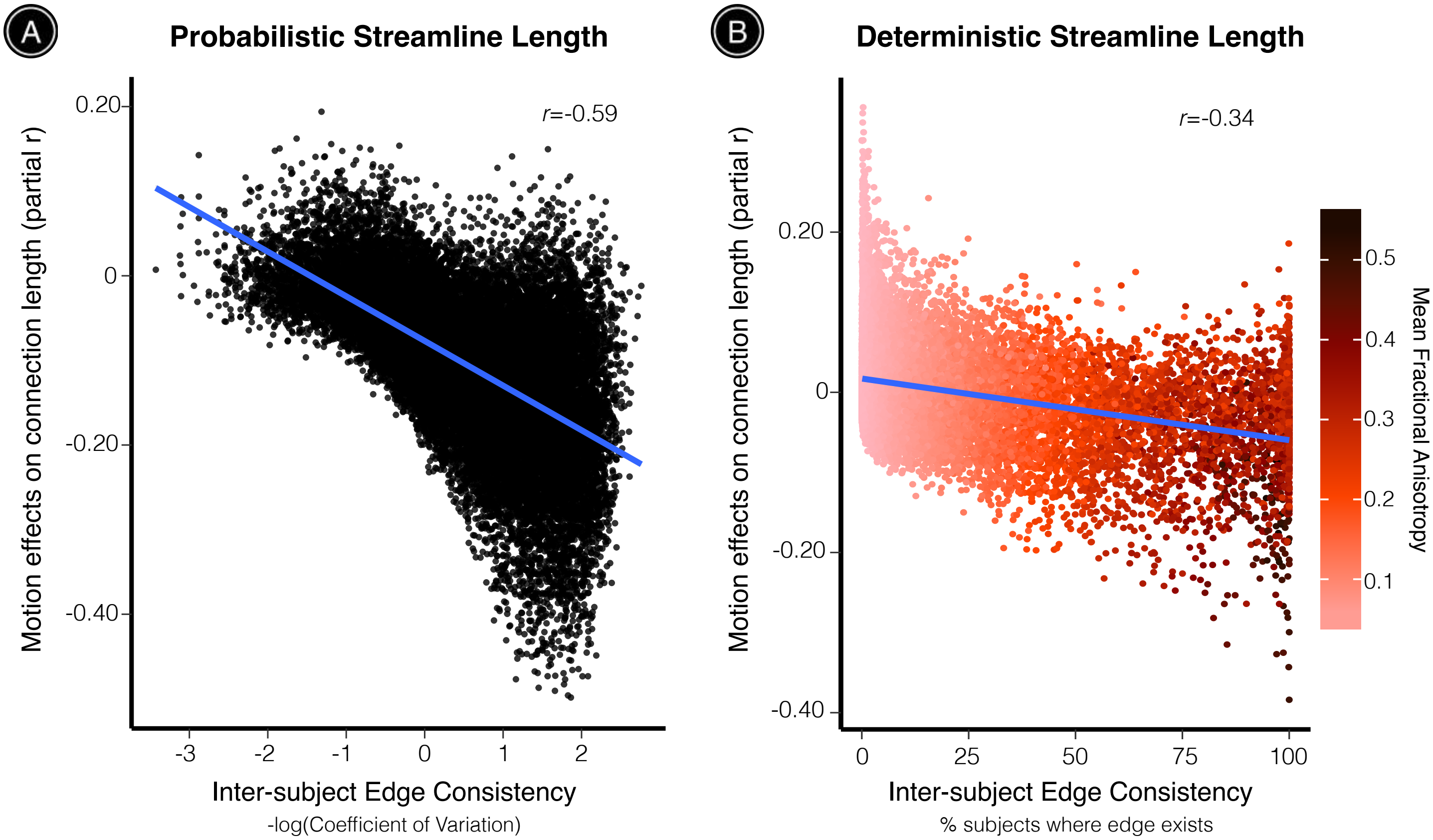


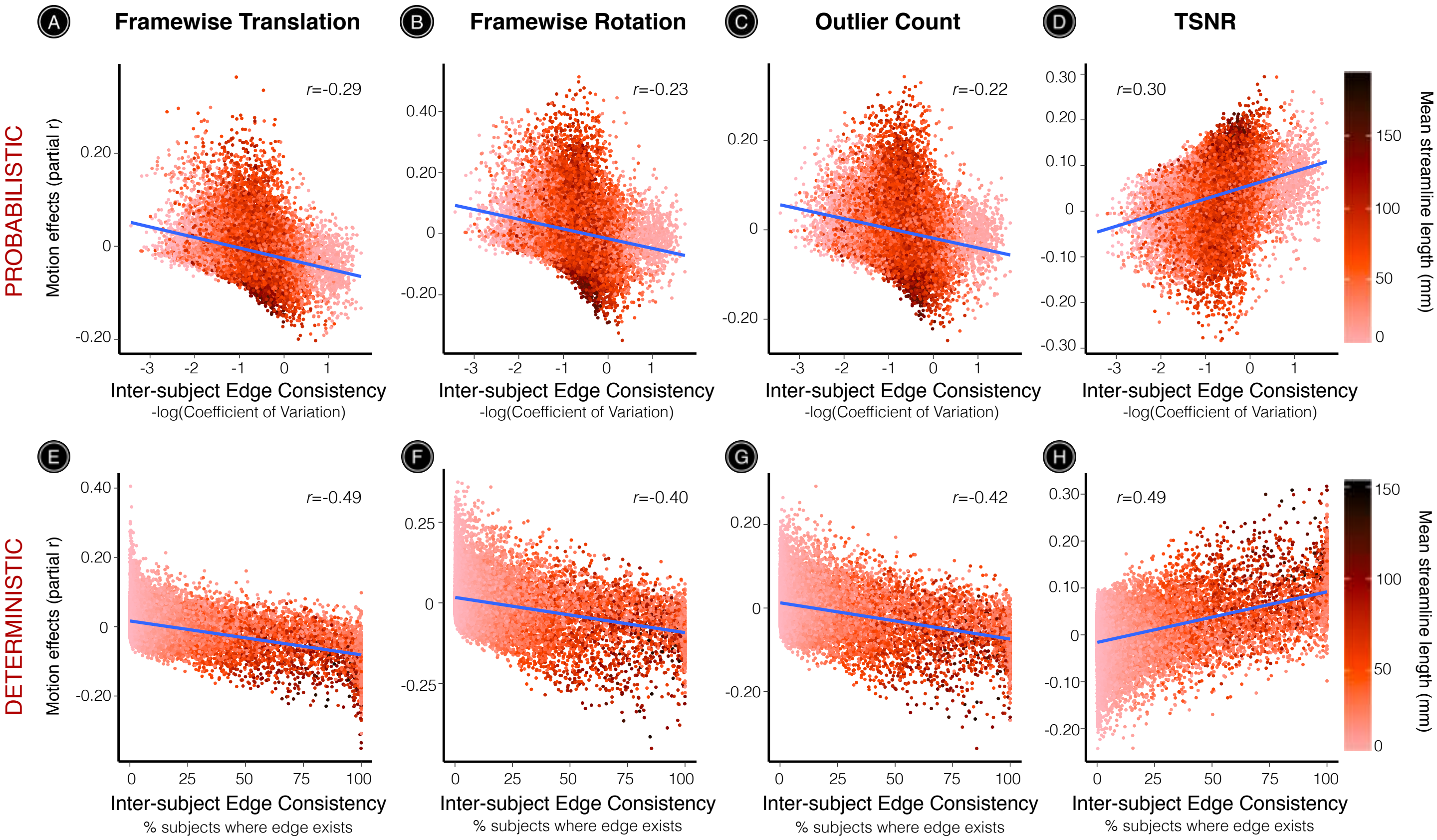

**Supplementary Figure 1. Motion effects on structural connectivity are modulated by connection length.** (**A**) When edge weights were defined by the probabilistic streamline count, the direction and magnitude of motion effects on edge strength were significantly associated with mean streamline length (*r*=-0.21). (**B**) When edge weights were defined by the mean fractional anisotropy (FA) of streamlines connecting a node pair, the direction and magnitude of motion effects on edge strength were also significantly associated with mean streamline length (*r*=-0.50). Specifically, head motion was associated with enhanced short-range connectivity and diminished long-range connectivity. The significance of all third-level correlations was evaluated using 10,000 permutations (permutation-based $p < 0.0001$). Blue lines represent a linear fit.



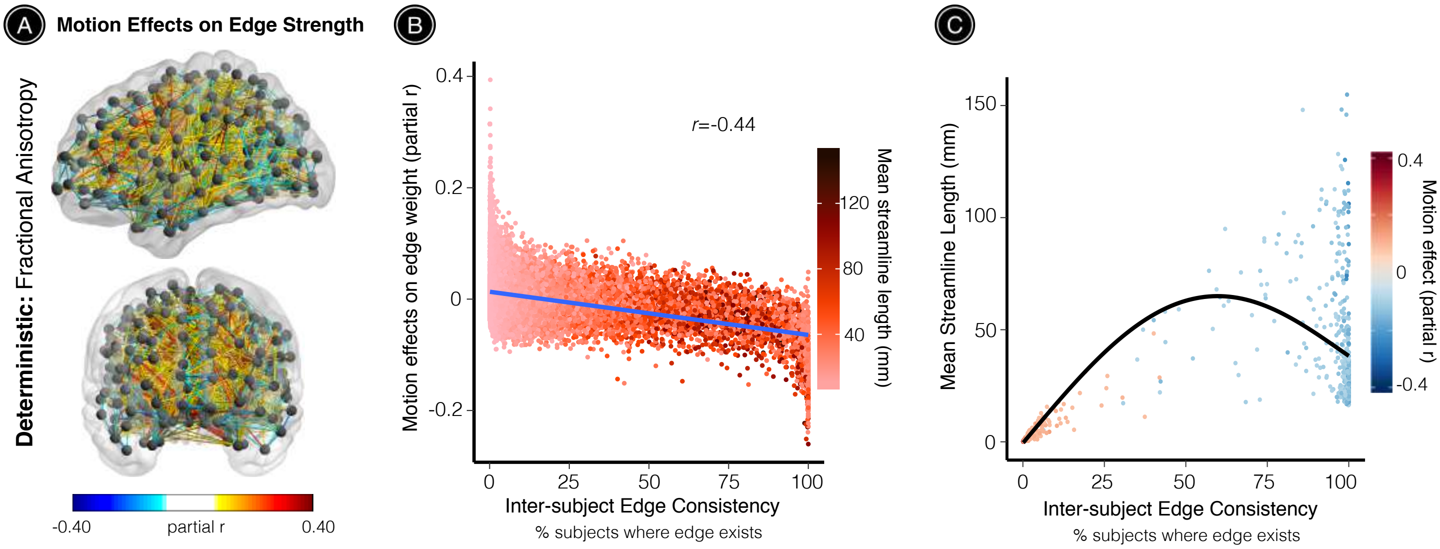

**Supplementary Figure 2. Consistency- and length-driven motion effects using alternative edge weights.** (**A**) When edge weights were defined by the connectivity probability between two nodes, 13% of all network edges were significantly impacted by motion. The direction and strength of motion effects were significantly associated with inter-subject edge consistency (*r*=-0.36) and mean streamline length (*r*=-0.20). (**B**) When edge weights were defined by the average inverse mean diffusivity (MD) along streamlines connecting a node pair for brain networks derived from deterministic tractography, 13% of all network edges were significantly impacted by motion. The direction and strength of motion effects were significantly associated with inter-subject edge consistency (*r*=-0.43) and with mean streamline length (*r*=-0.43). (**C**) When edge weights were defined by the number of deterministic streamlines connecting a pair of nodes, 12% of all network edges were significantly impacted by motion (5% negative effects). While the absolute number of edges impacted by motion was highly consistent with that of other edge weights, motion effects on streamline count-weighted networks were only weakly correlated with inter-subject edge consistency (*r*=-0.08) and with mean streamline length (*r*=-0.17) due to a higher proportion of positive motion effects on edge strength. All statistical inferences were adjusted for multiple comparisons using FDR ($Q < 0.05$). The significance of all third-level correlations was evaluated using 10,000 permutations (permutation-based $p < 0.0001$).




**Supplementary Figure 3. Motion effects on connection length are modulated by inter-subject edge consistency.** (**A**) When directly evaluating the relationship between head motion and connection length (mean length of probabilistic streamlines connecting a node pair), 62% of all network edges were significantly impacted by motion. The strength and direction of motion effects on connection length were significantly correlated with inter-subject edge consistency ($r$=-0.59). **(B**) When we evaluated the relationship between head motion and deterministic connection length (mean length of deterministic streamlines connecting a node pair), 10% of all network edges were significantly impacted by motion. The direction and strength of motion effects were significantly associated with inter-subject edge consistency ($r$=-0.34) and with mean FA ($r$=-0.39). Specifically, head motion was associated in increased connection length for low-consistency, low-FA connections, and decreased connection length for high-consistency, high-FA connections. All statistical inferences were adjusted for multiple comparisons using FDR ($Q < 0.05$). The significance of all third-level correlations was evaluated using 10,000 permutations (permutation-based $p < 0.0001$).




**Supplementary Figure 4. Effects remain highly similar using alternative measures of head motion or DTI data quality.** For networks derived from probabilistic tractography, edge weights were defined by the probabilistic streamline count between each pair of nodes. (**A**) Using the translation component of the affine registration from each volume to the first *b*=0 volume, we calculated the average magnitude of translation over all 71 volumes in the scan. This measure of framewise translation significantly impacted the strength of 5% of network edges. The direction and strength of these effects on probabilistic streamline count were significantly associated with inter-subject edge consistency ($r$=-0.29) and with mean streamline length ($r$=-0.20). (**B**) Using the rotation component of the affine registration from each volume to the first *b*=0 volume, we calculated the average magnitude of rotation over all 71 volumes in the scan. This measure of framewise rotation significantly impacted the strength of 28% of network edges. The direction and strength of these effects were significantly associated with inter-subject edge consistency ($r$=-0.23) and mean streamline length ($r$=-0.20). (**C**) The mean voxel outlier count across all 64 diffusion-weighted volumes significantly impacted 13% of network edges. The direction and strength of these effects were significantly associated with inter-subject edge consistency ($r$=-0.22) and mean streamline length ($r$=-0.19). (**D**) The mean temporal signal-to-noise ratio (TSNR) across all 64 diffusion-weighted volumes significantly impacted 25% of network edges. The direction and strength of these effects were significantly associated with inter-subject edge consistency ($r$=0.30) and mean streamline length ($r$=0.20). For networks derived from deterministic tractography, edge weights were defined by the mean fractional anisotropy (FA) along streamlines connecting each pair of nodes. (**E**) Mean framewise translation significantly impacted the strength of 7% of deterministic network edges. The direction and strength of these effects were significantly associated with inter-subject edge consistency ($r$=-0.49) and mean streamline length ($r$=-0.46). (**F**) Mean framewise rotation significantly impacted the strength of 14% of network edges. The direction and strength of these effects were significantly associated with inter-subject edge consistency ($r$=-0.40) and mean streamline length ($r$=-0.42). (**G**) The mean voxel outlier count significantly impacted the strength of 7% of network edges. The direction and strength of these effects were significantly associated with inter-subject edge consistency ($r$=-0.42) and mean streamline length ($r$=-0.42). (**H**) TSNR significantly impacted the strength of 9% of network edges. The direction and strength of these effects were significantly associated with inter-subject edge consistency ($r$=0.49) and mean streamline length ($r$=0.48). All statistical inferences were adjusted for multiple comparisons using FDR ($Q < 0.05$). The significance of all third-level correlations was evaluated using 10,000 permutations (permutation-based $p < 0.0001$).




**Supplementary Figure 5. Replacing signal outliers attenuates overall impact of head motion on structural connectivity, but motion effects are still modulated by inter-subject edge consistency and length.** All 949 DTI datasets were reprocessed using a recently-introduced method for simultaneously correcting diffusion images for eddy currents, participant motion, and replacing signal dropout using a non-parametric signal prediction (Andersson et al., 2016). We then fit the diffusion tensor model to the reprocessed DTI data and re-ran deterministic tractography to assess the impact of head motion on structural connectivity. (**A**) When edge weights were defined by the average FA along deterministic streamlines connecting a node pair, only 4% of all network edges were significantly impacted by motion, compared to 14% of edges impacted by motion without outlier replacement. (**B**) While replacing signal outliers attenuated the overall relationship between head motion and structural connectivity, the direction and strength of motion effects were still significantly associated with edge inter-subject consistency ($r$=-0.44) and with mean streamline length ($r$=-0.29). (**C**) As seen previously, inter-subject edge consistency exhibited a parabolic relationship with mean streamline length. Specifically, head motion significantly enhanced the strength of relatively short-range, low-consistency network edges, and diminished the strength of relatively long-range, high-consistency network edges. All statistical inferences were adjusted for multiple comparisons using FDR ($Q$ < 0.05). The significance of all third-level correlations was evaluated using 10,000 permutations (permutation-based $p$ < 0.0001).