MoodLens: Towards Improving Nonverbal Emotional Expression with an In-lens Fiber Optic Display

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ABSTRACT
Using an outward-facing display mounted on eyeglasses, MoodLens seeks to help individuals express emotion who have lost the ability to speak or use facial muscles. MoodLens looks like normal eyeglasses when not in use and allows the wearer to experience eye contact normally. We collected data from non-disabled participants (i.e., potential conversation partners for the wearer) who viewed smiling, neutral and frowning emoticons on MoodLens accompanied by computerized speech. The emoticons were recognizable at conversational distances and altered the perceived emotional content of the speech significantly.

Author Keywords
Assistive Technologies; Affective Computing; Wearable computers; Augmentative and Alternative Communication

ACM Classification Keywords
K.4.2 [Computers and Society]: Social Issues – Assistive technologies for persons with disabilities

INTRODUCTION AND MOTIVATION
Individuals with severe physical disabilities caused by Amytrophic Lateral Sclerosis (ALS), stroke, cerebral palsy, and other conditions may not be able to use facial expressions, hand gestures, or speech to communicate. A large body of research has focused on augmentative and alternative communication (AAC) systems [1], yet most lack emotional output that could improve quality of life, relationships, and a sense of independence for users [4]. While AAC emotional expression research has primarily focused on improving voice output [2][3] by varying pitch, rhythm, and volume, few options exist for AAC users to simulate facial expressions for nonverbal communication during conversation. One opportunity is to use "emotive wearables" to display mood, though current devices were not designed as assistive technology [5].

DESIGN PROCESS
MoodLens continues the work of Fueston [6] who interviewed nine participants (ages 25 – 67, 3 men, 3 individuals with ALS, 3 healthcare practitioners, 3 family caregivers) about emotional expression options and what they require from an emotional expression interface.

We studied Fueston's interview data and prototype testing results to gather three requirements: face-to-face conversation (potential end users specified "look at me" and "[not feeling] like a piece of technology"), non-obstructiveness (speech pathologists specified the mouth area), and wide range of emotion (end users emphasized "happy, joy"; caretakers and family emphasized "pain, anger") [6]. Since emoticons have been shown to significantly improve perception of emotional content of text communication [7], we hypothesize that we can meet these requirements with emoticons displayed on eyewear, as opposed to a laptop or tablet, so as to preserve current eye contact patterns.

Eye contact activates distinct regions of the social brain that an averted gaze will not [8]. Integrating eye contact as a design constraint allows the wearer to receive an inherent "reward value" each time a conversation partner looks at the display.

"Inside Out HUD" Mockup and Field Test
Eyeglasses provide an ideal mount for MoodLens by being familiar, customizable, and generally comfortable while sitting in front of the eyes. Eyewear has already been widely explored for heads-up displays (HUDs), but an "inside out HUD" that allows a *conversation partner* to see information without looking away from the *wearer* is less explored. Before building a functional prototype, we made physical mock-ups using tape, permanent marker, and a pair of eyeglasses. Figure 1 presents the four alternatives tested (*on-frame, center or corner; in-lens, opaque or transparent*). One author wore the designs (Figure 1) for a full day each in an informal study in public settings (home, university campus, grocery store, public transport, etc.) and asked conversation partners (family, friends, acquaintances, strangers) about the display and at what distance they could see the display. Mock-ups and field-testing quickly addressed two concerns: How do others perceive or react to the display size, color, and placement? How far from the wearer's eye can an image be placed to not be obstructive and still allow for eye contact? The transparent in-lens design was selected as the best design alternative for non-verbal communication based on the mock-up test trials and further literature review [9][10][11] because it allows for

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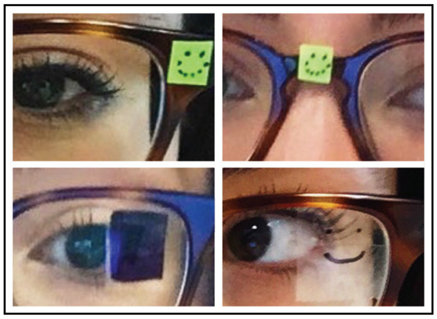

Figure 1. Mock-ups, clockwise: On-frame right and center, in-lens transparent, opaque.

eye contact appears to be normal eyeglasses when turned off. The on-frame design could not provide both eye contact (center only) and appealing aesthetic (corner only). The in-lens opaque design raised privacy concerns when confused with a camera, eliciting responses consistent with reports of "automated capture equipment" causing public discomfort [9] and security concerns associated with visibility of expensive HUDs [11].

FIBER OPTIC "TRANSPARENT" DISPLAY

MoodLens consists of a fiber optic cable matrix producing a 1cm x 1cm display sitting at the top left of the wearer's eyeglasses. The first prototype is constructed using an LED matrix and fiber optic cables. It is limited to 8x8 pixels but

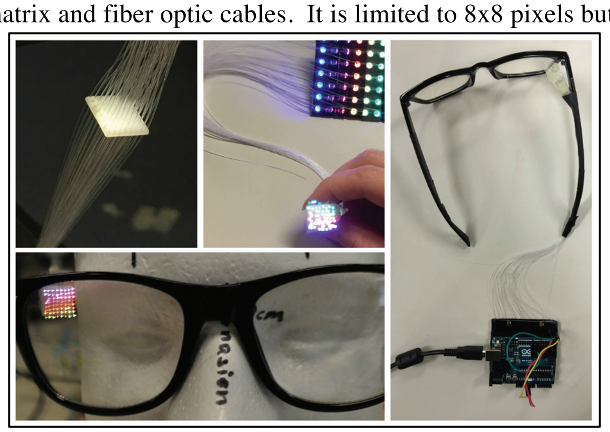

Figure 2. Clockwise from left: the 3D printed casing, a rainbow mapped to the display, the full system, and the display in glasses.

can produce over 30 different facial expressions, gestures, and symbols (Figure 2). We chose green light as it requires less light intensity to be perceived than red or blue.

METHODS

MoodLens has multiple intended users: a *wearer* and *conversation partner*(s). Before testing with the wearer (i.e., an individual with ALS), we evaluated MoodLens' ability to communicate emotional expression from the wearer to the conversation partner. User requirements determined the three most important metrics:

1. **Visibility:** At what distance, with minimal training, can emoticon expressions be distinguished on the display?
2. **Expressivity:** Do emoticons representing facial expressions enhance emotional content in computerized text-to-speech?
3. **Acceptability:** Are a pair of glasses with a display facing outwards bothersome, awkward, or uncomfortable to conversation partners?

Visibility Testing

Twenty participants (ages 19 - 39, mean age 21.42, 7 male) with normal or corrected-to-normal vision and hearing were recruited via word-of-mouth at Georgia Tech and compensated 5 USD. All but one participant completed every part of the 60-minute study. Participants viewed the glasses from different distances, reported the image displayed, and rated their certainty in the chosen image. To remove any bias introduced by facial expressions from a live user, we placed the glasses on a head mannequin (Figure 3). The test took place in standard office environment under fluorescent lighting. In a training phase, the experimenter explained that emoticons will be displayed on the interface but did not specify what kind. Each participant stood one meter from the head mannequin and viewed expressions in this order: smile, neutral, frown. Participants described each expression with free-form text and used a 7-point Likert scale to report certainty (*not at all certain* to *absolutely certain*). After the third expression, the experimenter asked the participant to report their answers and confirmed they were correct, and then repeated the trial a second time in a random order. After training, the testing phase measured visibility directly in front of the interface (Figure 3) from seven locations one meter apart. Participants began seven meters away, selected their best guess from a list of the training phase expressions, rated their certainty, and proceeded to six meters to repeat the

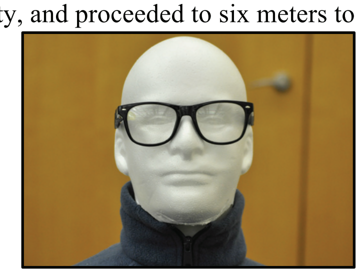

Figure 3. Mannequin wearing display in fluorescent lighting.

process. After reaching one meter, participants returned to seven meters for the next round. There were three rounds total, one expression per round, no repetition. A balanced Latin square determined three unique orders of presentation to counterbalance ordering and learning effects in the data.

Expressivity Testing

Participants watched videos of an actor keeping a neutral face while wearing the display glasses. Computerized text to speech produced the phrases "I am feeling good today," "I am feeling okay today," and "I am feeling bad today". Meanwhile, the display glasses were used to show a positive, neutral, or negative emoticon (Figure 4). A randomly ordered video sequence covered every combination of expressions twice: voice only, display only, and both. The voiced phrase began at 2 seconds into each video while emoticons where displayed during the entire video segment. Each video was evaluated independently. Before beginning, participants rated a baseline video of the actor's facial appearance with no voice or display to check if it was slightly positive or negative. The voice and display combinations were rated for expression (*negative* to *positive, calm* to *excited, not at all understandable* to *completely understandable*), the observer's assumption for how the MoodLens wearer is feeling (*negative* to *positive*, *calm* to *excited*) and the observer's certainty for both (*not at all certain* to *completely certain*). Participants reported whether they looked at the glasses display (*yes, sometimes, no*). Emotion ratings were modeled after Russell's circumplex model of affect [13].

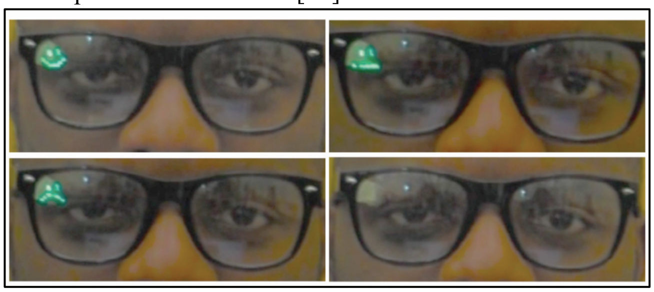

Figure 4. Actor wearing the display (image cropped); Clockwise: smile, neutral, turned off, frown.

We chose video rather than a live actor to insure that the actor's resting face was consistent between each trial. Most micro-expressions - small muscle movements lasting 1/25 to 1/3 second that subconsciously affect interpretation of emotion [13] - were controlled for and removed by studying slowed down video for mouth, eye, eyebrow, etc. twitches. Transitions between video segments allowed participants to separate expressions mentally, reducing order effects.

Acceptability Testing

Participants completed a survey reporting basic demographics, their own familiarity with glasses, the glasses social acceptability assessment, and their own familiarity with wearable technology. Questions to measure attitude towards the display were modeled after Profita et al. [14] and adapted to specifically suit MoodLens. 7-point Likert scales were used to respond to statements on display appearance (*awkward, normal, silly, easy to wear, bothers me, comfortable to wear, looks embarrassing, annoying, weird, natural, cool*). Queries alternated positive (i.e. *normal*) and negative (i.e. *awkward*). The questions were repeated with the display turned *off* and turned *on*.

RESULTS AND DISCUSSION

Visibility Results

Hypothesis V1.	Emoticons can be distinguished at a conversational distance, i.e. 1-3 meters. **Supported.**

At distances of four meters or less, participant answers approach 100% accuracy (n=6 per sequence with total n=18) (Table 1), suggesting that MoodLens is visible at normal conversational distances.

Distance (meters)	µ Certainty (1 to 7)	µ Accuracy (%)
7	3.22	92.59
6	4.06	96.30
5	5.50	94.44
4	6.44	98.15
3	6.83	100.00
2	7.00	100.00
1	7.00	100.00

Table 1. Visibility test mean certainty and accuracy for up to seven meters from the device (n=18).

Expressivity Results

Hypothesis E1.	A positive emoticon increases valence for positive voice statements. **Supported.**
Hypothesis E2.	A negative emoticon decreases valence for negative voice statements. **Not supported.**
Hypothesis E3.	A neutral emoticon reduces valence variance for neutral voice statements. **Not supported.**
Hypothesis E4.	Positive and negative expressions increase and decrease valence for neutral expressions, respectively. **Supported.**

MoodLens successfully altered emotional content of computerized text-to-speech. The smiley face was most effective in improving expressions while neutral and frown emoticons were mixed but still contributed statistically significant results (Table 2 and Figure 5).

Expression Before	Expression After	µ Δ Valence	P-Value
"Good"	"Good" :-)	+ 3.12	$p < 0.001$ t = 14.93, n = 17
"Bad"	"Bad" :-(	- 0.29	$p > 0.05$ t = -2.49, n = 17
"OK"	"OK" :-|	- 0.33	$p < 0.05$ t = -2.49, n = 17
"OK"	"OK" :-)	+ 1.33	$p < 0.001$ t = 5.924, n= 17
"OK"	"OK" :-(	- 1.28	$p < 0.001$ t = -5.181,n = 17

Table 2. Expression valence results, all paired t-test, one-tailed.

Asymmetrical Expression Improvement

Though the negative emoticon made the neutral statement significantly more negative, it did not significantly enhance the negative statement. Social stigma against expressing negative emotions has possibly made verbal statements "negative enough" such that negative facial expressions are not needed to further enhance negativity. Since hypothesis E2 was not supported, further investigation was conducted comparing the "bad" statement with :-(individually. It was found each produce similar effects of negativity ("bad" M=1.789, :-(M=1.579). This equivalence suggests they could be used interchangeably for emotional expression.

"Neutral" Emoticon's Varying Behavior

The neutral emoticon :-| was interpreted as perfectly neutral or slightly negative depending on context. The statement or expression used alone was almost perfectly neutral (ok M=3.946, :-| M=3.842), however, when the :-| expression was included with the "ok" statement, it became slightly more negative but to a significant degree (Table 2). It is plausible the emoticon we labeled as "neutral" may more often be used as a slightly negative expression. For example, participants' qualitative descriptions during visibility test training included words such as "serious," "bored" and "indifferent" to describe this expression. These results suggest that though this emoticon is not ideal for perfect neutrality, it can convey slight negativity.

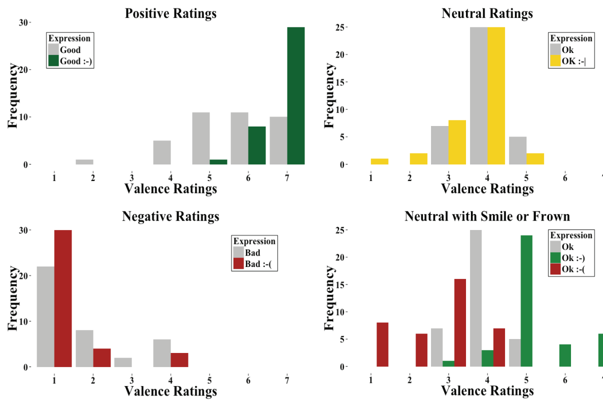

Figure 5. Valence ratings without (grey) and with (colored) display, clockwise: positive with positive, neutral with neutral, neutral with positive or negative, negative with negative.

Acceptability Results

Hypothesis A1.	The glasses look normal when not in use, turned "off." **Supported.**
Hypothesis A2.	The glasses are socially acceptable when in use, turned "on." **Supported.**

The glasses were perceived as normal when turned off (M = 6.45, where 7 is *Strongly agree* with the statement *Looks normal*). However, when the glasses were turned on participants neither agreed nor disagreed (M = 3.9). Also, disagreement with negative statements such as *Looks awkward, weird, silly…* etc. had a statistically significant decrease between being turned off and on but ratings remained low. That is, the *awkward* measure saw a 0.9 increase in mean (t = 2.1965, n = 19, p-value = 0.02, one-tailed) but participants found it not awkward (M = 2.65).

CONCLUSIONS AND FUTURE WORK

Our results suggest MoodLens is visible, expressive, and acceptable when a wearer communicates to a conversation partner. Further data analysis may suggest whether the valence of statements outweighs the valence of emoticons, as suggested in previous work with text-based expression. Future work includes conducting usability tests with potential wearers, such as individuals with ALS, with control through brain-computer interfaces (BCIs) or electromyography (EMG) switches. Perhaps one day MoodLens will allow individuals with facial paralysis to smile again. :-)

REFERENCES

1. D. Mcnaughton and J. Light, "What We Write about When We Write About AAC : The Past 30 Years of Research and Future Directions," *Augmentative and Alternative Commun.,* vol. 4618, no. March, 2016.
2. I. R. Murray, J. L. Arnott, and E. A. Rohwer, "Emotional stress in synthetic speech," *Speech Commun.*, vol. 20, no. 1–2, pp. 85–91, 1996.
3. J. Wülfing, D.-S. Augustin, L. Hoffmann, and D.-S. Augustin, "What does it mean to communicate (not) emotionally?," in *Proceedings of the 2nd Workshop on Speech and Language Processing for Assistive Technologies*, 2011, pp. 94–100.
4. A. Brownlee and M. Palovcak, "The role of augmentative communication devices in the medical management of ALS," *NeuroRehabilitation*, vol. 22, no. 6, pp. 445–450, 2007.
5. G. Mura, "Wearable technologies for emotion communication," *Metu J. Fac. Archit.*, vol. 25, no. 1, pp. 153–161, 2008.
6. J. Fueston and M. M. Jackson, "Expressiv: An Expressive System for Individuals with Facial Paralysis," Georgia Institute of Technology, 2015.
7. J. B. Walther and K. P. D'Addario, "The impacts of emoticons on message interpretation in computer-mediated communication," *Soc. Sci. Comput. Rev.*, vol. 19, no. 3, pp. 324–347, 2001.
8. A. Senju and M. H. Johnson, "The eye contact effect," *Trends Cogn. Sci.*, vol. 13, no. 3, pp. 127–134, 2009.
9. K. Wolf and A. Schmidt, "Innovations in Ubicomp Products Lifelogging : You're Wearing a Camera?," *Pervasive Computing.,* pp. 8–12, 2014.
10. P. A. Rauschnabel, A. Brem, and B. S. Ivens, "Who will buy smart glasses?," *Comput. Human Behav.*, vol. 49, pp. 635–647, 2015.
11. R. McNaney, J. Vines, D. Roggen, M. Balaam, P. Zhang, I. Poliakov, and P. Olivier, "Exploring the acceptability of google glass as an everyday assistive device for people with parkinson's," *Proc. 32nd Annu. ACM CHI '14*, pp. 2551–2554, 2014.
12. J. Posner and J. A. Russell, "The circumplex model of affect," *Development and Pyschopathology,* pp. 715–734, 2005.
13. P. Ekman, "Lie catching and microexpressions," *Philos. Decept.*, pp. 118–133, 2009.
14. H. Profita, J. Clawson, S. Gilliland, C. Zeagler, T. Starner, J. Budd, and E. Yi-Luen Do, "Don't Mind Me Touching My Wrist: A Case Study of Interacting with On-Body Technology in Public," *ISWC 2013*, pp. 89–96, 2013.