Chapter 3
Multimodal AI Approaches for Pain Assessment:
Wearables, Speech, and Facial Biometrics

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ABSTRACT

Artificial Intelligence (AI) and Machine Learning (ML) are transforming pain assessment and prediction by offering objective, data-driven alternatives to traditional self-reported methods. This chapter explores multimodal AI approaches that integrate facial expression recognition, speech pattern analysis, and wearable biosensors to assess and monitor pain in real-time. Natural Language Processing (NLP) is also employed to extract pain descriptors from clinical narratives and unstructured health records. In addition, ML models enable the prediction of pain onset and severity, facilitating personalized treatment planning and proactive intervention. While these technologies offer substantial benefits, challenges such as data bias, privacy

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concerns, and integration into clinical workflows remain. Future directions include explainable AI, brain imaging integration, and the development of virtual health assistants to enhance the accuracy and equity of AI-driven pain care.

INTRODUCTION

Pain is one of the most common and complicated phenomena that present themselves in clinical care, but also one that is difficult to assess accurately. Due to its notoriously difficult and unreliable description of pain, its subjective nature, which is influenced by biological, psychological and social factors (Dworkin & O'Connor, 2005), it has proved extremely difficult to quantify in an objective and consistent manner. The primary tools used to determine the severity of the patient's pain are conventionally made to rely on patient self-reporting via Numeric Rating Scale (NRS), Visual Analogue Scale (VAS), and Wong-Baker FACES scale. Such scales are widely used and useful, although they are confounded by numerous confounding factors such as the individual's pain threshold, mental health status, communication abilities, cultural norms, and even language barriers (Turk & Melzack, 2011). For example, chronic pain sufferers may attempt to hide or falsify the intensity and sort of pain they are experiencing out of worry of being tagged as a pain stigmatizer or being disbelieved, consequently underreporting or misrepresenting symptoms. In addition, children, individuals with cognitive impairment such as elderly patients, individuals with speech impairment or language differences face a substantially higher difficulty in self-reporting pain, leaving many gaps in pain management (Herr et al., 2011). Recent studies (e.g., Vadeboncoeur et al., 2022) continue to confirm the difficulties in using these subjective assessment tools, particularly for individuals with cognitive or linguistic challenges.

The programs from characteristics of subjective assessment set limitations that not only confine effective diagnosis but also impair the development of the best treatment form. The consequence of inadequate assessment is that patients can receive insufficient pain relief, poor quality of life, and the development of secondary psychological problems like depression and anxiety (Gatchel & Turk, 2007). Thus, delays or inaccuracies in pain assessment are likewise associated with longer recovery, increased risk of complications, and increases in hospital costs resulting from longer length of stay or readmission (Apkarian et al., 2009). More recent reviews (e.g., McGee et al., 2021) highlight that inadequate pain assessment still contributes to significant gaps in patient care and treatment effectiveness.

These complexities, however, have been addressed with the advent of Artificial Intelligence (AI) and Machine Learning (ML), which have opened up new possibilities for more objective and data-driven pain assessment. Because it can do more things