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Joyful Facial Mimicry: Can It Be Quantified By Observation Alone?

Pauline G[1,2], Pierre B[1], Juliette P[1], Vitalie R[1], Alessandra T[1], Pauline N[1,2] and Nathalie E[1,2,*]

[1]*Neurology department, Maison-Blanche hospital, Reims, France*
[2]*University of Paris Cité, MC2Lab (UR 7536), Boulogne-Billancourt, France*

[*]**Corresponding author:** Nathalie E, Neurology department, Maison-Blanche hospital, Reims, France; E-mail: nehrle@chu-reims.fr

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Abstract

Objective: Facial mimicry, or congruent facial muscle activation in response to a perceived emotional facial expression, has mainly been explored in electromyography. The objectives of this study were to establish whether facial mimicry in healthy adults could be documented for joyful expressions from the visual observation of video recordings and to test the applicability of this methodology in neuropsychology.

Method: Twenty-two healthy participants and four brain damaged patients (parietal or frontal lesion) were included. While being videotaped, participants judged stimuli expressing different emotions that varied in presentation medium and emotion transmitter. Three independent raters assessed participants' happy facial expressions (presence and intensity).

Results: Healthy participants produced more joyful expressions for stimuli expressing joy compared to other emotions and for laughter compared to smiles, suggesting that the video visual observation method could enable facial mimicry to be quantified. In contrast, inconsistent results were obtained for the intensity of joyful expressions expressed. In patients, impaired performances were obtained, with one patient expressing significantly more joyful expressions than controls with normal judgments and another one presenting the reverse pattern.

Conclusions: The findings obtained in healthy participants suggest that is possible to quantify facial mimicry through visual observation, allowing an evaluation of emotional productions in clinical practice. The application in neurological patients suggests a double dissociation between explicitly emotional judgment and facial mimicry and highlights the importance of having a test available to clinically assess facial emotional productions.

Keywords: Emotion; Social; Laughter; Smile; Neuropsychology; Facial expression

Introduction

Mimicry consists of the unconscious and unintentional imitation of the behavior of an interaction partner, such as the other person's posture, prosody or facial expressions [1]. Facial mimicry refers to the congruent muscular facial activations in response to an emotional facial expression perceived in another person [2]. Even though mimicry supposedly leads to a mirroring of another's expression, the mechanisms of emotional communication can lead to facial expressions that are congruent with the perceived emotion but expressed in another modality. For instance, we can express joy by our facial expression when laughter is heard. The notion of facial mimicry will be used in this sense in this article.

Facial mimicry plays an important role in the communication of affective states [3-4], participating in social cognition [5-8]. In human adults, the existence of facial mimicry has been robustly demonstrated thanks to facial electromyography (EMG). It consists in recording the action potentials of the motor units of the facial muscles by placing electrodes on the surface of the skin. Studies show that these facial reactions are rapidly triggered, in less than 500 ms [9-10], even when the stimuli are not consciously perceived [11-12]. These results suggest that emotional stimuli provoke an automatic muscular facial reaction.

Using EMG, facial mimicry has been documented for different types of material: images of faces [2,9,12-15], video excerpts of faces [15-19], image morphing to generate videos of faces morphing from a neutral expression into an emotional expression [10,20] and sounds [21]. However, an absence of mimicry has sometimes been observed whilst using pictures of faces [15,22-23]. Considering the nature of the emotion, the congruence between the stimulus emotion and the one expressed by contagion is robust for anger and joy [2,9-10,12-13,17-18,21,24-26]. Data for sadness and surprise are scarcer [14], or even diverging for fear and disgust [11,14-15,17-18]. Several variables may impact the presence of mimicry as measured by EMG (e.g. gender and/or age, personality, task instructions). For example, stronger facial mimicry is observed in women compared to men [14,27-29]. Older adults are also more expressive than young people but only for disgust [19], no difference being documented for joy or anger [19,30-31]. Regardless of sex and in younger people, facial mimicry has been found to be more pronounced in highly empathetic people in comparison to less empathetic people, who present poor to no mimicry [15,32-35]. The task in which the subject is engaged is also thought to have an influence, with a non-emotional judgment generating a reduction [36] or even a disappearance of facial mimicry [24], in comparison to a treatment centered on emotions. Concerning the emitter of the emotion, an increase in mimicry is observed when the emotion is expressed by a woman when compared to a man for joy, sadness and anger [27,37-38], regardless of the sex of the observer. As for possible interactions between emotions, a paradoxical habituation effect could exist since participants report a form of disgust after numerous laughter presentations [39].

These studies have several limitations, however. Even though the influence of the emotion emitter's sex has been reported, most studies only include women [9,18,24,26,40-43]. The stimuli are often very selective, conveyed by a single material such as images, sounds or videos, and focus on a limited number of emotions. Most of them are emotionally intense, presented in a static manner [2,9,12-13,14,25,44] and selected among the "images of facial affect" [45]. In an attempt to overcome some of these drawbacks, some studies used more artificial stimuli, such as avatars [22,26,42] or morphed images [10,20,23,46]. The effect of the task to be accomplished has seldom been considered [47-49], the stimuli being often processed in a passive manner, without any specific instructions.

The perception of emotional facial expressions has been widely documented, while the assessment of emotional facial productions has been neglected, due to the cumbersomeness of the methodology used to objectify it. In order to collect expressive variables, previous studies mainly used EMG as the criterion that reflects facial mimicry. With this cumbersome methodology, however, it is difficult to document facial productions, whether experimentally or in clinical practice. Despite its obvious clinical interest with respect to neuropsychological or psychiatric diagnoses and the importance of facial productions in social cognition [5-8], simple visual observation instead of EMG has rarely been applied [50-51]. Moreover, the results of the above two studies are debatable since the former used an insufficient number of facial expressions to be exploitable experimentally, whilst the latter demonstrated the feasibility of this methodology. The aim of the present study was to establish whether the facial mimicry of healthy adults could be reliably documented by untrained coders from the simple visual observation of video recordings. This approach was chosen with the possible transfer to clinical practice in mind. We focused on joyful expressions because of the robust effects of facial mimicry demonstrated with EMG for this emotion. We predicted that healthy participants would exhibit more joyful expressions and that their expressions would be more intense for stimuli expressing joy than for other emotions. The study also had two secondary goals. The first one was to select the experimental conditions that make it possible to observe the greatest number of joyful facial responses in healthy participants to maximize its future neuropsychological application. To this effect, we manipulated different variables linked to the stimuli (material, emitter of the emotion) and to the task carried out by the participants. Consistent with the literature, we predicted that healthy participants' facial expressions would be more joyful and more intense for dynamic joyful stimuli than for static joyful stimuli and for stimuli judged on an emotional characteristic rather than a non-emotional characteristic. The second goal was to verify the applicability of this methodology in neuropsychology in order to document the emotional expressive capacities of patients. We therefore included four patients with a frontal or parietal lesion, who was likely to present socio-cognitive disorders with respect to humor [52-58], the theory of mind59-60 and more generally the mirror neuron system [61-62]. We predicted that patients might be impaired both in the perception and expression of emotions.

Materials and Methods

Participants: Twenty-two healthy participants (11 men and 11 women; mean age = 22.64 ± 1.59 (20-25); average number of years of study = 14.36 ± 1.62 (12-17)), without any reported neurologic or psychiatric history, participated in this study. The data included were obtained in compliance with the Helsinki Declaration. All the participants signed a first informed consent form. In order to avoid biasing the results of the study, the participants were filmed, the goal being initially presented as observing ocular movements during the treatment of social stimuli. At the end of the protocol, the participants signed a second informed consent form (necessary for the exploitation of their experimental data) which indicated the real goal (the analysis of emotional facial expressions). None of the participants decided to quit the study during this second signature.

The study also included four patients (Table 1). JM, a 23-year-old man with an educational level of 15 years, presented with a revealed intra-parenchymal expansive cerebral process of the posterior part of the right parietal lobe (Table 1) indicative of a grade three glioma, revealed by two epileptic seizures. No new seizure had occurred since the introduction of treatment. SL, a 27-year-old woman with an educational level of 15 years, presented an intra-parenchymal expansive cerebral process of the left precentral region indicative of a low-grade glioma. LM, a 54-year-old man with an educational level of 14 years, presented with an intra-parenchymal expansive cerebral process of the left superior frontal lobe indicative of a low-grade glioma, revealed by one epileptic seizure. IS, a 56-year-old woman with an educational level of 12 years, presented with an expansive intra-parenchymal cerebral process of the right frontal region indicative of a meningioma. Only IS was tested postoperatively, while the other three patients (JM, LM, SL) were tested preoperatively. Patients also signed the two consent forms for the experimental protocol along with a third one allowing the exploitation of these clinical data and cerebral imagery for this study.

Material: The stimuli for the facial mimicry task were free of rights or their use for research had been approved by their authors (e.g. https://freesound.org/; https://www.istockphoto.com/fr; https://www.youtube.com/; (Figure 1). The average duration of the stimuli (static and dynamic stimuli) was 6 seconds (± 2.15 seconds) and they were selected by the four authors for their cultural naturalness for a French public. Seventy-two stimuli expressed a joyful emotion (36 smiles; 36 laughs), twenty-seven a negative emotion (anger, fear or sadness) and thirty-six a positive emotion of surprise, totalling 135 stimuli. Concerning the laughs, one third of the items were visually static stimuli (n=12), one third dynamic visual stimuli (n=12) and one third dynamic acoustic stimuli (n=12). For the smiles, one third were static stimuli (n=12) and the other two-thirds were dynamic stimuli (n=24). For the laughs, the dynamic visual stimuli were further broken down into strictly visual stimuli (n=6) and stimuli associated to sounds (n=6). For all the joyful stimuli, the emitter was a baby (n=24), a woman (n=24) or a man (n=24).

Complementary to the experimental task, questionnaires were administered. Positivism was evaluated thanks to a French adaptation of the Life Orientation Test (scale LOT-R [63]). It consisted in an auto-questionnaire comprising 10 items for which the participants had to indicate to what extent they agreed with the proposition on a 5-point scale (0=don’t agree at all; 4=agree completely). The anxiodepressive profile was evaluated with the HADS auto-questionnaire (Hospital Anxiety and Depression Scale [64]). Answers to the 14 questions were in the form of a 4-point Likert scale and concerned the previous week. Empathy was measured with the IRI auto-questionnaire (Interpersonal Reactivity Index [65]). It consisted of 28 items, for each of which the participant had to indicate to what extent the statement corresponded to him/her on a 5-point Likert scale (1=doesn’t describe me at all; 5=describes me perfectly), giving an overall result and four sub-scores (“Perspective taking”, “Empathy concern”, “Personal distress” and “Fantasy”).

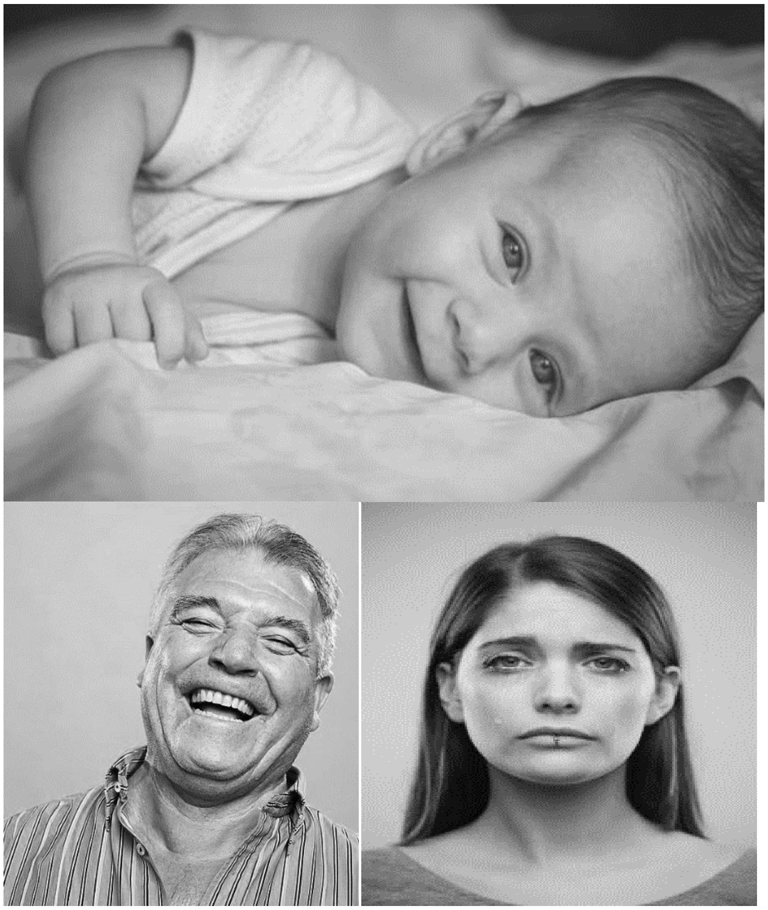


Figure 1: *Examples of visual static stimuli (in color in experiment).*

Procedure: Following the reading of the information note and the signature of the first informed consent form, the participants completed the two facial mimicry tasks, during which they were filmed. One of these tasks focused on a specifically emotional goal (judgment of the subjective emotional intensity) whereas the second focused on the natural or real aspect of the stimuli (judgment of realism). The questionnaires were then administered, followed by the second informed consent.

The judgment of emotional intensity task consisted in indicating orally how intense the presented emotion was on a 10-point scale (1 = not at all intense; 10 = very intense). For the judgment of realism task, the participant had to indicate how natural or real the presented emotion was on a 10-point scale (1 = not at all natural or real; 10 = very natural or real). Each participant completed both tasks. Furthermore, two series were constituted (n= 67, n= 68) from the 135 original stimuli. The order of the tasks and the two series of stimuli were counterbalanced between participants according to a Latin square plan. The total time taken to complete the task was timed for each participant. At the end of the test, participants were asked to evaluate on Likert scales their feelings regarding the task (from 1 very pleasant to 5 very unpleasant) and its subjective duration (from 1 very short to 5 very long).

Coding of facial mimicry: The participants were filmed during the facial mimicry task thanks to a camera installed on the personal computers of the scorers. A sound was added between each of the 135 stimuli in order to sequence the videos of the participants more easily for each stimulus ("photos" application of the Windows program). Once this separation had been achieved, the raters scored the facial expressions of the participants, without seeing the stimuli, from the sequenced files which were presented randomly and without sound.

Three independent scorers, without any specific training in the treatment of facial emotions, assessed the joyful facial expressions of the participants. A binary scoring of joyful emotions was applied for each stimulus (presence or absence of a joyful facial expression) along with a quantitative scoring of the expressive intensity (from 0 "lack of expression" to 5 "very strong expression"). Analysis of the film for each participant took about six hours and a half (one hour of sequencing, one hour and a half of scoring for each scorer, one hour of data entry).

Results

We analyzed two expressive variables (the number of joyful expressions and the expressive intensity of these emotions) as well as two behavioral variables (emotional intensity and realism) (Table 2). Considering the number of participants, non-parametric tests were applied (ANOVA of Kruskal-Wallis, Wilcoxon tests, Spearman correlations). The patient's performances were compared to that of the group of healthy participants with Crawford's t-tests. The JAMOVI program [66] was used and the significance threshold was set at $p \leq 0.05$.

Results of the healthy participants

Effect of the order of tasks and the series of stimuli: The task order and series of stimuli did not have any significant effect on the average number of joyful expressions (tasks: U=47, p=0.4; series: U=42, p=0.24), their intensity (tasks: U=57, p=0.85; series: U=40, p=0.19), the judgment of emotional intensity (tasks: U=56, p=0.79; series: U=55.5, p=0.77) or the judgment of realism (tasks: U=57, p=0.85; series: U=46, p=0.37). The data of the four conditions were therefore confounded in the following analyses.

Effect of demographic variables: The sex of the participants did not have a significant effect on the number of joyful expressions (U=52, p=0.63), their intensity (U=38, p=0.16), the judgment of emotional intensity (U=44, p=0.31) or of realism (U=45, p=0.35). The data of the two sexes were therefore confounded in the following analyses.

The following calculated correlations were found not to be significant: between the number of joyful expressions for joyful stimuli and age or level of education (age: rho=-0.11, p=0.64; level of education: rho=0.4, p=0.07); between the intensity of the joyful expressions for joyful stimuli and the age or level of education (age: rho=0.12, p=0.59; level of education: rho=0.23, p=0.3); between the score of judgment of emotional intensity and the age or level of education (age : rho=-0.2, p=0.1; level of education : rho=-0.2 ; p=0.38). A significant correlation was found, however, between the judgment of realism and both the age and level of education (age: rho=0.44, p=0.04; level of education: rho=0.42, p=0.05).

Transversal scores

The interrater reliability was measured with correlations by averaging the scores of the three scorers. The interrater reliability was high for the average number of joyful expressions (rho=0.71, p<0.001) and the mean intensity of joy expressed (rho=0.71, p<0.001). The healthy participants judged the task as relatively pleasant (mean score of 2.7) and as moderately short (mean score of 3.1). The average duration of the task was 24.6 minutes.

Effects of the factors linked to the stimuli

Judgment of the emotional intensity: The healthy participants judged the stimuli expressing joy as significantly more intense than those expressing a negative emotion (W=65, p=0.05). On the other hand, the intensity was judged as similar when the stimuli expressed joy in comparison to another emotion (W=98, p=0.37) or to surprise considered separately (W=128.5, p=0.96).

Furthermore, when the stimuli corresponded to laughter, the emotional intensity was evaluated as significantly higher than when the stimuli expressed another emotion (W=240, p<0.001), whether it was a negative emotion (W=238, p<0.001) or surprise (W=244, p<0.001). The stimuli corresponding to laughter were also judged as significantly more intense than the stimuli corresponding to a smile (W=253, p<0.001). The reverse profile was observed when the stimuli corresponded to a smile, which was judged as significantly less intense (W=2, p<0.001), whether it was a negative emotion (W=3, p<0.001) or surprise (W=15, p<0.001).

The dynamic stimuli expressing joy were judged as significantly more intense than the static stimuli (W=252, p<0.001). Among the dynamic stimuli, the visual and acoustic dynamic stimuli (W=174.5, p=0.01) and the visual dynamic stimuli (W=231, p<0.001) were perceived as more intense than the acoustic dynamic stimuli. On the other hand, the distinction between visual dynamic stimuli and visual and acoustic dynamic stimuli was not statistically significant (W=164, p=0.23). Concerning the emitter of the expressed emotion, the joy expressed by the babies was judged as significantly more intense than that expressed by the adults (W=52, p=0.02) but no significant difference was found depending on the sex of the adult emitter (W=65, p=0.08).

The judgment of men did not differ from that of women according to the emitter of the emotion (emitter men: W=53.5, p=0.69; emitter women: W=49.5, p=0.51).

Judgment of realism

The healthy participants judged the stimuli expressing joy as significantly more natural than those expressing another emotion (W=225, p=0.002), whether it was a negative emotion (W=209, p=0.006) or surprise (W=252, p<0.001).

Similarly, when the stimuli corresponded to laughter, the expressed emotion was judged as significantly more natural than when the stimuli expressed another emotion (W=253, p<0.001), whether it was a negative emotion (W=253, p<0.001) or surprise (W=253, p<0.001). The stimuli corresponding to laughter were also judged as significantly more natural than the stimuli corresponding to a smile (W=253, p<0.001). When the stimuli corresponded to a smile, the expressed emotion was judged as significantly more natural in comparison to surprise considered separately (W=188.5, p=0.05) but no significant difference was found in comparison to all the stimuli expressing another emotion than joy (W=92, p=0.28) or a negative emotion (W=3, p<0.001).

The dynamic stimuli expressing joy were judged as significantly more natural than the static stimuli expressing joy (W=236, p<0.001) and, more particularly, the visual and acoustic dynamic stimuli (W=253, p=0.01) and the visual dynamic stimuli (W=235, p<0.001) in comparison to the acoustic dynamic stimuli. On the other hand, the distinction between visual dynamic stimuli and visual and acoustic dynamic stimuli was not statistically significant (W=99, p=0.84). Concerning the emitter of the expressed emotion, the joy expressed by the babies was judged as significantly more natural than that expressed by the adults (W=0, p<0.001). The joy expressed by a man was judged as more natural than that expressed by a woman (W=166, p=0.02).

The judgment of men did not differ from that of women according to the emitter of the emotion (emitter men: W=51, p=0.58; emitter women: W=56.5, p=0.84).

Number of joyful expressions

The healthy participants produced more joyful expressions when the stimuli expressed joy than when they expressed another emotion (W=20, p<0.001), whether it was a negative emotion (W=238, p<0.001) or surprise (W=202, p=0.01).

Among the joyful stimuli, the healthy participants produced more joyful expressions when the stimuli corresponded to laughter than when they expressed another emotion (W=246, p<0.001), whether it was a negative emotion (W=248, p<0.001) or surprise (W=18, p<0.001). The healthy participants also produced more joyful expressions for smiles than for the negative emotions (W=46, p=0.009) but this difference disappeared when we considered all the other emotions (W=169, p=18) or solely surprise (W=137, p=0.75). Furthermore, the number of joyful expressions was higher for laughs than for smiles (W=248, p<0.001).

The dynamic stimuli generated more joyful expressions than the static stimuli (W=0, p<0.001). Among the dynamic stimuli, the visual and acoustic dynamic stimuli (W=68, p=0.06) and the visual dynamic stimuli (W=183.5, p=0.019) led to a greater number of joyful expressions than the acoustic dynamic stimuli. No significant difference was observed between the visual dynamic stimuli and the visual and acoustic dynamic stimuli (W=117, p=0.33). Concerning the emitter of the expressed emotion, babies elicited more joyful emotions than adults (W=66, p=0.05) but no significant difference appeared depending on the sex of the adult emitter (W=127.5, p=0.69). The task carried out did not have a significant effect on the number of joyful emotions expressed (W=149.5, p=0.24).

In order to target the number of expressions specifically related to facial mimicry in comparison to the number of joyful expressions produced in total, we subtracted the number of joyful expressions obtained from stimuli expressing a negative emotion from the number of joyful expressions recorded for joyful stimuli for each participant individually. With this weighting, the participants produced in average again a greater number of joyful expressions for laughs than for smiles (W=5, p<0.001). Considering the greater number of joyful expressions collected for the visual dynamic stimuli (visual stimuli and visual and acoustic stimuli) and for babies, we applied the same weighting to these variables. The difference between laughs and smiles was found to be significant for the visual dynamic stimuli (W=218, p=0.002) but not for the babies (W=152, p=0.009).

Men did not produce more joyful expressions than women according to the emitter of the emotion (emitter men: W=49.5, p=0.51; emitter women: W=48.5, p=0.47).

Intensity of the emotion expressed

The intensity of the joyful expressions (table 1) did not differ between the stimuli expressing joy and those expressing another emotion (W=89, p=24), including surprise (W=110, p=0.87). On the other hand, the intensity of the joyful expressions was significantly higher when the stimuli expressed a negative emotion in comparison to joy (W=59, p=0.03).

When we considered laughter separately among the joyful stimuli, the intensity did not differ for laughter when compared to the other stimuli (W=164, p=0.24), whether they were negative emotions (W=130, p=0.92) or surprise (W=176, p=0.11). On the other hand, smiles considered separately among the joyful stimuli generated less intense joyful expressions than the other emotions (W=46, p=0.01), whether they were negative emotions (W=31, p=0.001) or surprise (W=185, p=0.06). The joy expressed was more intense for laughter than for smiles (W=223, p<0.001).

In order to target the emotional intensity of joyful expressions specifically related to facial mimicry in comparison to that produced overall, we applied the following formula: we subtracted the intensity of joyful expressions recorded for the stimuli expressing negative emotions from the value of the joyful expressions' intensity for the joyful stimuli. With this method of calculation, the participants expressed joy more intensely in response to laughter than to smiles (W=223, p=0.001).

The joyful expressions produced by the men were not significantly more intense that those of the women according to the emitter of the emotion (emitter men: W=58, p=0.92; emitter women: W=42, p=0.25).

Correlations

The calculated correlations between the number of joyful expressions for the joyful stimuli and the intensity of joyful expressions were not significant (rho=0.19, p=0.4). The correlations for the number of joyful expressions and the scores obtained for the questionnaires (HAD, LOT-R, IRI) only revealed a statistical link with the LOT-R (rho=0.48, p=0.02). No significant correlation was found between the intensity of the joy expressed and the questionnaire scores.

The number of joyful expressions for the joyful stimuli and the joyful expressions' intensity were not significantly correlated with the values of the judgment of emotional intensity (number of joyful expressions: rho=0.01, p=0.97; joyful expression's intensity: rho=0.04, p=0.88) or of realism (number of joyful expressions: rho=-0.07, p=0.75; joyful expressions' intensity: rho=0.03, p=0.91). The correlations for these same variables and the scores obtained in the questionnaires (HAD, LOT-R, IRI) revealed a moderate statistical link only between the value of the judgment of emotional intensity and the scores of the LOT-R (rho=0.47, p=0.03), of the IRI (rho=0.46, p=0.02) and the IRI sub-score evaluating "Perspective taking" (rho=0.55, p=0.01) and between the value of the judgment of realism and the scores of the IRI (rho=0.44, p=0.04) and the IRI sub-score evaluating "Empathy concern" (rho=0.43, p=0.05).

The group of healthy participants was split into two subgroups according to the IRI score: the half with the highest scores were in the "high empathy" group, while the other half were in the "low empathy" group. While the "high empathy" group did not express a greater number of joyful emotions (U=44, p=0.3), nor more intense joyful expressions (U=49, p=0.48) than the "low empathy" group. The "high empathy" group judged the joyful expressions as more intense (U=30, p=0.05) and more natural (U=12, p=0.02) than the "low empathy" group. For the HAD, no participant exceeded the depression cut-off. For anxiety, six participants obtained a score greater than or equal to 11 and had a certain risk of anxiety. Since social anxiety may negatively moderate facial mimicry (Dimberg et Thunberg, 2007), we controlled the effect of pathological anxiety on the number of happy facial expressions produced when the items were happy and their intensity by contrasting the results of the six participants with a pathological anxiety score versus the healthy participants. The results did not show a significant difference between the groups (number of joyful expressions: U=40, p=0.59; joyful expressions' intensity: U=32, p=0.26; judgment of the emotional intensity: U=44.5, p=0.83, judgment of realism: U=40, p=0.58).

Results of the Patients

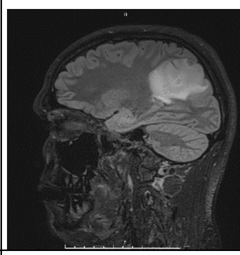
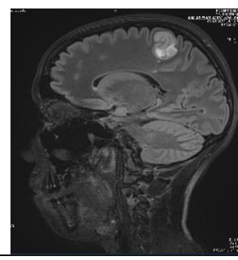
Neuropsychological data

As indicated in Table 1, the patient JM presented a normal IQ (107, WAIS-IV), with a dissociation between his preserved verbal performances (episodic memory, language) and his affected visuo-spatial capacities (constructive disturbances, problem with the perception of the overall shape, low visual abstraction, difficulty reading time on dials, slowness in copying tasks). These data are in favor of a classic functional cerebral lateralization, with dysfunctions at the level of the minor hemisphere. The patient LM also presented a normal IQ (90, WAIS-IV), with a dissociation between his preserved verbal performances (episodic memory, language) and his affected visuo-spatial capacities (constructive disturbances, visual abstraction, bells test time, simultagnosia). These data are in favor of a reverse functional cerebral lateralization, with dysfunctions at the level of the minor hemisphere. The patient SL presented a normal low IQ (82, WAIS-IV), with a disturbance of numeracy and language skills selectively and a preservation of other skills (episodic memory, constructive and gnosia skills). These data are in favor of a classic functional cerebral lateralization, with dysfunctions at the level of the major hemisphere. The patient IS presented a normal IQ (95, WAIS-IV), with a disturbance of constructive and visual executive skills (abstraction, planning, attention) and preservation of executive verbal, numeric, lexical, gnotic and executive skills. These data are in favor of a classic functional cerebral lateralization, with dysfunctions at the level of the minor hemisphere.

The patients JM, LM and SL did not present a negativity bias (LOT-R scores: JM: t=-0.14, p=0.44; LM: t=-1.02, p=0.16; SL: t=-0.72, p=0.24), or a pathological anxio-depressive tendency

(HAD anxiety scores: JM: t=-0.7, p=0.25; LM: t=-0.23, p=0.41; SL: t=0.49, p=0.32; HAD depression scores: JM: t=0.45, p=0.33; LM: t=-0.79, p=0.22; SL: t=0.45, p=0.33) and the empathy was normal (IRI scores: JM: t=-1.16, p=0.13; LM: t=-0.47, p=0.32; SL: t=-0.16, p=0.43). The patient IS did not show either a pathological anxiety tendency (HAD anxiety score: t = 1.44, p = 0.08) or reduced empathy (IRI score: t = 1.03, p = 0.16) but presented a negativity bias (LOT-R score: t = 2.73, p = 0.006) and a pathological depressive tendency (HAD depression score: t = 2.93, p = 0.004).

Table 1: *Clinical data and neuropsychological results of patients expressed according to the tasks' standard scores.*

	JM results (range)	SL results (range)	LM results (range)	IS results (range)
Demographic data				
Sex	man	woman	Man	woman
Age	23	27	54	56
Educational level	15	15	14	12
Clinical data				
Tumor	grade three glioma	grade three glioma	low-grade glioma	meningioma
Localization tumor	posterior part of the right parietal lobe	left precentral region	left superior frontal lobe	right frontal region
Status	preoperative	preoperative	preoperative	postoperative
Imagery				
Neuropsychological results				
Efficiency test (WAIS-IV)				
Full-scale IQ	107 (68th centile)	82 (12th centile)	90 (25th centile)	95 (37th centile)
Verbal comprehension index	116/150 (86th centile)	92/150 (30th centile)	100/150 (50th centile)	104/150 (61st centile)
Perceptual reasoning index	110/150 (75th centile)	88/150 (21th centile)	70/150 (2nd centile)	82/150 (12th centile)
Working memory index	88/150 (21st centile)	71/150 (3rd centile)	109/150 (73rd centile)	102/150 (50th centile)
Processing speed index	117/150 (87th centile)	100/150 (50th centile)	89/150 (23rd centile)	105/150 (63rd centile)
Information subtest	10/19 (50th centile)	8/19 (25th centile)	8/19 (25th centile)	6/19 (9th centile)
Digit span subtest	7/19 (16th centile)	7/19 (16th centile)	12/19 (75th centile)	9/19 (37th centile)
Arithmetic subtest	9/19 (37th centile)	3/19 (1st centile)	11/19 (63rd centile)	11/19 (63rd centile)
Similarities subtest	15/19 (95th centile)	9/19 (37th centile)	12/19 (75th centile)	15/19 (95th centile)

Picture completion subtest	9/19 (37th centile)	9/19 (37th centile)	3/19 (1st centile)	6/19 (9th centile)
Block design subtest	14/19 (91st centile)	7/19 (16th centile)	7/19 (16th centile)	8/19 (25th centile)
Digit-symbol coding subtest	13/19 (84th centile)	10/19 (50th centile)	8/19 (25th centile)	11/19 (63rd centile)
Episodic memory tests				
California Verbal Learning Test (CVLT)				
Five immediate free recalls	9-13-14-13-14/16 (normal)	9-10-11-13-15/16 (normal)	7-13-13-16-15/16 (normal)	7-10-13-12-12/16 (normal)
Total of the 5 immediate free recalls	63/80 (normal)	58/80 (normal)	64/80 (normal)	54/80 (normal)
Free recall interference list	8 (normal)	5 (- 1.6 σ)	12 (normal)	5 (normal)
Free recall first list after interference	13 (normal)	13 (normal)	13 (normal)	11 (normal)
Total recall first list after interference	14 (normal)	14 (normal)	12 (normal)	13 (normal)
Recognition (/16)	16 (normal)	16 (normal)	15 (normal)	16 (normal)
Free delayed recall (/16)	13 (normal)	15 (normal)	13 (normal)	11 (normal)
Total delayed recall (/16)	14 (normal)	15 (normal)	13 (normal)	12 (normal)
Rey-Osterrieth complex figure				
Copy	29/36 (- 4.1 σ)	/36 (- 5.4 σ)	/36 (- 12.6 σ)	/36 (- 10 σ)
Immediate recall (/36)	18.5/36 (normal)	23/36 (normal)	11.5/36 (normal)	12.5/36 (normal)
Delayed recall (/36)	18.5/36 (normal)	23/36 (normal)	11.5/36 (normal)	15.5/36 (normal)
Language tests				
Chapman-Cook written comprehension	88 seconds (normal) 0 error (normal)	171 seconds (- 3.6 σ) 2 errors (- 7.4 σ)	139 seconds (- 2.1 σ) 1 error (- 3.5 σ)	92 seconds (normal) 0 error (normal)
Fluency "Fruits"	15 words in 2 mn (normal)	18 words in 2 mn (normal)	16 words in 2 mn (normal)	22 words in 2 mn (normal)
Boston naming test	77/80	70/80	77/80	73/80

(French version: DO80) (/80)	(normal)	(deficit)	(normal)	(deficit)
Visuo-spatial test				
Bells test (/35)	35/35 in 66 seconds (normal)	33/35 in 110 seconds (normal)	32/35 in 211 seconds (normal)	31/35 in 103 seconds (- 1.8 σ)
Embedded figures test	15/15 (normal)	14/15 (normal)	13/15 (6 errors) (deficit)	15/15 (normal)
Executive tests				
Wisconsin Card Sorting Task	6 categories in 77 cards (5 perseverative responses) (normal)	6 categories in 98 cards (21 perseverative responses) (normal)	6 categories in 71 cards (7 perseverative responses) (normal)	1 category in 128 cards (55 perseverative responses) (deficit)
Ruff graphic fluency	109 designs (2 perseverations) (normal)	80 designs (3 perseverations) (normal)	NA	NA

Table 2: *Results of the healthy participants and of patients for the experimental tasks and scales.*

	Healthy participants (n=22) mean (standard deviation)	**JM (T of Crawford, p)**	**SL (T of Crawford, p)**	**LM (T of Crawford, p)**	**IS (T of Crawford, p)**
EXPERIMENTAL TASKS					
EXPRESSIVE VARIABLES					
Number of happy expressions					
Emotions of stimuli					
Happy stimuli	0.47 (0.17)	0.86 (t=2.24, p=0.02)	0.55 (t=0.46, p=0.33)	0.53 (t=0.35, p=0.37)	0.61 (t=0.81, p=0.22)
Other emotional stimuli	0.37 (0.15)	0.86 (t=3.2, p=0.002)	0.62 (t=1.63, p=0.06)	0.38 (t=0.07, p=0.47)	0.6 (t=1.5, p=0.07)
Laughter	0.53 (0.17)	0.94 (t=2.36, p=0.01)	0.53 (t=0, p=0.5)	0.61 (t=0.46, p=0.33)	0.69 (t=0.92, p=0.18)
Smiles	0.4 (0.18)	0.78 (t=2.01, p=0.03)	0.56 (t=0.87, p=0.2)	0.44 (t=0.22, p=0.42)	0.53 (t=0.71, p=0.16)

Surprise	0.4 (0.17)	0.86 (t=2.65, p=0.01)	0.53 (t=0.75, p=0.23)	0.44 (t=0.23, p=0.41)	0.58 (t=1.04, p=0.31)
Negative emotions	0.33 (0.15)	0.85 (t=3.39, p=0.001)	0.74 (t=2.67, p=0.01)	0.3 (t=-1.2, p=0.42)	0.63 (t=1.96, p=0.03)
Non-emotional characteristics of stimuli					
Dynamic stimuli	0.54 (0.18)	0.88 (t=1.47, p=0.08)	0.52 (t=-0.11, p=0.46)	0.64 (t=0.6, p=0.28)	0.71 (t=0.92, p=0.18)
Static stimuli	0.33 (0.17)	0.96 (t=3.62, p=0.001)	0.58 (t=1.44, p=0.08)	0.29 (t=-0.23, p=0.41)	0.39 (t=0.35, p=0.37)
Multimodal video stimuli	0.69 (0.25)	1 (t=1.21, p=0.12)	0.67 (t=-0.08, p=0.47)	1 (t=1.21, p=0.12)	1 (t=1.21, p=0.12)
Unimodal video stimuli	0.66 (0.25)	0.83 (t=0.67, p=0.26)	0.5 (t=-0.63, p=0.27)	0.83 (t=0.67, p=0.26)	0.83 (t=0.67, p=0.26)
Sound stimuli	0.51 (0.2)	0.84 (t=1.61, p=0.06)	0.44 (t=-0.34, p=0.37)	0.56 (t=0.25, p=0.41)	0.68 (t=0.83, p=0.21)
Baby stimuli	0.52 (0.22)	0.88 (t=1.6, p=0.06)	0.54 (t=0.09, p=0.47)	0.63 (t=0.49, p=0.32)	0.71 (t=0.85, p=0.2)
Adult stimuli	0.44 (0.18)	0.85 (t=2.11, p=0.02)	0.52 (t=0.44, p=0.33)	0.5 (t=0.33, p=0.37)	0.55 (t=0.6, p=0.28)
Women	0.44 (0.19)	0.92 (t=2.47, p=0.01)	0.59 (t=0.77, p=0.22)	0.42 (t=-0.1, p=0.46)	0.65 (t=1.08, p=0.15)
Men	0.45 (0.19)	0.79 (t=1.75, p=0.05)	0.46 (t=0.05, p=0.48)	0.54 (t=0.46, p=0.32)	0.46 (t=0.05, p=0.48)
Task					
Judgment of emotional intensity	0.49 (0.18)	0.86 (t=2.01, p=0.03)	0.53 (t=0.22, p=0.42)	0.44 (t=-0.27, p=0.39)	0.63 (t=0.76, p=0.23)
Judgment of realism	0.45 (0.19)	0.86 (t=2.11, p=0.02)	0.56 (t=0.57, p=0.29)	0.61 (t=0.82, p=0.21)	0.45 (t=0, p=0.5)

Intensity of happy expressions					
Emotions of stimuli					
Happy stimuli	2 (0.54)				
Other emotional stimuli	2.07 (0.63)				
Laughter	2.12 (0.62)				
Smiles	1.85 (0.47)				
Surprise	2 (0.65)				
Negative emotions	2.16 (0.65)				
JUDGMENT VARIABLES					
Subjective emotional intensity					
Emotions of stimuli					
Happy stimuli	6.17 (0.91)	5.53 (t=-0.69, p=0.25)	7.28 (t=1.19, p=0.12)	6.14 (t=-0.03, p=0.49)	9.11 (t=3.16, p=0.002)
Other emotional stimuli	6.32 (0.88)	6.43 (t=0.12, p=0.45)	6.48 (t=0.18, p=0.43)	5.53 (t=-0.88, p=0.2)	8.42 (t=2.33, p=0.02)
Laughter	7.3 (0.97)	7.06 (t=-0.24, p=0.41)	8.11 (t=0.12, p=0.21)	6.72 (t=-0.59, p=0.28)	9.55 (t=2.27, p=0.02)
Smiles	5.03 (0.93)	4 (t=-1.08, p=0.15)	6.44 (t=1.48, p=0.08)	5.56 (t=0.58, p=0.29)	8.67 (t=3.83, p=0.001)
Surprise	6.16 (1)	5.89 (t=-0.26, p=0.4)	6.56 (t=0.39, p=0.35)	5.22 (t=-0.92, p=0.18)	8 (t=1.8, p=0.04)
Negative emotions	6.48 (0.87)	7.21 (t=0.82, p=0.21)	6.38 (t=-0.11, p=0.46)	5.93 (t=-0.62, p=0.27)	9 (t=2.83, p=0.005)
Non-emotional characteristics of stimuli					
Dynamic stimuli	6.63 (0.91)	6.17 (t=-0.49, p=0.31)	7.67 (t=1.12, p=0.14)	6 (t=-0.68, p=0.25)	9.21 (t=2.77, p=0.006)
Static stimuli	5.21 (1.09)	4.25 (t=-0.86,	6.5 (t=1.16,	6.42 (t=1.09,	8.92 (t=3.33, p=0.003)

		p=0.2)	p=0.13)	p=0.15)	
Multimodal video stimuli	8.15 (1.29)	9 (t=0.64, p=0.26)	7.67 (t=-0.36, p=0.36)	7.67 (t=-0.36, p=0.36)	9.33 (t=0.9, p=0.19)
Unimodal video stimuli	7.68 (1.43)	7 (t=-0.47, p=0.32)	9.67 (t=1.36, p=0.09)	6 (t=-1.15, p=0.13)	10 (t=1.59, p=0.07)
Sound stimuli	6.34 (1.13)	6 (t=-0.29, p=0.39)	7.85 (t=1.31, p=0.1)	5.53 (t=-0.7, p=0.25)	8.69 (t=2.03, p=0.03)
Baby stimuli	6.62 (1.3)	4.92 (t=-1.28, p=0.11)	7.33 (t=0.53, p=0.3)	7 (t=0.29, p=0.39)	9.58 (t=2.23, p=0.019)
Adult stimuli	5.94 (0.99)	5.83 (t=-0.11, p=0.46)	7.25 (t=1.29, p=0.11)	5.71 (t=-0.23, p=0.41)	8.86 (t=2.86, p=0.004)
Women	6.1 (1.05)	5.92 (t=-0.17, p=0.43)	7.83 (t=1.61, p=0.06)	5.83 (t=-0.25, p=0.4)	9 (t=2.7, p=0.007)
Men	5.78 (1.06)	5.75 (t=-0.03, p=0.89)	6.67 (t=0.82, p=0.21)	5.58 (t=-0.19, p=0.43)	8.75 (t=2.74, p=0.006)
Subjective realism					
Emotions of stimuli					
Happy stimuli	6.35 (0.72)	5.89 (t=-0.63, p=0.27)	7.53 (t=1.6, p=0.06)	8.19 (t=2.5, p=0.01)	6.56 (t=0.83, p=0.39)
Other emotional stimuli	5.93 (0.55)	5.17 (t=-1.35, p=0.1)	6.06 (t=0.23, p=0.41)	6.9 (t=1.73, p=0.05)	6 (t=0.12, p=0.45)
Laughter	6.95 (0.78)	6.5 (t=-0.57, p=0.29)	7.83 (t=1.1, p=0.14)	8.39 (t=1.82, p=0.04)	7.44 (t=0.61, p=0.27)
Smiles	5.76 (0.81)	5.28 (t=-0.58, p=0.28)	7.22 (t=1.76, p=0.05)	8 (t=2.71, p=0.01)	5.67 (t=-1.11, p=0.46)
Surprise	5.44 (0.54)	4.61 (t=-1.5, p=0.07)	5.59 (t=0.27, p=0.39)	6.72 (t=2.32, p=0.02)	5.94 (t=0.91, p=0.19)
Negative emotions	5.99 (0.7)	5.31 (t=-0.95, p=0.18)	6.29 (t=0.42, p=0.34)	7.15 (t=1.62, p=0.06)	6.07 (t=0.11, p=0.46)
Non-emotional characteristics of stimuli					
Dynamic stimuli	6.83 (0.89)	6.17 (t=-0.73, p=0.24)	7.25 (t=0.46, p=0.33)	7.83 (t=1.1, p=0.14)	7.08 (t=0.28, p=0.39)

Static stimuli	5.46 (1.13)	5.17 (t=-0.25, p=0.4)	8.08 (t=2.27, p=0.02)	8.92 (t=3, p=0.007)	5.5 (t=0.04, p=0.49)
Multimodal video stimuli	8.42 (1.35)	9.33 (t=0.66, p=0.26)	9 (t=0.42, p=0.34)	8.67 (t=0.18, p=0.43)	10 (t=1.15, p=0.13)
Unimodal video stimuli	8.29 (1.47)	7 (t=-0.86, p=0.2)	8.33 (t=0.03, p=0.49)	9 (t=0.47, p=0.32)	9.67 (t=92, p=0.18)
Sound stimuli	5.91 (1.31)	4.83 (t=-0.81, p=0.22)	7.25 (t=1, p=1.16)	7.02 (t=0.83, p=0.21)	5.58 (t=-0.25, p=0.4)
Baby stimuli	8.38 (1.17)	7.67 (t=-0.59, p=0.28)	8.83 (t=0.38, p=0.36)	10 (t=1.35, p=0.1)	9.75 (t=1.15, p=0.13)
Adult stimuli	5.34 (0.94)	5 (t=-0.35, p=0.36)	6.88 (t=1.6, p=0.06)	7.29 (t=2.03, p=0.03)	4.96 (t=-0.4, p=0.35)
Women	5.16 (0.98)	5.25 (t=0.09, p=0.47)	6.92 (t=1.76, p =0.05)	6.58 (t=1.42, p=0.09)	3.75 (t=-1.41, p=0.09)
Men	5.53 (1.02)	4.75 (t=-0.75, p=0.23)	6.83 (t=1.25, p=0.11)	8 (t=2.37, p=0.01)	6.17 (t=0.61, p=0.27)
SUPPLEMENTARY VARIABLES					
Pleasant character (/5)	2.68 (0.64)	3 (t=0.89, p=0.32)	2 (t=-1.04, p=0.16)	2 (t=-1.04, p=0.16)	1 (t=-2.57, p=0.009)
Subjective duration (/5)	3.09 (0.68)	3 (t=-0.13, p=0.45)	3 (t=-0.13, p=0.45)	3 (t=-0.13, p=0.45)	2 (t=-1.57, p=0.07)
Objective duration (minutes)	24.55 (4.84)	20 (t=-0.92, p=0.18)	20 (t=-0.92, p=0.18)	28 (t=0.7, p=0.25)	19 (t=-1.12, p=0.14)
QUESTIONNAIRES					
HAD anxiety	7.95 (4.12)	5 (t=-0.7, p=0.25)	10 (t=0.49, p=0.32)	7 (t=-0.23, p=0.41)	14 (t=1.44, p=0.08)
HAD depression	3.91 (2.37)	5 (t=0.45, p=0.33)	5 (t=0.45, p=0.33)	2 (t=-0.79, p=0.22)	11 (t=2.93, p=0.004)
IRI	65.5 (15.6)	47 (t=-1.16, p=0.13)	63 (t=-0.16, p=0.43)	58 (t=-0.47, p=0.32)	82 (t=1.03, p=0.16)
Sub-score IRI "Perspective taking"	19.5 (4.85)	18 (t=-0.3, p=0.38)	17 (t=-0.5, p=0.31)	20 (t=0.1, p=0.46)	25 (t=1.11, p=0.14)
Sub-score IRI "Empathy concern"	19.4 (4.85)	17 (t=-0.48, p=0.32)	19 (t=-0.1, p=0.46)	21 (t=0.3, p=0.38)	28 (t=1.73, p=0.05)
Sub-score IRI "Personal	10.5 (4.22)	2 (t=-1.97,	14 (t=0.81,	13 (t=0.58,	12 (t=0.35, p=0.37)

distress"		p=0.03)	p=0.21)	p=0.28)	
Sub-score IRI "Fantasy"	16.1 (5.78)	10 (t=-1.03, p=0.16)	13 (t=-0.53, p=0.3)	4 (t=-2.05, p=0.03)	17 (t=0.15, p=0.44)
LOT-R	14.5 (3.4)	14 (t=-0.14, p=0.44)	17 (t=0.72, p=0.24)	11 (t=-1.02, p=0.16)	5 (t=-2.73, p=0.006)

Judgments

For the task of judgment of emotional intensity, there was no significant difference between the patient's scores of JM, LM and SL and those of the healthy participants, regardless of the category of the items (Table 2). However, the patient IS judged the stimuli to be more intense than the healthy participants, regardless of the emotion expressed. Moreover, for joyful stimuli, the patient IS judged the emotion to be more intense than the healthy participants, regardless of the emitter and the sex of the carrier of the emotion, but selectively for static and acoustic stimuli.
For the task of judgment of realism, there was no significant difference between the scores of the patients JM and IS and those of the healthy participants, regardless of the category of the items. The patient LM judged the stimuli to be more real than the healthy participants, when they expressed joy (laughter and smiles) or another emotion (surprise) and the patient SL judged the stimuli to be more real than the healthy participants, but selectively for smiles. For joyful stimuli, the patient LM judged the emotion to be more real than the healthy participants, when the stimuli were static, expressed by male adults, and the patient SL judged the emotion to be more real than the healthy participants, when the stimuli were static and expressed by women.
The patients JM, LM and SL also evaluated the characteristics of the tasks similarly to the healthy participants (pleasantness: JM: t=0.89, p=0.32; LM : t=-1.04, p=0.16; SL: t=-1.04, p=0.16; subjective duration: JM: t=-0.13, p=0.45; LM: t=-0.13, p=0.45; SL: =-0.13, p=0.45) and their completion times were comparable (objective duration: JM: t=-0.92, p=0.18; LM: t=0.7, p=0.25; SL: t=-0.92, p=0.18). The patient IS also evaluated the duration of the tasks similarly to the healthy participants (subjective duration: t=-0.13, p=0.45) and her completion time was comparable (objective duration: t=-0.92, p=0.18) but she found the tasks to be more pleasant than the healthy participants (t=-2.57, p=0.009).

Number of joyful expressions

In view of the results obtained in healthy participants, only the number of joyful facial productions was analyzed.
When compared with the healthy participants (Table 2), no significant difference was found between the joyful expressions of the patient LM, regardless of the category of the items (Table 2). The patients SL and IS expressed significantly more joy, but selectively when the item expressed a negative emotion (SL: t=2.67, p=0.01; IS: t=2.67, p=0.01). No other significant difference was observed between the joyful expressions of the patients SL and IS and those of the healthy participants, regardless of the category of the items.
Moreover, the patient JM expressed significantly more joy when the item expressed a joyful emotion (t=2.24, p=0.02). This greater number of joyful expressions was observed both for stimuli expressing laughter (t=2.36, p=0.01) and smiles (t=2.01, p=0.03), regardless of the sex of the emitter (woman: t=2.47, p=0.01; man: t=1.75, p=0.05) and the task carried out (judgment: of realism t=2.11, p=0.02; judgment of emotional intensity: t=2.01, p=0.03). Concerning the emitter of the emotion, the patient JM expressed significantly more joy when the emitter was an adult (t=2.11, p=0.02), while the difference with healthy participants was smaller when the emitter was a baby (t=1.6, p=0.06). Concerning the presentation format of the stimuli, the patient JM expressed significantly more joy when the item was presented in the form of images (t=3.62, p=0.001), with a lesser difference with healthy participants for dynamic items (t=1.47, p=0.08), whatever the modality (sounds: t=1.61, p=0.06; multimodal videos: t=1.21, p=0.12; unimodal videos: t=0.67, p=0.26). However, the patient JM also expressed significantly more joy than the healthy participants when the item expressed a negative emotion (t=3.39, p=0.001), another emotion than joy (t=3.2, p=0.002) or surprise (t=2.65, p=0.01).

Discussion

Since the technique previously used experimentally to document facial mimicry, EMG, is extremely cumbersome, and precludes any transfer to clinical practice, the goal of this study was to show the feasibility of quantifying, from the simple observation of videos, the number of joyful facial expressions produced in reaction to emotional stimuli. Four elements seem to support the validation of simple observation as an alternative methodology. Firstly, and in accordance with our main hypothesis, the number of emotions produced was sufficiently high when the stimuli expressed joy (40% of the productions of the healthy participants), enabling a quantitative analysis to be applied on this variable. Even though this protocol is less precise than electromyography, which also allows the recording of non-visible muscular responses, the video observation of faces could enable the documenting of joyful facial mimicry with less cumbersome equipment. Secondly, a greater number of joyful expressions were recorded for stimuli involving laughter than other emotions or smiles. This suggests that the joyful facial productions observed are not incidental and are believed to be linked on the one hand to the nature of the emotions presented and on the other hand to the intensity of the joyful expressions, in favor of facial mimicry. Thirdly, the scoring of the different observers was convergent. This high interrater reliability, in the absence of any training regarding the scoring of facial expressions and without seeing the stimuli, would allow easy application in standard clinical practice. This supports the results of Sato and Yoshikawa [51] who reported the validity of naked-eye visual observation both with qualified scorers and naïve evaluators. Our results show however a higher occurrence of joyful facial expressions (double that reported by Sato and Yoshikawa, 2007), which can be explained by the use of more polymorph stimuli than those used by these authors. Fourthly, the tasks seem to be well tolerated by the participants since the stimuli were judged as natural, particularly the joyful stimuli, and the task duration was evaluated as short. All these elements warrant considering future studies based on the present methodology to quantify facial mimicry from video recordings.

A secondary goal of the present study was to select the experimental conditions that generate the best joyful facial response possible for the operationalization of facial mimicry. The tasks presented need to be reduced in number to allow clinical and experimental application. Among the two facial indices recorded in the present study (number of joyful expressions and intensity of these expressions), intensity does not seem to constitute a good indicator. The intensity expressed was equivalent for laughter and for non-joyful emotions, and lower for smiles in comparison to non-joyful emotions. Thus, joyful stimuli generate a higher number of joyful expressions than non-joyful stimuli, but the expressions are less intense. This result can be explained by a defensive process, as laughter can have the function of relieving tension [67]. Intensity cannot therefore be retained as a good indicator of facial mimicry, even when weighted by the intensity recorded for joyful stimuli compared to negative stimuli. The number of joyful expressions, on the other hand, constitutes a variable that seems consistent with the emotional category of the stimuli (a greater number of joyful expressions were observed for joyful emotions in comparison to non-joyful emotions) and with the intensity expressed (laughter generated a greater number of joyful expressions than smiles). Among the variables linked to the support and in accordance with our first secondary hypothesis and with the literature [15,22-23,46], a greater number of joyful responses were produced for dynamic stimuli in comparison to static stimuli. The same difference was also found when we weighted the number of joyful expressions produced according to a base level, suggesting its robustness. We also recorded a greater number of joyful expressions for stimuli involving babies in comparison to adults. For this variable however, the difference disappeared when weighting was applied. The responses recorded to babies cannot therefore be linked to facial mimicry but are rather in favor of a positive emotional feeling towards them. This category of stimuli does not seem relevant therefore for future studies regarding the observation of joyful facial mimicry. It can be concluded that dynamic stimuli involving adults and corresponding to laughter are the most suitable stimuli. Future studies will have to verify however the possible anchoring effects produced if the variability of the emotional stimuli presented is diminished [68-70]. Besides the selection of stimuli, we took the precaution of weighting the number of joyful expressions produced with the number of joyful expressions recorded for negative emotions. This method of analysis should make it possible to quantify facial mimicry more specifically [71-72] by distinguishing it from emotional expressions non-linked to imitation [73]. All of these elements (stimuli selected and calculation method) should lead to an optimization of the scoring of the recorded joyful expressions. A last methodological precaution concerns the statistical links between the number of joyful expressions and the score of the positivity scale (LOT-R) which will require a control of this parameter in future studies, both for the group results and for the individual clinical case.

Another secondary goal was the clinical application of the present protocol in order to explore the explicit and implicit processing of joyful emotions. The explicit processing was operationalized using the judgment tasks (emotional intensity and realism) and the implicit treatment using the joyful expressions produced. Concerning the present protocol, JM presented explicit judgments (emotional intensity and naturalness) equivalent to those of the control group. On the other hand, his rate of joyful expressions was higher regardless of the stimuli presented, including those expressing negative emotions. LM presented the opposite profile: his rate of joyful expressions was equivalent to that of the control group, regardless of the category of stimuli. On the other hand, although his judgments in terms of emotional intensity were equivalent to those of the control group, his judgments in terms of realism were significantly higher for stimuli expressing joy (laughs and smiles), surprise, as well as for static stimuli and stimuli expressed by men. The results of JM and LM suggest a double dissociation between explicit emotional judgments and implicit facial mimicry. Clinically, these two impairments do not lead to the same disability and have to be handled differently. Whereas LM may not require specific care if no ecological difficult exists, the inappropriate expressions of JM have to be improved because of the social consequences in non-verbal communication. Finally, SL and IS presented intermediate profiles: their rate of joyful expressions was higher than those of the control group, but the difference was significant only for stimuli expressing a negative emotion, suggesting a profile similar to JM but of lesser magnitude. For SL and IS, judgments were affected, but selectively for one type of judgment respectively and for certain categories of stimuli only. A possible explanation for these impairments could be a thymic bias but the scores obtained with the scales of anxiety, depression and positivity were normal, excluding such an alternative explanation for JM, LM and SL. In total, these results suggest a disturbance of facial mimicry for three of the four patients included, with a selective impairment of facial mimicry for one patient while his judgments seemed preserved. These results support the importance of a clinical assessment of facial emotional productions.

With respect to future studies of brain-damaged or psychiatric patients and considering the absence of difference obtained between the judgment of realism and that of emotional intensity, only the latter should be retained as the operationalization of the explicit processing of emotions. Furthermore, contrary to the judgment of realism, the judgment of intensity was not correlated to the demographic data (age and level of education). It will however be important to consider the links between this variable and empathy since a correlation was evidenced with the IRI scale and the judgment of intensity.

Several results obtained with the present protocol seem to diverge from what was documented with the EMG technique. The effect of the sex of the participant [14,27,28-29] was not found in our study. Other studies will be necessary to evaluate the robustness of this result. In EMG, the hypothesis of a high sensitivity of the recording in women when compared to men, possibly due to the thinness of the skin, has been proposed [74]. This possible bias could explain the presence of an effect of the sex which is selective to the EMG technique. The documented links with empathy and joyful expressions in EMG [15,32-35] did appear selectively with the judgments but were not evidenced with the number of joyful expressions. To our knowledge, this point has never been explored, as the two studies that used the observation of videos did not document this empathetic capacity. Complementary studies based on observation will be necessary. The effect of the sex of the emitter of the emotion demonstrated in the case of joy [27,37-38] as not observed. This result could be explained by the presence of various emitters in the present protocol, including babies, possibly reducing the effect of sex between the adults. Finally, while the judgment of non-emotional characteristics was described as generating a lesser mimicry in comparison to an emotional judgment in EMG [24,36], the judgment of emotional intensity and of realism tasks generated a comparable number of joyful expressions in our study. Two hypotheses seem to explain this profile. Either the absence of effect could be linked to the fact that the judgment of realism task necessitates in any case an analysis of emotions; or the observation of videos does not enable the difference, only demonstrable thanks to the EMG technique, to be taken into account. Unfortunately, we were not able to create a more neutral instruction for our protocol concerning the processing of emotions, considering the variability in format of the stimuli presented. The presence of anxiety-depressive symptoms was not considered an exclusion factor from the study, which is a limitation. Indeed, six participants exceeded the threshold of pathological anxiety, which could be explained by the current health crisis. However, the anxious participants did not differ significantly from the non-anxious participants on the variables of interest.

Conclusion

In conclusion, the results of this preliminary study seem to indicate the feasibility of the quantification of joyful facial emotions through the observation of videos, in healthy participants and in brain-damaged patients, suggesting a possible clinical application. The data collection could be optimized by using dynamic stimuli rather than static ones and by taking into account in the calculation method of the recorded expressions a relative level of expression to optimize the quantification of facial mimicry in clinical neuropsychology. The judgment of emotional intensity task could be favorable. This methodology should make it possible to carry out group studies in neurology and in psychiatry. These studies should lead to the integration of the expressive dimension of emotions in future clinical practice, this point having been neglected until now despite the possibility of a disturbance of facial mimicry (here, three of the four patients are concerned) and the major impact of facial expressive impairments in non-verbal communication. Finally, this methodology of visual observation seems to represent a good alternative to EMG to document the production of facial emotional expressions in clinical and experimental practice, a point that has been neglected until now.

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Declaration of Interest Statement

The authors report no conflict of interest.

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