Deep Transfer Learning for Visually Induced Motion Sickness Detection Using Symmetric Projection Attractor Reconstruction of the Electrocardiogram

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Aims: Here, we sought to leverage the symmetric projection attractor reconstruction (SPAR) technique to uncover novel insights into the expression of motion-induced nausea, and explore whether machine models can distinguish between malaise and normal from electrocardiogram (ECG)-generated attractor images.

Methods: We obtained the SPAR transforms of ECG signals recorded from healthy participants at rest and during nausea, for a binary image classification task using a total of 6 pretrained deep neural networks (i.e., ResNet-50, ResNet-101, DenseNet-201, Xception, Inception-v3, and Inception-ResNet-v2) with transfer learning. Bayesian optimization with 100 iterations was utilized to tune the hyperparameters mini-batch size, learning rate, momentum, and L2 regularization. To evaluate model performance, we performed a leave-one-participant-out cross-validation (LOPOCV).

Results: We observed that the DenseNet-201 network performed better than other networks as evaluated by accuracy for attractors generated using $N = 3, 5,$ and 6 points ($70.14\%, 70.14\%,$ and 69.91%, respectively). When examining model performance using the receiver operating characteristic (ROC) curve and the area under a ROC curve (AUC), we found that ResNet-50 and ResNet-101 achieved AUC scores considered acceptable – for 4-point attractors (AUC 0.7091 and AUC 0.7275), respectively. The DenseNet-201 model demonstrated acceptable AUCs for attractors computed using embedding dimensions ($N = 3$; AUC 0.7325) and ($N = 6$; AUC 0.7098). Attractor visual examination revealed that the arms of the $(3, 1)$ attractor at baseline are wider than those of the nausea $(3, 1)$ attractors. Further, we observed that baseline $(5, 1)$ attractors are less dense near the center than their nausea counterparts.

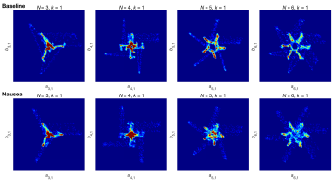

Figure 1. Example attractors.

Conclusion: Our observations provide new insights into how physiologic characteristics captured via ECG-derived attractor images may be important for distinguishing expression of motion-induced malaise. The SPAR method may help assess the efficacy of new therapeutics for motion sickness management.