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## Multimodal Fiber-Optic sensing for Non-invasive Profiling of Psychological Stress on Human Skin

Human skin contains multiple biochemical and structural compartments—including tissue, interstitial fluid, blood-derived constituents, and sweat—that reflect both physiological and psychological states. Current approaches for assessing stress-related biomarkers are often invasive, labor-intensive, expensive, or limited to a small number of molecular targets. Here, we investigate the feasibility of a high-throughput multimodal optical sensing platform for the non-invasive assessment of psychological stress through skin spectroscopy.

Raman, diffuse reflectance, fluorescence, and spectrally resolved fluorescence lifetime signals were acquired from the palmar and dorsal forearm skin of healthy volunteers using a multimodal fiber-optic probe. Psychological stress was induced using the Montreal Imaging Stress Task (MIST), which combines cognitive load, time pressure, and social-evaluative challenge. Stress induction was validated using electrodermal activity and heart rate variability recorded by wearable biosensors. Spectral data were preprocessed to correct for instrumental artifacts and analyzed using principal component analysis coupled with supervised machine-learning classifiers. The multimodal integration of optical modalities outperformed individual techniques. On palmar skin, after excluding one participant who did not exhibit a physiological stress response, the multimodal classifier achieved 86% classification accuracy and an AUC of 0.89 in discriminating baseline from stress conditions.

To gain insight into the molecular origin of the observed spectral changes, a reference library of stress-associated biomolecules was established. Candidate biomarkers—including cortisol, interleukins, TNF- $\alpha$ , neuropeptide Y, and sodium lactate—were characterized in both solid and diluted forms using the same multimodal optical platform. Preliminary spectral unmixing analyses suggested stress-dependent modulation of specific molecular signatures, including significant changes in Raman components associated with IL-1 $\alpha$  between baseline and stress conditions.

These findings demonstrate the potential of multimodal optical skin spectroscopy as a rapid, label-free, and non-invasive approach for detecting psychological stress while providing molecular-level information on its biochemical correlates.

### References

“High-throughput multispectral skin sensing for non-invasive detection of psychological stress,” in the SPIE Digital Library as part of the proceedings of the SPIE Photonics Europe conference; DOI <http://dx.doi.org/10.1117/12.3106139>