Smiling and frowning induced by facial neuromuscular electrical stimulation (fNMES) modulate felt emotion and physiology

Supplemental materials

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## S1. Information sheet provided to participants

**Participant Information Sheet**

Title of the Project: Neuromuscular electric stimulation and social cognition

Research Team: Dr Sebastian Korb, Themis Efthimiou, Dr Joshua Baker

We would like to invite you to take part in this research study called “User experiences and comfort with facial Neuromuscular Electrical Stimulation”. Before you decide whether or not to take part, it is important for you to understand why the research is being done and what it will involve. Please take time to read the following information carefully.

**Inclusion/exclusion criteria**

You are eligible to take part in the study if you are between 18 and 45 years old, and if you have good visual acuity (with or without glasses/contact lenses).

You cannot take part in the study if you do not correspond to the inclusion criteria, or if you have a history of or make current (last month) use of illicit and/or psychotropic drugs, if you have been diagnosed with a neurological or psychiatric condition, if you have any major heart conditions (e.g. pacemaker), or if you wear a beard (as this precludes attaching electrodes to the face).

**What is the purpose of the study?**

The purpose of the study is to find out how stimulation of certain areas of the face impacts your comfort and physiological responses. We will use “neuromuscular electrical stimulation” (NMES, a safe and non-painful technique) to stimulate certain parts of your face with weak electrical impulses.

Results are expected to be relevant for our understanding of the physiological effects and the general applicability of facial NMES.

**Why have I been invited to participate?**

The study is part of a larger project, which includes several experiments, runs for 3 years, and involves the testing of several hundreds of participants. You have been invited to participate in this study, because you correspond to the inclusion/exclusion criteria.

Inclusion criteria: age 18-45 years; good visual acuity (with or without glasses/contact lenses).

Exclusion criteria: history or current use of illicit and/or psychotropic drugs, known major heart condition (e.g. pacemaker), current or past neurological or psychiatric disorder; beard (as this precludes attaching electrodes to the face).

**Do I have to take part?**

Your participation in the study is entirely voluntary. If you do decide to take part you will be asked to provide written consent. You have the right to withdraw at any time for whatever reason and without explanation or penalty. If you are a student, your withdrawal will have no impact on your marks, assessments or future studies. You can also ask that your data be deleted at any time, up to six months after your participation.

If you wish to withdraw from the study, or have any other concerns, you only need to inform the experimenter(s) orally.

It is also possible that the experimenter or other members of the research team may decide to terminate your participation in the study prematurely without your prior consent. The reasons for this may be that you do not meet the requirements of the study or that the investigator has the impression that further participation in the study is not in your interest.

**What will happen to me if I take part?**

Your participation in the study consists of 1 appointment at the research laboratory (duration about 1.5 – 2 hours). You will be welcomed and tested by the principal investigator of the project, or by members of his team.

We will introduce you to the NMES procedure and verify your NMES threshold. You will then complete a task at the computer. Over several trials, you will receive facial NMES for a duration of 5 seconds at various intensities. At the end of each stimulation period, we will ask you some questions about your experience with facial NMES e.g., how comfortable it was. Your face will be video-recorded throughout.

Up to 4 electrodes will placed in the lower part of your face. These are medically suitable, self-adhesive electrodes, which are either cleaned or disposed of after each use. They are used for light electrical stimulation of the corresponding parts of your face, which takes place with medically certified and computer-controlled stimulators. Thereby NMES simulates the natural activation of a muscle.

In this study, the aim is not to produce strong muscle contractions, but rather to slightly stimulate certain parts of the face. We calibrate the NMES for each participant, by gradually increasing its intensity until a slight muscle contraction becomes visible. During the stimulation, you will feel a tingling sensation. This can sometimes feel uncomfortable, but is of short duration and has no long-term consequences. Importantly, rest assured that we follow international guidelines about electrical stimulation, and have extensively and successfully pre-tested the stimulation parameters. We will also always monitor your wellbeing.

After the electrodes have been set up, we will attach additional electrodes to your non-dominant hand to measure your heart rate and skin response. You will then participate in a task where you will receive facial NMES and report on your experience. During the task, you will either see a blank screen or an image with positive and negative content. Please be aware that some of these images might be disturbing, but they come from a scientifically recognised database and have been thoroughly used in research. Once the task is complete, the electrodes will be repositioned, and the task will be repeated a second time.

**What are the possible disadvantages and risks of taking part?**

There are no health risks associated with NMES as long as limits are not exceeded and safety measures are followed. NMES, also known as TENS (Transcutaneous Electrical Nerve Stimulation), has been used for some time, especially in the field of physiotherapy and rehabilitation, including in the face.

Medical stimulators and electrodes are used for this study. During the initial calibration phase, the stimulation intensity is gradually increased, until a clear muscle activation is visible. This can sometimes lead to an unpleasant feeling and occasionally to brief pain sensations. In that case we adjust the electrode position, until the optimal and most comfortable NMES experience is obtained. Importantly, the NMES impulses are of short duration (few seconds) and are not harmful to your health.

Please inform the experimenter(s) and/or the lead investigators if you experience any major symptoms, side effects, sickness, or injuries.

**What are the possible benefits of taking part?**

By participating, you can gain insight into scientific psychological and neuroscientific practice. You will also contribute to a better scientific understanding of the basis of human behaviour, and in the development of facial NMES.

**What information will be collected?**

We will collect the following data: your responses to the computer tasks (e.g., response times and accuracy), your basic demographics (age, gender, etc.), video recording of your face during the computer tasks, heart rate, electrodermal activity from your non-dominant hand, and your self-report responses on some self-report questionnaires measuring mood and personality characteristics (e.g., empathy).

Your data will be pseudonymised, i.e., you will be assigned already at time of testing an anonymous ID code, under which the data will be stored. This means that it is not possible for anyone who does not have the “key” to draw conclusions about your person. Your video recordings will never be shared outside of the researchers’ team, and will not be published.

Only the researchers involved in the study will have access to the data “key”, and thus to the confidential data (e.g., your name and contact details). These persons are subject to the obligation of secrecy.

You will also not be mentioned by name in any publications of the data of this study.

**Will my information be kept confidential?**

All your information will be kept confidential. Already at data collection, your data will be associated with a letter/number code. We will thus strip any identifying information out of the experimental data, but keep a master list that gives the identity of each participant. The master list will be stored on a secure institutional server, the anonymised data will be stored independently of the participant’s name and contact details. All digital data will be kept on password-protected computers and data storages. All paper sheets (where applicable) will be kept in locked closets/rooms at the university and will only be accessible by the members of the research team.

Aggregated anonymous data may be uploaded to a dedicated research repository (e.g. OSF) at the time of publication of the corresponding papers.

Your data will be for 10 years after the completion of the project, and will be destroyed after that (electronic files will be deleted, paper sheets will be shredded).

**What is the legal basis for using the data and who is the Data Controller?**

By signing written consent, you provide the legal basis for the processing of your data. Essex University’s Data Protection Officer can be contacted at dpo@essex.ac.uk.

**What should I do if I want to take part?**

If you want to participate in this study, please write an email to psynmes@gmail.com, and provide us with your full name and telephone number. We will contact you as soon as possible.

**What will happen to the results of the research study?**

The results of the research are expected to be published as a journal article and/or used as a conference paper/presentation. The results may also be part of a university dissertation or thesis (Master’s, PhD). Importantly, any results will be anonymised and you will not be identifiable.

**Who is funding the research?**

This research is funded through a grant by the Austrian Science Fund (FWF) awarded to the principal investigator.

**Who has reviewed the study?**

This study has been approved by the University of Essex Faculty of Science and Health Ethics Subcommittee, ERAMS reference: ETH2122-1966.

**Concerns and Complaints**

For any concerns regarding the study you can also contact the principal investigator of the project, Sebastian Korb using the contact details below. Should you still be concerned, or should you think that your complaint has not been addressed to your satisfaction, or should you feel that you cannot approach the principal investigator, please contact the departmental Director of Research in the department responsible for this project, Silke Paulmann (Email: paulmann@essex.ac.uk). If you are still not satisfied, please contact the University’s Research Governance and Planning Manager, Sarah Manning-Press (Email: sarahm@essex.ac.uk). Please include the ERAMS reference: ETH2122-0049.

**Name of the Researcher/Research Team Members**

|  |  |
| --- | --- |
| Role | Name |
| PI | Sebastian Korb |
| Researcher | Themis Efthimiou |
| Researcher | Joshua Baker |

## S2. OASIS Database Images

This appendix lists the images extracted from the OASIS database and used in the experiment. The table includes the image category, emotion, mean valence, and mean arousal as classified in the original OASIS standardisation. Positive images were only shown in the ZM block and negative images were only shown in the DAO block. images were split between the two blocks, but no image was shown to the participant more than once to avoid emotional habituation in their response.

**Table S2.**

Description of Images from theOpen Affective Standardized Image Set (OASIS)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Image | Category | Emotion | Mean Valence | Mean Arousal |
| dog 6 | animal | positive | 6.49 | 5.03 |
| lake 9 | scene | positive | 6.41 | 4.11 |
| flowers 2 | object | positive | 5.95 | 3.46 |
| wedding 4 | object | positive | 5.81 | 3.12 |
| cat 5 | animal | positive | 6.22 | 4.86 |
| beach 1 | scene | positive | 6.37 | 4.74 |
| barrels 1 | object | neutral | 4.21 | 2.47 |
| cotton swabs | object | neutral | 4.06 | 1.86 |
| cups 2 | object | neutral | 4.14 | 2.20 |
| fence 2 | object | neutral | 4.22 | 2.30 |
| Fire hydrant 1 | object | neutral | 4.20 | 2.33 |
| keyboard 1 | object | neutral | 4.17 | 2.15 |
| cups 1 | object | neutral | 4.28 | 2.03 |
| office supplies 2 | object | neutral | 4.09 | 1.84 |
| sidewalk 6 | object | neutral | 2.83 | 1.92 |
| bark 5 | object | neutral | 4.20 | 2.06 |
| skyscraper 1 | scene | neutral | 4.13 | 2.25 |
| roofing 3 | object | neutral | 3.93 | 2.08 |
| dog 26 | animal | negative | 1.30 | 4.86 |
| garbage dump 2 | scene | negative | 1.60 | 3.78 |
| car accident 2 | object | negative | 1.97 | 4.09 |
| dog 24 | animal | negative | 1.89 | 4.77 |
| war 8 | scene | negative | 1.72 | 5.14 |
| plane crash 4 | object | negative | 2.05 | 4.11 |
| bird 3 | animal | positive | 6.04 | 3.43 |
| beach 7 | scene | positive | 6.07 | 4.31 |
| galaxy 7 | scene | positive | 6.06 | 4.50 |
| dog 12 | animal | positive | 6.29 | 4.41 |
| nature 1 | scene | positive | 6.12 | 4.43 |
| sunset 3 | scene | positive | 6.12 | 3.71 |
| yarn 4 | object | neutral | 4.20 | 1.98 |
| sidewalk 1 | scene | neutral | 4.31 | 2.30 |
| storage 2 | object | neutral | 4.01 | 2.25 |
| wall 3 | object | neutral | 4.06 | 1.81 |
| paperclips 3 | object | neutral | 4.05 | 1.84 |
| paper 2 | object | neutral | 4.09 | 1.93 |
| tornado 3 | scene | negative | 2.66 | 4.68 |
| pigeon 6 | animal | negative | 2.32 | 3.82 |
| flood 3 | scene | negative | 2.29 | 4.29 |
| destruction 10 | scene | negative | 2.10 | 3.59 |
| jail 4 | scene | negative | 2.11 | 3.43 |
| injury 3 | person | negative | 1.97 | 4.70 |
| rocks 3 | object | neutral | 4.31 | 2.20 |
| cardboard 2 | object | neutral | 4.31 | 2.20 |
| sidewalk 3 | scene | neutral | 4.30 | 2.23 |
| socks 1 | object | neutral | 4.20 | 1.90 |
| yarn 1 | object | neutral | 2.60 | 1.87 |
| roofing 2 | object | neutral | 4.06 | 2.13 |

*Note*. The table includes a brief description of each image, along with its category, emotion, and mean valence rating, and arousal ratings during standardisation.

S3. Model comparisons for covariates

**Table S3.**

Model comparisons for covariates

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Fit1 | AIC | BIC | Fit2 | AIC | BIC | *p* |
| fNMES + fNMES:image | 1866 | 1895 | fNMES + fNMES:image + TAS | 1866 | 1900 | .230 |
| fNMES + fNMES:image | 1910 | 1940 | fNMES + fNMES:image + Negative Affect | 1912 | 1946 | .718 |
| fNMES + fNMES:image | 1910 | 1940 | fNMES + fNMES:image + Positive Affect | 1897 | 1932 | < .001 |
| fNMES + fNMES:image + Positive Affect | 1897 | 1932 | fNMES + fNMES:image + Positive Affect + Discomfort | 1762 | 1801 | < .001 |

*Note*. The simplest model, including a main effect of fNMES and an fNMES by image interaction, was compared to models including as covariates TAS, the positive and negative affect subscales of the PANAS (measured at the beginning of the experiment), and ratings of discomfort in each trial. The best-fitting model included both positive affect and discomfort. Please note that the simplest model in the first and second rows differ because two participants had incomplete TAS data (*n* = 56). These two participants were excluded from the simplest model because TAS did not improve the model. However, they were added back to later comparisons (*n* = 58).

S4. Model splitting muscle and fNMES intensity

An LMM was conducted to predict self-reported valence with the following predictors fNMES intensity, muscle, image, PANAS, and discomfort (*R2* = 0.71; marginal *R2* = 0.31). The output is reported as type 3 ANOVAs with posthoc comparisons conducted using the emmeans package with a Bonferroni correction applied.

The main effect of muscle is statistically significant (*F*(1, 963) = 95.74, *p* < .001. Overall, self-reported valence was higher in the ZM compared to the DAO conditions (*Mdiff* = -0.30, SE = 0.03, *t*(962) = 9.79, *p* < .001. A second main effect of image is statistically significant (*F*(2, 962) = 18.54, *p* < .001. Overall, self-reported valence was higher in the no-image compared to the congruent (*Mdiff* = -0.19, SE = 0.04, *t*(962) = 4.92, *p* < .001) image condition and the neutral image condition (*Mdiff* = -0.21, *SE* = 0.04, *t*(962) = 5.56, *p* < .001).

The interaction between fNMES intensity and muscle is statistically (*F*(2, 962) = 26.96, p < .001). Posthoc comparisons revealed that self-reported valence was higher in the ZM condition when fNMES intensity was 50 (*Mdiff* = -0.48, SE = 0.05, *t*(963) = 8.96, *p* < .001) and 100% (*Mdiff* = -0.44, *SE* = 0.05, *t*(962) = 8.34, p < .001) of MT. No difference in valence between the two muscles emerged when fNMES was off (*Mdiff* = 0.02, *SE* = 0.05, t(962) = 0.33, *p* = .742).

The interaction between muscle and image is statistically significant (*F*(2, 963) = 67.07, *p* < .001). Posthoc comparisons revealed valence was higher in the ZM compared to the DAO conditions when the image was congruent in emotion (*Mdiff* = -0.81, *SE* = 0.05, *t*(963) = 15.02, *p* < .001). No other statistically significant differences emerged (all *ts* > -1.14 and all *ps* > .255.

A three-way interaction between fNMES intensity, muscle, and the image type was statistically significant (*F*(4, 962) = 16.25, *p* < .001) see Table below for decomposition.

**Table S4.**

Post-hoc comparisons with a Bonferroni correction between muscles (dao – zm) for each fNMES and image condition.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| fNMES intensity | Image | *Mdiff* | *SE* | *t* | *df* | *p* |
| 0 | Congruent | -0.03 | 0.09 | 0.34 | 962 | .735 |
| 50 |  | -1.36 | 0.09 | 14.63 | 964 | < .001 |
| 100 |  | -1.02 | 0.09 | 11.12 | 962 | < .001 |
| 0 | Neutral | 0 | 0.09 | 0.01 | 962 | .989 |
| 50 |  | -0.03 | 0.09 | 0.37 | 962 | .709 |
| 100 |  | -0.08 | 0.09 | 0.82 | 962 | .414 |
| 0 | No image | 0.08 | 0.09 | 0.90 | 962 | .369 |
| 50 |  | -0.04 | 0.09 | 0.40 | 962 | .693 |
| 100 |  | -0.23 | 0.09 | 2.48 | 962 | .013 |

*Note*. Shaded cells indicate statistically significant results. Negative mean differences indicate that self-reported valence is higher in the ZM compared to the DAO condition.