From neutral to emotional: The Facial Expression Intensity Test (FExIT)

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ABSTRACT

The Facial Expression Intensity Test (FExIT) measures the level of perceived intensity of emotional cues in a given facial expression. The test consists of a series of faces taken from the NimStim set (Tottenham et al., 2009) whose expressions vary from a neutral expression to one of the six basic emotions, with ten levels of morphing. The FExIT is validated by means of an emotion-related ERP component (i.e., the early posterior negativity, EPN), which shows a systematic modulation of its amplitude with the level of expression intensity. The participant's task in this test is to identify the expressed emotion among 8 options (i.e. the six basic emotions, a "neutral" and a "I don't know" option). The task is not timed. The score of the FExIT is either the proportion of correctly identified emotions, or the proportion of the attribution of an emotion to the facial stimulus (i.e. the attribution of any emotion but not "neutral" or "I don't know"). Given that the facial expression intensity varies continuously from low to high, the FExIT allows the determination and comparison of threshold levels for correct responses. The freely accessible set of the 700 facial stimuli for the test is divided into two equivalent face lists, which further allows for pretest/posttest experimental designs. The test takes approximately 25 min to complete and is simple to administer. The FExIT is thus a useful instrument for testing different experimental settings and populations.

KEY WORDS: Test; Faces; Emotional expressions; Expression intensity; EEG/ERP; EPN

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ETHICS APPROVAL

Participants gave their informed consent to the procedure prior to the experiment. The Human Research Ethics Committee of East France (CPP Est III) approved the study in compliance with the French law. All methods were performed in accordance with relevant guidelines and regulations.

COMPETING INTERESTS

All authors certify that they have no affiliations with or involvement in any organization or entity with any financial interest or non-financial interest in the subject matter or materials discussed in this manuscript.

AVAILABILITY OF DATA AND MATERIALS

The FExIT can be used freely for research purposes. Stimuli and code for presentation are available on <https://osf.io/v6hbp/>. None of the experiments was preregistered.

1. INTRODUCTION

Background. In 2013 a study by Kidd and Castano drew much attention because it suggested that consuming “literary” fiction by award-winning and canonical authors, but not “nonfiction” or “popular” fiction, *instantly* improved one’s aptitude to recognize the emotions of conspecifics. Since reading fiction allows the projection of oneself into the lives of the characters in a book (e.g. Oatley, 2016), the abovementioned research finding was one among the first pieces of scientific evidence to suggest a causal relationship between reading a specific kind of fiction and a readers’ emotional and social skills.

What these researchers had actually demonstrated was the following. When participants had read excerpts written by award-winning authors prior to testing, they scored slightly higher in the “Reading the Mind in the Eyes Test” (RMET; Baron-Cohen et al. 2001). The RMET consists of a series of photographs of actors and actresses faces in which only the eye region is shown (Baron-Cohen et al. 2001). Each photograph is displayed with 4 descriptor words referring to facial expressions of complex emotions (e.g., irritated, impatient, ashamed). The participants’ task is to select the descriptor that best describes these expressions. The RMET was originally developed to detect mild deficits in social understanding, and the test differentiates between high-functioning autism and controls (Baron-Cohen et al. 2001). The study by Kidd and Castano (2013), which used a between-subject design, thus showed that the ability to correctly select the adequate

descriptor word in this test was higher in the group of participants who had read “literary” fiction than in the groups of participants who had read “nonfiction”, “popular” fiction, or nothing at all.

However, a series of ensuing studies cast doubt on the validity of these results because the initial findings were difficult to reproduce. While some studies replicated the findings (Kidd and Castano, 2018; van Kuijk et al., 2018), others did not (e.g. Camerer et al. 2018; Panero et al. 2016; Samur et al. 2018). A recent meta-analysis that examined effect sizes in a number of different experiments that compared the impact of reading narrative fiction with those of reading nonfiction, or no reading at all, nonetheless concluded that reading narrative fiction leads to a significant improvement in socio-cognitive performance. However, the effect is small (Dodell-Feder and Tamir 2018). A more sensitive test than the RMET could therefore be useful to capture these potential effects.

There are a number of tests in the literature that measures the perception and recognition of facial expressions of emotions, ranging from the “Brief Affect Recognition Test” (BART) from Ekman and Friesen (1974), to the “Diagnostic Analysis of Nonverbal Accuracy” (DANVA; Nowicki and Carton, 1993), to the test battery recently introduced by Wilhelm et al. (2014). The latter battery contains 16 different tasks that allow the multivariate assessment of the perception and recognition of facial expressions, including composite facial expressions, facial expressions of different intensities and from different viewpoints. However, in order to capture subtle effects of an experimental

variable on the perception of facial emotions, a test that allows establishing a psychometric relationship between some physical aspect of the stimulus and the participants' judgment would be beneficial. Systematically manipulating the intensity of facial expressions from a neutral expression to fully formed expressions of emotions (with sufficiently small steps), and determining how this manipulation affects the likelihood of recognizing facial emotions would be one option. Such systematic manipulations can be achieved through morphing techniques that gradually transform one image (i.e., a neutral face) into another (i.e., a fully formed facial expression). While studies that use morphing techniques to manipulate facial expression intensities exist (see e.g., Delicato, 2020; Gao and Maurer, 2009; Marneveck et al., 2014; Wilhelm et al., 2014), they are limited either by the number of the proposed facial emotions (e.g. {happy}{fearful}, Delicato, 2020; {happy}, {sad}, {fearful}, Gao and Maurer, 2009) and/or by the number of levels of manipulated expression intensities (e.g. from 5% to 35% expression intensity in 4 morphing levels; Marneveck et al., 2014). The test that we will present here manipulates expression intensity for the six basic emotions (Ekman et al. 1969), from neutral expressions to fully formed facial expressions, in 10 morphing levels. This allows establishing a psychometric function that relates to participants' judgements.

The FExIT. The Facial Expression Intensity Test (FExIT) consists of a series of individual faces (taken from the NimStim set of facial expressions (Tottenham et al., 2009) whose expression intensity is manipulated in ten morphing levels so as to vary from neutral to one of the six basic emotions (i.e., anger, disgust, fear, happiness, sadness, and surprise;

Ekman et al. 1969). Basic emotions are a special class of emotions that are considered as “building blocks” for all other emotional states (Ekman 1999; Izard 2011; Panksepp & Watt 2011). The participant’s task in the FExIT is to choose, among eight options (i.e., the six emotions, a “neutral”, and an “I don’t know” option), the one that correspond best to the emotion expressed in a given facial stimulus. By gradually varying the intensity of the facial expression, this test allows the establishment of a probability threshold at which a facial expression is correctly identified. Monitoring this threshold identifies whether a given experimental manipulation (e.g. prior reading of literary fiction), a pathological condition, or factors related to age, sex, culture, etc. will alter participants’ sensitivity to the identification of facial emotions. To validate the FExIT as a test that captures the expression of facial emotions we recorded event-related brain potentials (ERPs) while participants performed the test and analyzed prototypical emotion-related ERP components. These different components will be briefly introduced in the following section.

Emotion-related and face-related ERP components. In a recent comprehensive review of 102 ERP studies that investigated the processing of emotional compared to neutral facial expressions, Schindler & Bublatzky (2020; see also Schupp et al., 2006a) discussed two groups of relevant ERP components. The first group consists of the so-called EPN (Early Posterior Negativity) and the LPP (Late Positive Potential), which are considered as *prototypical emotion-related ERP components*. The EPN is a negative deflection over temporo-occipital regions (and over fronto-central electrodes, with a polarity reversal)

that is observed approximately 200 and 300 msec after stimulus onset (Schupp et al. 2006a). This early negative potential, which is triggered unintentionally and effortless (c.f. automatically), indexes the guidance of selective attention through emotional cues (Schupp et al., 2006a). The LPP is a late positive potential over centro-parietal regions that occur around 300-600 ms after stimulus onset. This late potential varies with the intensity of the emotional stimulus and is sensitive to manipulations of attention. The second group of ERP components, which consist of the early positive component P100 (approximately 80-120 ms post stimulus), the N170 (a negative deflection over temporo-occipital sensors approximately 150 and 200 ms) and the ensuing positive component P200, reflect the encoding of *basic visual facial features*. Of these three components, the systematic effects of expressions of facial emotions have also been reported for the N170 component (Hinojosa et al., 2015; Schindler & Bublatzky, 2020). Analyzing these two groups of ERP components allows us to determine whether variation in the intensity of facial expressions in the FExIT affects visual facial- and/or emotion-related components. As we will show, the amplitude of the early emotion-related ERP component (i.e., the EPN) varies systematically with the intensity of the facial expression.

2. STAGE I: DEVELOPMENT AND SELECTION OF FACE-STIMULI

Pilot experiment for the selection of face stimuli.

A pilot experiment served to discard face stimuli for which participants provided inconsistent responses.

Participants. Fifteen members of the laboratory volunteered for this pilot experiment.

Stimuli. The NimStim set of facial expressions (Tottenham et al., 2009) was used to construct our face-stimuli. The NimStim set is a validated set of pictures of facial expressions exhibited by 43 young adult actors of different races and genders. These actors were instructed to pose for six different emotions (i.e., {angry}, {disgust}, {fear}, {happy}, {sad}, and {surprised}) and for a {neutral} facial expression. The initial validation of the stimuli by Tottenham et al. was accomplished by asking 81 (51 females/30 males) untrained, healthy adult participants to label each stimulus. The mean proportion of correct emotion identification was 0.81 (SD=0.19, median=0.88) and the overall agreement between raters' labels and emotion expression had a mean kappa across stimuli of 0.79 (SD=0.17; median kappa=0.83); Tottenham et al., 2009). In our study we used faces from 18 of the initial 43 actors.

Using the freeware multimorphing package from Sqirlz Morph software (www.xiberpix.net) we generated sequences of 10 image frames for each of the 6 emotions, going from the NimStim {neutral} expression (0% emotion) to the NimStim emotional expression (100% emotion). This resulted in a total of $18 \times 6 \times 10 = 1080$ face stimuli. The morphed images were converted into grayscale bitmap images and matched for luminance and contrast. An oval cut-out of the faces was used to hide hair and neck (see Figure 1 for an example). The cut-out occupied a matrix of 256×320

pixels and was presented on a light gray background with constant luminance of 262.53 cd/m². For each face stimulus we also created a visual mask by scrambling the pixels in the image, row-by-row (see Figure 2).

FIGURE 1. Task stimuli. Example of facial stimuli showing 10 expression intensities from neutral face (0%) to the (maximal) disgusted expression (100%).

Procedure. A total of 1080 face-stimuli was presented in two separate experimental blocks (2x540 stimuli), on two different days. Participants were facing a screen (100 Hz refresh rate) against a dark background. At a viewing distance of 60 cm the oval cut-out subtended a visual angle of $5.7^\circ \times 9.5^\circ$. Each trial began with a fixation cross displayed for 1 s followed by the face-stimulus (350 ms) and the visual masked (1s), presented centered on the screen. After the offset of the mask, a question mark appeared at the center of the screen surrounded by the 8 response options (see Figure 2 for an illustration). The participant's task was to label the face either as "angry", "surprise", "disgust", "fear", "happy", "sad", "neutral", or "I don't know" by moving the cursor with a computer-mouse to one of the 8 response options. The task was not timed,

and the next trial was triggered immediately after the participants responded. The 540 pictures in a block were presented randomly. A break was introduced after every 50 trials.

FIGURE 2. Description of an experimental trial. Participants were requested to fixate on a fixation cross presented for 1 s. The fixation cross was immediately followed by the presentation of a face stimulus for 350 ms, followed by a visual mask displayed for 1 s. The mask was replaced by a screen displaying the 8 response options, which remained on the screen until participants responded.

Results and selection of the FExIT stimuli. Based on the data from the 15 participants we calculated an averaged response profile for each of the 18 actors and each of the 6 different emotions as a function of the 10 levels of expression intensity ("EI") (see Figure 3).

FIGURE 3. Proportion of correct identifications (group mean) as a function of the ten emotional intensities (EI) for the six emotions by the same actor. The faces in the inset represent maximal emotional intensity expressed by the actor.

As shown in the figure, correct responses increase with the level of EI, resulting in a sigmoid response function. Face stimuli that did not elicit such a sigmoid function and face stimuli for which the average response accuracy at 100%-EI did not reach a correct recognition probability of 0.5, were excluded from the stimulus set (e.g., the sad-face in Figure 3). At the end of this procedure we created two equal lists of 350 stimuli, each composed of 40 stimuli representing angry faces (i.e., 4 different actors x 10 EIs), 60 stimuli representing surprise, 50 stimuli representing disgust, 80 stimuli representing happiness, 70 stimuli representing fear, and 50 stimuli representing sadness. These two lists represent the stimuli set of the FExIT, which is thus a test that allows a within-subject design, with pre- and posttest measures. To validate the FExIT, we recorded ERPs while 75 participants were performing the test and we analyzed facial- and emotion-related ERP components. This validation is presented in the next section.

3. STAGE II: VALIDATION THROUGH THE ANALYSIS OF FACIAL- AND EMOTION-RELATED ERP COMPONENTS

Data presented here were collected as part of a larger study with a pretest/posttest experimental design including 4 conditions (Cayol and Nazir, in preparation). The data described here consists of the combined pre-tests of the 4 conditions.

Participants. Seventy-five 19 to 33 years old French young adults (48 females/27 males) with normal or corrected vision participated in the main experiment (due to technical problems with data from the EEG experiment four of an initial group of 79 participants had to be excluded). All participants provided written informed consent prior to the experiment, which was approved by the Human Research Ethics Committee (CPP Sud-Est II). All methods were performed in accordance with the relevant guidelines and regulations.

Experimental procedure. Participants were comfortably seated in front of a computer screen (approximate distance ~60 cm). The experimental procedure was identical to that used in the pilot study (see Figure 2). The participants' task was to identify the emotion of each of the faces. The 350 face stimuli were presented in 7 blocks of 50 trials each. Testing took approximately 25 minutes.

ERP recording and data analyses. EEG data were collected using an elastic cap from the 128-channel system (HydroCel Geodesic Sensor Net, Electrical Geodesics, Inc., Eugene, OR, USA) with Net Station EEG Software (5.1.2). All electrodes were physically referenced to Cz (fixed by the EGI system) and the signal was sampled at 1000 Hz. Electrode

impedance was maintained below 10 K Ω and stimuli presentation was controlled by a PC running the Presentation® software (Neurobehavioral Systems, Inc). The horizontal electro-oculogram (EOG) was recorded from two electrode sites at the outer canthi of each eye, and the vertical EOG was recorded from electrodes situated on the infra-orbital and supra-orbital regions of the left eye.

Off-line EEG processing and analyses were performed using Fieldtrip. The time window for the analyses was fixed between -200 ms pre- and 1000 ms poststimulus onset, with 200 ms prestimulus EEG serving as the baseline. EEG data were filtered with a band stop at 2-32 Hz. Artifacts were detected by MATLAB arithmetic using EOG values, and epochs with potentials exceeding $\pm 150 \mu\text{V}$ were automatically rejected. Data were segmented and averaged according to emotional valence category. Data for electrodes with atypical signal quality within all trials were reconstructed using spherical spline interpolation procedures. After removing trials containing artifacts, an average of 96% of trials (range: 75–100% across participants) were selected for further analysis.

Behavioral data

Descriptive results. Individual data were first averaged for each of the six emotions and for each of the ten expression intensities. Figure 4a shows the mean proportion of correct responses, averaged over all participants and emotions, as a function of the ten emotional intensities. Recall that given the six emotions, plus the neutral response and the possibility to respond “I don't know”, the theoretical chance level for a given

response is 12.5% (indicated in the figure by the dotted line). Figure 4b displays the results for the six emotions separately. The colored graphs in the figure presents the data separately as a function of gender (blue for females and orange for males). As evident from these figures, a steady increase in the proportion of correct responses was observed as emotional intensity increased. With the exception of faces with a {happy} or a {surprise} expression, averaged performance for the group of male participants was inferior to that of the group of female participants. We will come back to this point later.

FIGURE 4. Left panel: Correct identification of emotions as a function of emotional intensity averaged over all emotions. Right panel: Correct identification of emotions as a function of expression intensity (EI) for each of the six emotions. The horizontal gray dashed line corresponds to the theoretical chance level (12,5%). The horizontal grey solid line indicates the .75 response threshold.

To reduce the data set for the analyses of ERP data, we averaged trials from two adjacent expression intensities such that expression intensities 1 and 2 represent the neutral condition, i.e., EI-0%; expression intensities 3 and 4 represent EI-25%; expression intensities 5 and 6 represent EI-50%; expression intensities 7 and 8 represent EI-75%; and expression intensities 9 and 10 represent EI-100%.

Figure 5 shows the proportion of the 4 types of participant responses, i.e., the correct identification of the emotion, the attribution of an incorrect emotion, the use of the “neutral” and the “I don’t know” response option as a function of EI.

Note that the answer “I don’t know”, which occurred on the average in 2.65% ($\pm 4.02\%$) of trials, was not further considered in any of our analyses. Several aspects of the response profile are worth noting. First, and not surprisingly, the proportion of correct responses increases with EI, and the proportion of “neutral” responses decreases. However, second, in a significant proportion of trials (i.e., 0.28), participants attributed emotions to faces that are considered neutral in the NimStim set. This suggests, that a “neutral” face is difficult to define and that our EI-0% condition is in fact not neutral but rather a low EI condition. In the validation study of the NimStim set, this did not show as strongly as here because facial stimuli were either {neutral} (EI-0%) or {emotional} (EI-100%), which makes the choice easier. Third, in approximately one out of every four or five trials in each of the 5 EI conditions, an “incorrect” emotion was attributed to the face stimulus. This illustrates that deciding whether a given facial expression represents emotion X rather than emotion Y is not always straightforward. For example, the facial expressions in the lower part of Figure 1 could also be labeled {anger} instead of {disgust}. Along this line, the data in Figure 4 show that for emotions such as {disgust}, {fear} and {sadness}, “correct” performance does not or hardly get past the .75-threshold level. Therefore, “incorrect” responses reflect a disagreement about how to label the emotions expressed in the faces but testify nonetheless that participants perceived an emotion. For these reasons both, “correct” and “incorrect” trials will be considered as

trials in which participants attributed an emotion to the facial stimulus and will be analyzed as such along with the analysis of “correct” responses.

FIGURE 5. Proportions of the 4 types of responses (i.e. the correct identification of the emotion, the attribution of an incorrect emotion, the use of the “neutral” and the “I don’t know” response options) as a function of EI.

EEG data

Face-sensitive ERP components. Figure 6 shows a butterfly plot of recorded ERPs for all electrodes and all emotional intensities, averaged over trials and participants. This plot served to identify the time windows for the analyses of the different ERP-components, i.e., the P100, N170, P200, EPN and LPP.

After visual inspection of the grand-average ERPs and inspection of individual peaks, we defined time windows for each component as follows: P100 (50–125 ms), N170 (130–185 ms), P200 (190–220 ms), and EPN (220–320 ms). We also analyzed two late components, one with peaks defined within a time window spanning from 350 to 450

ms and another with peaks within a time window spanning from 460 to 700 ms poststimulus. We will refer to these components as LPP_1 and LPP_2 , respectively.

FIGURE 6. Butterfly plots of event-related potentials (ERPs) for all electrodes and all emotional intensities averaged over trials and participants. The vertical line at “0” indicates stimulus onset.

Region of interest. A nonparametric cluster-based permutation analysis (c.f. the Monte Carlo method; Maris & Oostenveld, 2007) was used to explicitly target electrode clusters that systematically respond to emotional change. For this, trials with correct responses from the EI-0% condition were contrasted with those from the EI-100% condition¹. On average, in the EI-0% condition, 0.69 of the trials were correctly identified as “neutral”, and in the EI-100% condition, 0.80 of the trials were correctly identified as expressing the target emotion.

A paired t-test was conducted for each electrode at each time bin within the defined time windows for each of the selected ERP components. T-values exceeding an *a priori* threshold of $p < 0.05$ were clustered based on adjacent time bins and

¹ For the identification of regions of interest, we relied on trials with “correct” responses only, to increase the chance of finding solid differences between the EI-0% and the EI-100% conditions.

neighboring electrodes. Cluster-level statistics were calculated by taking the sum of the t-values within every cluster. Comparisons were performed with respect to the maximum values of summed t-values. By means of a permutation test (i.e., randomizing data across conditions and rerunning the statistical test 1500 times), we obtained a reference distribution of the maximum of summed cluster t-values to statistically evaluate the actual data. Taken over all tested ERP components, the cluster-based permutation test revealed two regions of interest (Figure 7). One was located over the frontal region (a total of N=11 electrodes) and one over left and right temporo-occipital regions, respectively (total number of electrodes over the two hemispheres N= 22; Figure 7, right panel). No significant clusters were detected for fronto-central or centro-parietal regions, where LPP is typically recorded.

FIGURE 7. Comparison of face stimuli with neutral (0%) and maximal (100%) emotional intensity. On the left, grand-averaged ERPs for EI-0% {"neutral"} and EI-100% averaged across significant right occipital electrodes (N=12 electrodes; top), left occipital electrodes (N=10 electrodes; middle) and fronto-central

electrodes clusters (N=11 electrodes; bottom) (shades represent the SEM). On the right, corresponding t-statistic difference maps of ERP amplitudes in the two EI conditions. Crosses indicate significant channels ($p < 0.05$).

Table 1 summarizes results from the cluster-based permutation analysis for the different components at the frontal and temporo-occipital clusters (all $p < 0.05$). With the exception of effects in the time window of the EPN, no significant effects were observed at the frontal cluster. In contrast, except for the P100, all tested components showed a significant difference between the EI-0% and EI-100% conditions at the occipito-temporal cluster.

TABLE 1: Results from the cluster-based permutation analysis

	Time Interval (ms)	Temporo-occipital	Frontal
P100	50–125	n.s.	n.s.
N170	130–185	< .05	n.s.
P200	190–220	< .05	n.s.
EPN	220–320	< .05	< .05
LPP ₁	350–450	< .05	n.s.
LPP ₂	460–700	< .05	n.s.

Therefore, in all subsequent analyses we dropped the P100 component. Moreover, since no significant clusters were detected at fronto-central or centro-parietal regions for the analysis of LPP, we did not further consider effects in time windows beyond 350 ms. The effect of expression intensity of the facial stimuli was thus tested for N170, P200, and EPN at the temporo-occipital cluster. We also dropped analysis of the EPN time window at the frontal cluster, which we regard as the polarity reversal of the EPN seen at the temporo-occipital cluster.

First, we analyzed the ERP data independently of the response given by participants (i.e., “neutral”, “correct”, or “incorrect”). This was done because many ERP experiments in this domain do not ask participants to identify the perceived emotion and include all trials in their analyses. Therefore, this first analysis allows for a direct comparison to results in the literature. Second, analyses were performed on a subset of trials in which participants explicitly reported having perceived an emotion, (independent of whether the identified emotion was “correct” or “incorrect”) to verify whether the ERP patterns were affected by participants’ responses.

Analysis over all trials.

By focusing on temporo-occipital electrode clusters, we examined whether ERPs distinguished between the five facial EIs (0%, 25%, 50%, 75%, and 100%). Over the right hemisphere electrodes included E78, E77, E76, E75, E83, E84, E85, E90, E91, E95, E96, and E97, and over the left hemisphere electrodes included E51, E52, E58, E59, E60, E64, E65, E66, E70, and E71. Figure 8 plots grand average waveforms recorded at these two clusters. Very systematic modulations of the ERP components as a function of expression intensity are seen, in particular in the EPN time window and beyond.

FIGURE 8 ERP modulations by emotional intensity. Time course for all emotional intensity conditions (0%, 25%, 50%, 75% and 100%), averaged over right (A) and left (B) occipital clusters. Shaded gray squares show the time windows where a significant effect of emotional intensity was identified (i.e., N170, P200, EPN).

Data were analyzed using SPSS (SPSS, Inc., Chicago) and were checked for outliers via studentized residuals. Participants with data that showed a studentized residual of $> \pm 3$ were eliminated from the analysis (specified in the text). In some cases, the normality assumption (assessed by Shapiro-Wilk's test of normality on the studentized residuals) for one of the five EIs was not met. These cases are specified in the text, but data was not excluded from the analysis. The repeated-measures ANOVA contained as within-subject factors EI (0%, 25%, 50%, 75%, and 100%) and hemisphere (left, right). Greenhouse–Geisser correction was applied when necessary. A significance level of 0.05

was used for all analyses. Figure 9 gives the amplitudes of the peaks for the different ERP components. The results of the ANOVA are summarized in Table 2 and specified in details in detail below.

The N170

Data from one participant were discarded due to outliers. Data were normally distributed ($p > 0.05$) except for the 25% condition recorded over the temporo-occipital right hemisphere ($p = 0.036$). The effect of hemisphere was significant, $F(1,73) = 15.156$, $p < 0.001$, $\eta^2p = 0.172$, with ERPs recorded over the right hemisphere being more negative than those over the left hemisphere. The effect of EI was also significant $F(4,292) = 5.717$, $p = 0.001$, $\eta^2p = 0.073$, with more negative amplitudes as EI increases. The interaction between the two main factors was not significant. Pairwise comparisons for EI (with Bonferroni adjustment) are given in the bottom part of Table 2 and show a systematic difference only between the 100%-EI condition and the 0%-EI, 25%-EI, and 50%-EI conditions.

The P200

The effect of hemisphere was significant $F(1,74) = 29.844$, $p < 0.001$, $\eta^2p = 0.287$, with ERPs recorded over the right hemisphere being more positive than those over the left hemisphere. The effect of EI was also significant, $F(4,296) = 3.802$, $p = 0.007$, $\eta^2p = 0.049$, but the interaction between the two main factors was not. Pairwise comparisons for EI did not reveal any significant effects.

The EPN

Data from one participant were discarded due to outliers. There was a significant effect of hemisphere, $F(1,73) = 8.636$, $p = 0.004$, $\eta^2p = 0.106$, with ERPs recorded over the right hemisphere being more positive than those over the left hemisphere. The effect of EI was also significant, $F(4,292) = 14.485$, $p < .001$, $\eta^2p = .166$, as was the interaction between

the two main factors, $F(4,292) = 4.797$, $p = 0.002$, $\eta^2p = 0.062$. Separate analyses for the clusters over the two hemispheres revealed an effect of EI for the left hemisphere, $F(4,292) = 15.783$, $p < 0.001$, $\eta^2p = 0.178$, as well as for the right hemisphere $F(4,292) = 11.249$, $p < 0.001$, $\eta^2p = 0.134$. Pairwise comparisons for EI (with Bonferroni adjustment) for each of the two electrode clusters showed systematic differences between several EI conditions (see bottom part of Table 2).

FIGURE 9: Peak amplitudes for the N170, P200, and EPN under different EI conditions. Data are plotted separately for clusters over the right (RH) and the left (LH) hemispheres. Data are plotted using the standard error of the mean (SEM).

TABLE 2: Results of the ANOVA for the different components. Pairwise comparisons are shown at the bottom.

ERP	Time Interval (ms)	n	hemisphere	η^2p	Expression intensity	η^2p	interaction	η^2p
N170	130–185	74	(F1,73) =15.156 $p < .001$	.172	(F4,292) =5.717 $p = .001$	.073	n.s.	-
P2	190–220	75	(F1,74) =29.844 $p < .001$	.287	(F4,296) = 3.802 $p = .007$	.049	n.s.	-
EPN	220–320	74	(F1,73) =8.636 $p = .004$	.106	(F4,292) =14.485 $p < .001$	.166	(F4,292) =4.797 $p = .002$	.062

EPN LH	220-320	74			(F4,292) =15.783 p<.001	.178		
EPN RH	220-320	74			(F4,292) =11.249 p<.001	.134		

Pairwise comp.	N170					EPN left hemisphere					EPN right hemisphere				
	0%	25%	50%	75%	100%	0%	25%	50%	75%	100%	0%	25%	50%	75%	100%
0%	-				*	-		*	*	*	-		*	*	*
25%		-			*		-		*	*		-	*	*	*
50%			-		*			-	*	*			-		
75%				-					-					-	
100%					-					-					-

Discussion. In line with results in the literature that show differences in the amplitude of face- and emotion-related ERP components when processing neutral faces as opposed to faces that express emotions (c.f. Schindler & Bublatzky, 2020), the ERP components tested here (N170; P200; EPN) showed an effect of EI. However, a systematic and significant variation of the ERP amplitude with the level of EI was only observed for the emotion-related ERP component, EPN. EPN also exhibited the largest effect size, with a η^2p of 0.166 for the main effect of EI (note that η^2p of > 0.14 is considered a large effect (Cohen, 1988)). In contrast, ERP components related to the processing of basic visual facial features (N170; P200) seemed to be less sensitive to the gradual manipulation of EI.

While the results of our analysis are suggestive of the assumption that the amplitude of the EPN is modulated by the intensity of a facial expression, it is important to note here that this finding could also be an artifact of our analysis. Recall from Figure 7 that neutral faces (EI-0%) trigger different ERP amplitudes than faces with EI-100%. Recall also from Figure 5 that the proportion of “neutral” responses decreases from EI-0% to EI-100%. If the different ERP amplitudes in Figure 7 result from the participant’s response selection (i.e., deciding that a facial expression is “neutral” or “emotional”), rather than from the

quality of the physical stimulus (i.e., a face with different levels of emotional expression intensity), averaging over all trials would also result in such amplitude modulations. Therefore, before further interpreting our results, it is necessary to analyze EPN by excluding trials in which participants responded with “neutral”.

Analysis for trials in which participants attributed an emotion to the stimulus. This second analysis thus selectively focused on trials in which participants attributed an emotion to the facial stimulus (“correct” or “incorrect”) in order to establish whether the EPN would still distinguish between different levels of EIs when “neutral” responses are excluded. If the observed modulations of EPN in Figure 8 resulted from participant response selection, the difference between the five EIs should disappear. However, if these modulations are triggered by different levels of facial expression intensities, EPN amplitudes should still vary as a function of EI.

Since the number of trials for which participants indicated having seen an emotion was not equal in the five EI-conditions (i.e., it varies from an average of 18 trials in the EI-0% condition to an average of 66 trials in the 100%-EI condition), for each participant, we randomly chose 20 trials from each of the five conditions (note that in the EI-0% condition some participants had fewer than 20 trials). All analyses were performed as described previously.

Figure 10 plots grand average waveforms recorded at temporo-occipital clusters and shows a very similar pattern to that seen when all trials were considered (c.f. Figure 8).

FIGURE 10: ERP modulations by emotional intensity. Time course for all emotional intensity conditions (0%, 25%, 50%, 75%, and 100%), averaged over the right (A) and left (B) occipital clusters. Shaded gray squares show the time window where a significant effect of emotional intensity was identified. Bar charts provide mean amplitudes collapsed over the right (A) and left (B) occipital clusters. Error bars indicate standard errors.

For the ANOVA, data from two participants were discarded due to outliers. There was a significant effect of hemisphere, $F(1,73) = 7,409$, $p = 0.008$, $\eta^2p = 0.093$, with ERPs recorded over the right hemisphere being more positive than those over the left hemisphere. The effect of EI was also significant, $F(4,288) = 9,320$, $p < 0.001$, $\eta^2p = 0.115$, but the interaction between the two main factors was not. Pairwise comparisons (with Bonferroni adjustment) still showed systematic differences between several EI conditions (see bottom part of Table 3).

TABLE 3: Results of the ANOVA for the EPN. Pairwise comparisons are shown at the bottom.

	Time Interval (ms)	n	hemisphere	η^2p	Expression intensity	η^2p	interaction	η^2p
EPN	220-320	73	(F1,73) = 7,409, p=.008	.093	(F4,288) = 9,320, p<.001	.115	n.s.	-

Pairwise comp.	EPN				
	0%	25%	50%	75%	100%
0%	-			*	*
25%		-	*	*	*
50%			-		
75%				-	
100%					-

Figure 11a plots the amplitudes of EPN in the different EI conditions when trials were considered, independent of participant responses (blue curve; same data as in Figure 9) and when only the 20 randomly selected trials for which participants reported having perceived an emotion were considered (orange curves). While an overall increase in the relative negativity (data are less positive) of EPN was observed when trials with neutral responses were excluded from the analysis, amplitude modulations due to EI were nearly identical in the two data sets.

FIGURE 11. (a) Peak amplitudes for the EPN as a function of expression intensities (0%, 25%, 50%, 75%, and 100%). The blue curves show results when all trials were considered, independent of participant responses. The orange curves show results when only the 20 randomly selected trials for which

participants reported having perceived an emotion were considered. Data are plotted separately for clusters over the left (LH) and the right hemispheres (RH). Data are plotted using the standard error of the mean (SEM). **(b)** Peak amplitudes for the EPN in the EI-25% condition as a function of participants' response ("neutral" in blue versus attribution of "emotion" in orange). Data are plotted separately for the two hemispheres (LH, RH).

The effect of response choice. Since the data in Figure 11a exposed an overall difference in the amplitude of ENP when "neutral" responses were included in the analysis, we ran a final analysis on data for the EI-25% condition only. In the EI-25% condition, in approximately half of the trials, participants responded with "neutral", while in the other half, they attributed an emotion ("correct" or "incorrect") to the face stimuli (c.f. Figure 5). Therefore, this condition allows comparison of the EPN for the same facial stimuli as a function of participant response. The results are plotted in Figure 11b and reveal a main effect of response type, with a lesser relative negativity of the ENP for trials in which participants responded with "neutral". For the ANOVA data from one participant were discarded due to outliers. The effect of response type was significant, $F(1,73) = 11.801$, $p = 0.001$, $\eta^2_p = 0.139$. There was no effect of hemisphere, and the interaction between the two main factors was not significant either.

Discussion. When trials with "neutral" responses were excluded from the analysis, the EPN remains sensitive to the variation of EI (Figure 11a). The systematic modulation of the amplitude of this component with the intensity of the facial expression is thus not simply an artifact of mixing trials with "neutral" responses with those in which participants reported having perceived an emotion. Rather, the modulation of the EPN amplitude is triggered by the intensity of the facial expressions. Together with the fact that EI modulations did not systematically affect ERP components that reflect the encoding of basic visual facial features (i.e. P100, N170, P200 components) the variation of the EPN amplitudes can be considered as reflecting the level of perceived intensity of facial emotional cues. Finally, participant response type had also an impact on the

EPN amplitude (Figure 11b) because for facial stimuli with the same EI (25%), the ENP was less negative when participants responded with “neutral” compared to one of the six emotions. The nearly parallel curves in Figure 11a, (which represent the equivalent results for all EIs but with different number of trials in the two conditions) suggest that the effect of response type is additive to that triggered by the levels of EIs. The sigmoid output function of the FExIT can thus be affected on two independent dimensions, i.e., its height and its form. Each of these parameters might reflect distinct aspects of emotional processing.

4. MORE ABOUT USING THE FExIT

The two lists and the number of trials in the test. As mentioned before, with its two equivalent lists, the FExIT allows for a pretest/posttest experimental design. In Figure 12, we plotted the proportion of responses obtained for each of the two lists. Thirty-six participants saw List1 and thirty-nine participants saw List2². Results are given for trials with “correct” emotion attribution (left) and for trials with “correct” plus “incorrect” emotion attribution (right). Data are plotted with a 95% confidence interval (CI) and are presented as a function of the 10 levels of EI. In both analyses, the two curves are superposed, indicating that the lists are well balanced. In a pre- and posttest experimental design, one list can thus be used prior to the experimental manipulation and the other after the manipulation in order to avoid repetition effects. As we will show in the next section, FExIT can also serve to distinguish between populations. In this case, only one list is required. The number of trials in the FExIT can also be reduced to make the test more practical (e.g. every other EI). Finally, depending on the goal of a given experiment, certain emotions can be discarded from the test.

² The number of participants per list is not balanced because some participants were excluded from the study because of noisy ERP data (see Method section).

FIGURE 12: Performance for the two independent lists (List 1 in orange; List 2 in blue) of the FExIT. Left panel: Mean proportion of trials with "correct" emotion attribution. Right panel: Mean proportion of trials with "correct" and "incorrect" emotion attribution. Data are plotted as a function of the 10 EIs. Error bars are 95% confidence intervals (CI).

An example of the application of the FExIT: Uncovering potential gender differences in the perception of facial emotions. In Figure 13, we plotted the data as a function of participant's gender (48 females and 27 males). Since the two groups were not of the same size, the data were represented as box plots.

FIGURE 13: Box plots of performance as a function of gender (Female in blue; Male in orange). Left panel: Trials with "correct" emotion attribution. Right panel: Trials with "correct" and "incorrect" emotion

attribution. Data are plotted as a function of the 10 expression intensities (EI). The red arrows point to maximum data values in the female-group that are much higher than those in the male-group. The dots are outliers, defined as data beyond ($1.5 \times$ the interquartile range).

When trials with “correct” emotion attribution are considered (Figure 13, left panel), female participants seem to slightly outperform male participants (see also Figure 4). This is most evident for expression intensities EI7, EI8, and EI9. In these three conditions, the median of the male group is at the level of the lower quartile of the female group. When considering trials in which participants reported having perceived an emotion independently of whether the attributed label was “correct” or “incorrect” (Figure 13, right panel), the gender difference becomes less marked. However, for expression intensities EI6 and EI7, the median of the male group is still at the level of the lower quartile of the female group. Note also in this latter graph that for low EIs, the maximum data values as indicated by the whiskers of the box plot are higher for females than for males (highlighted by red arrows in the figure). Hence, in the upper quartile, females demonstrated a wider range of their responses than males, indicating a stronger tendency to attribute emotions to low-intensity facial expressions. Taken together, it is thus likely that there is an effect of gender on the perception of the expression of facial emotions, i.e. females have a stronger tendency to attribute emotions to face stimuli than males. Note that on the electrophysiological level, gender differences in the perception of the expression of facial emotions had been reported before, i.e., by Proverbio et al. (2006) for pictures of neutral vs. distressed infants.

For a further illustration of how to analyze FExIT scores, Figure 14 plots performance (median) for only the 50% of participants that scored above the median of the group (i.e., participants in the two upper quartiles; 24 females and 13 males). Data (circles) are plotted with a 95% confidence interval (CI). For “correct” emotion attribution (left panel) female participants performed significantly better than male participants for the EI5, EI7, EI8, and EI10 conditions (see the non-overlapping CIs). When “correct” and “incorrect”

emotion attribution were considered together (right panel) the gender difference was still present (e.g. see EI5, EI9), but weaker. To determine whether the female group attained the 0.75 response threshold at lower EIs than the male group, we fitted a sigmoid function to the data of each participant (all $R^2 > 0.96$ in the "correct" emotion attribution condition and > 0.92 in the "correct" and "incorrect" emotion attribution condition) and determined when the function crossed the 0.75 threshold. Averaged over all participants, the results for "correct" emotion attribution (left panel) showed that the group of female participants attained the threshold at an EI of 6.6 (CI = 0.15) and the group of male participants at an EI of 7.2 (CI = 0.12). The vertical blue and orange bars in the figure are plotted centered around these values and the width of the bars indicates the range of the respective CIs. Since these bars are not superposed the difference between female participants and male participants is significant. By contrast, in the right panel the respective EIs are 5 for females and 4.7 for males, and the CIs are superposed. This again suggest that the gender difference is less obvious when "correct" and "incorrect" emotion attribution are considered together.

FIGURE 14: Performance (median) as a function of gender (female in blue; male in orange) for the 50% of participants from each group with the highest performance (n=24 for the female group and n=13 for the male group). Left panel: Trials with "correct" emotion attribution. Right panel: Trials with "correct" and

"incorrect" emotion attribution. Data are plotted as a function of the 10 expression intensities (EI). Error bars are 95% confidence intervals (CIs) for the data. The .75 threshold is indicated by the gray horizontal line. A sigmoid function is fitted to the data points. The blue and orange vertical bars help determine the degree of EI that is necessary to pass this threshold. The width of these bars indicates the range of the CIs.

Finally, in Figure 15, instead of the median, we display the arithmetic mean of performance (with CIs) of data that we submitted to an ANOVA. To equalize the number of participants in the two gender groups, we considered only data from the first 27 female participants (out of the total of 48) who passed our experiment and compared their performance to that of the 27 male participants.

FIGURE 15: Performance (arithmetic mean) as a function of gender (female in blue; male in orange) for 27 participants from each group. Left panel: Trials with "correct" emotion attribution. Right panel: Trials with "correct" and "incorrect" emotion attribution. Data are plotted as a function of the 10 expression intensities (EI). Error bars are 95% confidence intervals (CIs) for the data. The .75 threshold is indicated by the gray horizontal line.

Outliers, as indicated in Figure 13, were replaced with the mean of the group. For the "correct" emotion attribution condition there were 7 outliers in the group of females and 5 in the group of males. For the "correct" and "incorrect" emotion attribution

condition these values were 5 and 13, respectively. Two separate repeated measures ANOVAs with gender as between group factor and EI as within group factor were performed. For the "correct" emotion attribution condition the ANOVA showed that there was a significant effect of EI ($F(9,468) = 1058,77$; $p < 0.001$) and a marginally significant effect of gender ($F(1,52) = 3.806$; $p = 0.056$). The interaction between the two variables was not significant. For the "correct" and "incorrect" emotion attribution condition only the factor EI was significant (EI ($F(9,468) = 775,08$; $p < 0.001$). Hence, once more, the analysis points to an effect of gender when participants have to label emotions "correctly" but not when emotion attribution is considered independently of the emotional label attributed to the facial stimulus.

Our experiment was not designed to test gender differences and the reported findings should be considered as preliminary. The results of the above analyses serve in the first place as illustration of how to look at the data obtained in the FExIT. Since the scores of the test can be described as a function of the physical magnitude of the EIs, determining response thresholds (c.f. Figure 14) is the preferred choice for evaluating differences between conditions and/or populations. When the number of participants is balanced, individual threshold values can be further submitted to an ANOVA.

5. GENERAL DISCUSSION

The FExIT consists of a series of faces taken from the NimStim facial stimuli set (Tottenham et al., 2009), which varies from neutral expressions to one of the six basic emotions (i.e., {anger}, {disgust}, {fear}, {happiness}, {sadness}, and {surprise}; Ekman et al. 1969), using 10 levels of morphing. These stimuli are freely accessible from [www](http://www.nimstim.org). The participant's task in this test is to identify the emotion being expressed by choosing one of 8 options, i.e., the six basic emotions, a "neutral", and an "I don't know" option. The score of the FExIT is either the proportion of correctly identified emotions, or the

proportion of the attribution of an emotion to the facial stimulus (i.e., the attribution of any emotion to the face but not “neutral” or “I don’t know”). The task is not timed. Since the score of the FExIT describes a continuum from the lowest to the highest intensity of facial expression, the test enables determination of a probability threshold for the scores. Moreover, as the test contains two equivalent lists of face stimuli, the FExIT allows for within-subject, pre- and posttest experimental designs. It is also adapted for comparing different populations, as we have demonstrated by contrasting the performance of females and males on the perception of facial emotions.

To validate the FExIT as a test that captures the perceived intensity of facial expressions of emotions, we analyzed a prototypical emotion-related ERP component, i.e., the early negative potential (EPN; e.g. Schupp et al., 2006a; Schindler & Bublatzky, 2020), recorded while 75 participants performed the test. In doing so, we showed that as the intensity of facial expression grows and the number of trials in which participants attribute an emotion to the facial stimulus increases, the amplitude of the EPN becomes progressively larger. This finding is consistent with earlier studies that manipulated a subset of facial expressions using two or three levels of intensities (e.g. low and high, plus neutral, Müller-Bardorff et al., 2016; EI-40%; EI-70%; EI-100%, Wu and Wang, 2019; see also Winston et al., 2003 for fMRI data) and showed that more intense facial expressions elicited a stronger response. EPN is a negative potential over temporo-occipital regions that peaks approximately 200–300 ms after stimulus onset. Modulation of the amplitude of this component by emotional stimuli has been demonstrated for a range of stimuli including complex pictorial scenes (see e.g. Olofsson et al., 2008), written language (see e.g. Citron, 2012), and faces (see e.g. Schindler & Bublatzky, 2020). The receptiveness of the EPN to emotional stimuli remains constant across repeated presentations of the same materials (e.g. Schupp et al., 2006b) and occurs in the absence of an active task (Schindler & Bublatzky, 2020). Critically, EPN is sensitive to situational and dispositional factors. For a neutral face, for instance, the amplitude of

the EPN is modulated by a preceding verbal description that contains cues of affective valence. Hence, a negative context-sentence such as “She thinks your comment is stupid”, will increase the amplitude of the EPN to a subsequently presented neutral face (Wieser et al. 2014; see also Liu et al., 2019; Rischer et al., 2020). Clark et al. (2020) also showed that trait empathy affects ENP. For individuals with either low or high empathy levels, EPN is generally larger compared to individuals with an empathy level at an intermediate range. The differential ENP amplitudes that we observed for the EI-25% condition when participants responded with “neutral” as opposed to one of the six emotions likely reflect the influence of such contextual factors. Whether situational and dispositional factors affect the same parameters of the sigmoid output function of the FExIT (i.e., its height or its form) remains to be established.

Emotional cues serve to direct attentional resources to prepare adequate behavior (i.e., avoidance or approach-related actions; see Ohman et al., 2000; Schupp et al., 2006). Since faces with increasing levels of EI progressively increase the amplitude of EPN, the FExIT can be considered as a test that measures the level of perceived intensity of emotional cues in a facial expression. The FExIT is simple to administer and, in its longest form, takes only 25 min to complete. Several modifications to the test are possible, ranging from reducing the number of trials by testing only every other one of the 10 EIs, to selectively testing only a subset of the six basic emotions. With these features, the FExIT presents a useful instrument for basic and clinical research in social-emotional domains.

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