

# EDDIE: An Embodied AI System for Research and Intervention for Individuals with ASD

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## Abstract

We report on the ongoing development of EDDIE (Emotion Demonstration, Decoding, Interpretation, and Encoding), an interactive embodied AI to be deployed as an intervention system for children diagnosed with High-Functioning Autism Spectrum Disorders (HFASD). EDDIE presents the subject with interactive requests to decode facial expressions presented through an avatar, encode requested expressions, or do both in a single session. Facial tracking software interprets the subject’s response, and allows for immediate feedback. The system fills a need in research and intervention for children with HFASD by providing an engaging platform for presentation of exemplar expressions consistent with mechanical systems of facial action measurement integrated with an automatic system for interpreting and giving feedback to the subject’s expressions. Both live interaction with EDDIE and video recordings of human-EDDIE interaction will be demonstrated.

## Introduction and related work

Individuals with ASD exhibit two diagnostically critical classes of symptom: social communication deficits, and restricted and repetitive behaviors. A common aspect of social communication deficits is a reduced ability to both interpret (decode) and produce (encode) facial expressions of emotion. Existing studies on encoding of facial emotions rely on social judgement to determine the accuracy of encoding, rather than reading of facial muscle movements (e.g., Volker et al. 2009). Children diagnosed with HFASD perform below typically developing (TD) children at encoding emotions, but show improvement with intervention (Volker et al., 2009; Rodgers et al., 2014).

Additionally, it is well documented that children with HFASD respond well to computer-assisted interventions (Ploog et al., 2013), and robotic agents (Scassellati et al., 2012). Presumably, this is partly due to both the reduced level of social demand associated with human-robot interactions as well as the ability of robots to provide reliable, repeatable, models of human behavior. We anticipate that coupling a robot with a game will also take advantage of

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Figure 1. A prototype EDDIE demonstrating a happy face.

ASD subjects’ tendency to restricted interests and repetitive behaviors, further improving effectiveness.

Direct modeling of human facial expression via muscle movements was validated by Ekman (Ekman & Friesen, 1978), through the Facial Action Coding System (FACS). In this system, individual muscle movements are represented by a numbered list of facial action units (FAUs), and collections of FAUs correspond to particular emotional states. For now, we focus on three expressions: happy, sad, and angry. The relevant FAUs are shown in table 1.

We are developing a low-cost platform which can deliver therapeutic interventions to children with HFASD. EDDIE, depicted in figure 1, is capable of producing facial expressions via a hardware system based on Jim (Selkowitz et al. 2015); observing and interpreting a user’s facial expression via Kinect interface (e.g. Alabassi et al., 2015); and providing verbal prompts and feedback via pre-recorded vocalizations. By connecting these functionalities, we will be able to deploy EDDIE to assess, train, and reassess subjects’ abilities to decode and encode facial expressions.

Emotion	FAU
Happy	6, 12
Sad	1, 4, 15
Angry	4, 5, 7, 23

Table 1: The three emotional states expressed by the Eddie prototype and the related FAUs.

## The Systems

We focus here on a few key features of the hardware. We have replaced Jim's Lego mechanical parts with 3D printable facial components. These structures allow more reliable articulation, greater strength, and easier distribution and reproduction. Additionally, minor noise and reliability issues reported with the Lego motors have been remedied by switching to servo motors. The MIDI interface has been retained between EDDIE and the control computer: the protocol provides timing tools needed to synchronize movement and vocalization.

The vision system is driven by a single Microsoft Kinect interface located behind EDDIE's avatar, roughly 1.0m from the subject. The Kinect SDK allows for the tracking of over 100 distinct facial points, and construction of a mesh consistent with Candide-3. We use changes in the distances between mesh vertices to infer muscular motions corresponding to the expression of FAUs. For example, FAU 4 corresponds to lowering of the eyebrow, a component of angry. We determine the presence of this FAU by computing the difference in eyebrow location before and during the expression. If the change exceeds the detection threshold, the FAU is marked as present. Each FAU is checked for each expression, and can be compared to table 1. If all FAUs are present, the expression attempt is marked valid, and encouragement is provided to the subject. If incorrect movements are detected, or expected movements are missing, EDDIE will vocalize this information as direct feedback to the subject to assist in future attempts at encoding.

### Modes of Operation and Deployment

EDDIE is expected to operate in four modes, each with possible therapeutic value. In *decoding* mode, EDDIE will present the subject with an expression and prompt the subject to provide a verbal interpretation of the expressed mode. In *request encoding* mode, EDDIE will verbally request that the subject provide a particular facial expression. The vision routines will check if appropriate FAUs were produced by the subject. If so, EDDIE will provide praise. If not, direct vocalized guidance and simulation on the avatar will be provided. In *decode and encode* mode, EDDIE will demonstrate an expression for the subject, and request verbal decoding as well as mimicry. Feedback will be provided as a combination of that decoding and request encoding modes. In *free-form* mode, subjects will be prompted to produce expressions of their choice, and when they match one of the known emotional states, EDDIE will mimic it. Periodic feedback will coach subjects away from mixed or incomplete expressions.

Because it runs on a personal computer, EDDIE is easy to install and operate. The appearance of EDDIE can be modified to provide units of any implied age or gender, in-



Figure 2. Samples of FAU 4, brow lowerer (left), and neutral (right). Taken from the WSEFEP set (Olszanowski et al., 2015).

cluding anthropomorphized non-humans. Likewise, the proposed game structure is modifiable and customizable, allowing for a range of custom therapies and studies. A time table for deployment with HFASD individuals cannot be determined at this time, but if pilot studies are positive, further therapy research is anticipated through the Institute for Autism Research at Canisius College.

In summary, EDDIE is an in-development, low cost, customizable platform for novel therapies to improve facial processing of emotion in HFASD subjects. The system provides three key advantages: objectively-based validation of expression accuracy via FACS; reliable, low-risk social interaction via a robotic interface; and an underlying game structure which takes advantage of the characteristics of HFASD subjects to maximize intervention impact

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