

Evoking Facial Expressions by Functional Electrical Stimulation in Healthy Volunteers

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Introduction: Individuals with facial or full-body paralysis face significant challenges in expressing themselves, which greatly limits their ability to communicate with family and loved ones. Augmentative and alternative communication technology including brain-computer interfaces (BCIs) has so far prioritized enabling verbal communication for these people. Natural communication, however, involves emotional facial expressions and other forms of non-verbal communication that are lacking in currently existing solutions. The present study explores the feasibility of using functional electrical stimulation (FES) to evoke facial expressions in healthy participants. In the future, this could lead to combining BCIs with FES to restore facial movement in people with severe paralysis.

Material & Methods & Results: We conducted an experiment to evoke up to six basic facial expressions with surface FES in healthy participants. We used an ELPHA 3000 medical device with Axelgaard surface hydrogel electrodes (2,5 cm in diameter) to deliver stimulation. Eighteen participants never previously exposed to facial FES were included (15 female, 2 male, 1 unknown; mean age of 23). Per participant, up to six facial expressions were stimulated (five on average) by applying two-second-long stimulations on two target facial muscles (**Table 1**) simultaneously only on the right side of the face. After every stimulation attempt, participants rated their discomfort level on a five-point Likert scale. We started with lowest stimulation intensity possible and, if participants' discomfort level was low, increased stimulation intensity by 1 mA until movement was observed. At final settings, stimulation was applied three times consecutively and videorecorded. In addition, participants reported what facial expression they perceived upon stimulation by choosing one out of all six options and their certainty about their answer on a five-point Likert scale. The stimulation results are summarized in **Table 1**.

Table 1. Results of FES stimulation of six facial expressions in 18 healthy participants. **Achieved observed movement (%)**: percentage of participants in whom stimulated facial expression was successfully evoked based on movement observed by two researchers. **Self-reported correctly**: percentage of facial expressions reported by participants that matched the target of stimulation. **Certainty**: mean and standard deviation of participants' certainty regarding self-reported evoked facial expressions. **Target muscles** are the muscles stimulated per expression. **Intensity** is the stimulation intensity required to achieve observed movement. **Discomfort** is the discomfort level at which the observed movement was achieved (0 = sensation absent; 1-5 = sensation present discomfort rating).

Facial expression	Achieved observed movement (%) [$n_{\text{achieved}}/n_{\text{attempt}}$]	Self-reported correctly (%)	Certainty (min: 1, max: 5)	Targeted muscles	Intensity (mA)	Discomfort (min: 0, max 5)
happy	94.4 [17/18]	43.14	3.5±1.50	<i>orbicularis oculi</i> (tighten the eyelid)	4.56±1.86	2.06±0.97
				<i>zygomaticus major</i> (elevate the lip corner)	7.18±1.32	1.94±0.97
angry	91.6 [11/12]	60.61	3.45±0.94	<i>corrugator</i> (lower the inner eyebrow)	6.32±1.12	3.20±0.79
				<i>orbicularis oris</i> (tighten/pucker the lip)	9.18±2.28	3.00±0.94
disgusted	100 [16/16]	58.33	3.18±1.39	<i>levator labii superioris alaeque nasi</i> (elevate upper lip)	7.06±1.42	2.27±1.16
				<i>depressor anguli oris</i> (lower the lip corner)	9.00±2.16	2.53±1.13
sad	88.9 [16/18]	20.83	3.33±1.64	<i>frontalis medial</i> (elevate the inner eyebrow)	5.88±1.04	2.85±0.99
				<i>depressor anguli oris</i> (lower the lip corner)	9.5±2.73	2.62±0.77
scared	100 [18/18]	14.81	3.00±0.93	<i>frontalis lateral</i> (elevate the entire eyebrow)	5.61±2.17	2.54±0.66
				<i>depressor anguli oris</i> (lower the lip corner)	9.44±2.50	2.46±0.78
surprised	85.7 [12/14]	33.33	2.44±0.67	<i>frontalis lateral</i> (elevate the entire eyebrow)	5.5±1.09	1.94±0.97
				<i>masseter</i> (lower the jaw and stretch the mouth)	7.76±1.70	1.94±0.97

Discussion & Significance: Present results show that FES can evoke noticeable movement at slight to moderate discomfort levels in more than 85% of tested participants for all facial expressions. Evoked expressions do not yet seem to be reliably perceived by participants as target expressions. Further work assessing perception of evoked expressions by independent observers will be done. Altogether, present work shows promising results for using FES to evoke facial movement for enabling non-verbal communication in people with severe motor paralysis.

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