Article

Is there a difference in Facial Emotion Recognition after Stroke with vs. without Central Facial Paresis?

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**Abstract:** The Facial Feedback Hypothesis (FFH) states that facial emotion recognition is based on the imitation of facial emotional expressions and the processing of the physiological feedback. In the light of limited and contradictory evidence, this hypothesis is still being debated. Therefore, in the present study, emotion recognition was tested in patients with central facial paresis after stroke. Performance during facial vs. auditory emotion recognition was assessed in patients with vs. without facial paresis. Accuracy for objective facial emotion recognition was significantly worse in patients with vs. without facial paresis and also in comparison to healthy controls. Moreover, for patients with facial paresis, the accuracy for facial emotion recognition was significantly worse than for auditory emotion recognition. Finally, in patients with facial paresis, the subjective judgements of their own facial emotion recognition ability differed strongly from their objective performance. This pattern of results demonstrates a specific deficit for facial emotion recognition in central facial paresis and thus provides support for the FFH and points out effects of stroke.

**Keywords:** Emotion recognition; Facial feedback; Central facial paresis; Stroke

1. Introduction

Emotion recognition is omnipresent in social interactions [1] and represents an important social competence [2]. Faces provide relevant clues for the recognition of emotions [2] [3]. One explanation how the facial recognition of emotions succeeds is proposed by the Facial Feedback Hypothesis (FFH) [4]. The present study therefore compares stroke patients with vs. without unilateral central facial paresis, i.e. the partial inability to perform facial movements [5] in order to test the FFH prediction of a specific deficit of visual-facial emotion recognition in central facial paresis.

*Emotion processing and the role of facial feedback*

Facial emotion expressions are part of nonverbal communication [3] and regarded as one of the most important nonverbal features in the identification of emotions [6]. Facial expression could be highly variable due to the precise control of the different facial muscles [1] and their voluntary or affective control [7]. Although, the notion of basic emotions considers a set of emotions as highly elementary, unique and independent of culture, time and place [8]. These basic emotions are: anger, disgust, fear, joy, sadness and surprise [9] [10]. Each of the basic emotions is characterized by specific patterns of facial muscle activities [8] [11]. These congenital, ubiquitous basic emotions [12]are typically used to observe (facial) emotion recognition [13].

The accuracy of emotion recognition varies, depending on the particular emotion presented. Joy is detected significantly more accurately and quickly than all other basic emotions, whereas fear is detected significantly less accurately and more slowly than the other emotions [14]. The basic emotions surprise and anger as well as disgust and sadness are similarly well-identified in accuracy (performance listed in descending order) [14]. Besides differences per emotion, emotion recognition depends on sex and age. Women are faster in facial emotion recognition than men [15]. With increasing age, emotion recognition performance decreases [16]. It has not yet been conclusively clarified whether the processing of emotions is innate [4] [17] or whether a concept of emotions must first be learned [18]. A combination is also conceivable, if basic emotions are considered biologically anchored [12] and innate [17], while all other, more complex emotions [8] have to be learned first [12]. The localisation of emotion processing is also controversy discussed with evidence for right, left, or left and right hemispheric activation [19]. Dominance of the right hemisphere has been described historically [20], whereas recent evidence highlighted a combination of different neuronal networks with different lateralisation [19].

In emotion processing, the importance of afferent information from the body is emphasised, e.g. facial expression [18]. In this sense, the FFH provides a theoretical account for the process of facial emotion recognition. It postulates that other persons’ emotions are recognised by one’s own facial information [4]. The decoding requires the imitation of the facial expression of the other person and the corresponding proprioceptive facial feedback [21] [22](synonym for facial feedback: facial reflex [11]). Neal and Chartrand [22] summarised the working steps of the FFH: (1) Imitation of the facial expression of the communication partner (discrete, unconscious, fast, automated, and specific for the emotion); (2) Transmission of afferent information from the face to the brain; (3) Experience and recognition of the emotion [22].

Whereas the spontaneous, quick, and unobtrusive imitation with the own face is basically unproblematic [23], pathological conditions affecting facial integrity may affect the abilities to initiate or imitate basic emotions corresponding facial expressions. This includes, for example, facial paresis, a unilateral or bilateral palsy of the facial musculature following a peripheral or central defect [24]. The central form of facial paresis considered in this study typically presents unilaterally, contralateral to the central lesion [25], after stroke [26].

Whether and what role facial feedback takes in emotion recognition has not yet been conclusively clarified. For example, different research results show evidence for and against the FFH in the case of limited facial feedback (due to illness or artificially provoked).

Significant deficits in facial emotion recognition were reported by Konnerth et al. [27] and Storbeck et al. [28] in patients with peripheral facial paresis respectively paralysis. Konnerth et al. [27] reported patients achieved lower values in accuracy than healthy controls, although the difference was not significant. Storbeck et al. [28] detected that accuracy in facial emotion recognition did also not differ significantly between patients with facial paresis and healthy controls. However, the time of visual emotion recognition was significantly slower compared to the control subjects in both studies [27] [28]. More specifically, Korb et al. [29] reported differences depending on the paralysed side of the face with higher affected facial emotion recognition for patients with left sided than right sided facial palsy. Such findings might be taken as supportive evidence for the FFH as persons with intact feedback show faster facial emotion recognition times [22] [30] [31] [32] [33]. This reduced accuracy of emotion recognition in patients with peripheral facial palsy could be explained by Niedenthal et al. [33] whereby self-experienced emotions can be recognized earlier than those that are not self-perceived [33]. In contrast, Keillor et al. [34] did not report differences in the accuracy of emotion naming, discrimination, or matching tasks in their single case study of a patient with bilateral facial paralysis in Guillain-Barré syndrome. Neither did Bogart and Matsumoto [35] report facial emotion recognition deficits in patients with congenital bilateral facial paresis in Moebius syndrome. However, Calder et al. [36] did observe differences in the accuracy of emotion recognition in at least one basic emotion in patients with Moebius syndrome.

A different way of investigating facial feedback in healthy participants is the injection of botulinum toxin in facial muscles for temporarily paralysis. Different studies using this method showed changed emotion recognition in accuracy and time [22] [32]. The results may point to the direct link between facial feedback and emotion processing [32].

Besides provoked limited facial movements, or limited facial movements due to peripheral facial palsy, also other disorders could affect (1) facial movements, and (2) facial emotion recognition, for instance central facial palsy after stroke, and Parkinson’s Disease. Stroke occurs suddenly caused by disturbed blood flow, and oxygen deficiency (ischemic), or bleeding (hemorrhagic) in the brain leading to individual disabilities [37], whereas Parkinson’s Disease is a neurodegenerative disorder with loss of dopamine in the substantia nigra, resulting in typical symptoms of rigor, tremor, and bradykinesia [38]. Both, central facial palsy after stroke [26] [39] and Parkinson’s Disease [40] [41] [42] could result in similar effects, i.e. reduced facial expression, and therefore reduced facial feedback. Following the FFH, facial feedback due to facial integrity is needed for facial emotion recognition [23]. Also, both in stroke [43], and Parkinson’s Disease [41], facial emotion recognition could be impaired. However, there is not necessarily a direct correlation between the limitations in facial expression and facial emotion recognition, at least in Parkinson’s Disease [41].

In summary, there is evidence that patients with limited facial feedback and facial mimicry abilities (e.g. in peripheral facial paresis) are potentially affected by limited facial emotion recognition. To date, to the best of our knowledge, patients with peripheral facial palsy were studied, whereas patients with central facial palsy were overlooked.

The care of patients with central facial palsy is insufficient and rehabilitation guidelines are required [44]. To improve treatment and establish guidelines, deficits or remaining abilities must be identified first. For this, we designed a study to proof the ability of facial emotion recognition in patients with central facial palsy.

Consequently, the aim of the study was to test facial emotion recognition of patients with central facial paresis after stroke in accuracy and time with visually presented, i.e. facial stimuli, in healthy subjects. Testing different modalities (facial and auditory) in two patient groups (with or without facial paresis after stroke) allows assessing whether there is a general deficit in emotion recognition – this could be possible after stroke [43] – or whether only one particular modality is (more) affected. If there are no deficits in emotion recognition at all, i.e. if the performance is comparable to that of healthy control subjects, it may be assumed that emotion recognition may be intact. Accordingly, the primary research question was: Can patients with central facial paresis after stroke recognise facial emotions?

2. Materials and Methods

*2.1 Participants*

Three groups of participants were considered for this study: (1) Patients with unilateral central facial paresis after stroke, (2) patients without facial paresis after stroke and (3) healthy subjects. The data of the patient groups (1) and (2) was collected within the study (data are available from the authors on request), whereas the reference values of the subject group (3) was already available [45] [46] [47] and served for an additional comparison (see also figure 1 to 3).

The inclusion and exclusion criteria are summarised in table 1. The patients were referred by various cooperation partners, hospitals, and local practices for speech-language therapy. Recruitment and data collection took place in the period from 22 February until 14 May 2019 in Germany.

**Table 1.** Inclusion and exclusion criteria.

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| **Inclusion criteria** | **Exclusion criteria** |
| Adult persons (≥18 years) with or without unilateral central facial paresis after stroke (ischemic or hemorrhagic) | Children and adults with peripheral facial paresis |
| Acute, post-acute or chronic phase of stroke | Other neurological or psychological diseases |
| For the investigation:  - Capacity for approximately 75 minutes,  thereof sitting approx. 10 minutes  - Ability to choose answer options  - Communication skills to follow instructions and to answer questionnaires | For the investigation:  - Impairment of the general status, communication skills and/or ability to answer, so that the investigation is not is possible |
| Normal or corrected visual and hearing ability |  |
| Ability to consent | No ability to consent |

A total of 67 patients were recruited. Four of these were drop-out cases (one case: disorientation; one case: suspected bucco-facial apraxia with no possibility to assess a facial paresis; two cases: antidepressant medication with suspected altered emotional regulation). The remaining 63 patients were assigned to the study group (patients with central facial paresis, n=34) or the control group (patients without facial paresis, n=29) according to their diagnosis of facial paresis. Sociodemographic data, information on the lesion, facial paresis, general mental capacity, and aphasia of the study and control group are given in tables A1 to A3, A5, and A6 (appendix A).

The study was approved by the local ethics committee (key: EK 271/18) of the Medical Faculty at RWTH Aachen University while all regulations of the ethics committee were implemented. All experiments were performed in accordance with relevant guidelines and regulations. All participants signed an informed consent form after receiving detailed information.

*2.2 Materials*

For both the facial emotion recognition and auditory emotion recognition the same conditions were set, i.e., an item was presented (visually or auditory) and the patients had ten seconds to respond. There were different options available as answer. The respective software recorded accuracy and time. For both modalities, a pre-test with ten items (initially randomized, later presented in the same order) was performed. The pre-test ensured that the task was understood [48](see also appendix B).

*Visual facial emotion recognition*

In our study we choose for the *CRAFTA Emotion Program (CRAFTA Facemirroring Assessment and Treatment Software)* [49] which consists of a standard test for accuracy and time of facial emotion recognition [47] [49]. Forty-two subjects, each showing a basic emotion with their face, were presented on a screen. The person was first shown in a neutral position before changing to an emotional facial expression (basic emotion). Six additional answer options were displayed on the screen according to the basic emotion [47] (see also appendix B).

*Auditory emotion recognition*

In addition to faces, voices (auditory) are the most important modalities in emotional communication [1]. A sub-portion of the *Montreal Affective Voices (MAV)* [45]was used as assessment. These are emotional, non-linguistic, vocal expressions on /a/ (to be compared with *a* as in *apple,* British English). Sixty Items of the six basic emotions [45] were used. The *Montreal Affective Voices* were presented with a specially programmed experiment with the software *PsychoPy,* version 3.0.0b9 [50] (see also appendix B).

*Subjective facial emotion recognition: Self-Assessment Questionnaires Emotion Recognition*

Coulson et al. [51] asked relatives of patients with facial paresis for their assessment of the emotional recognition. Based on this, two standardized questionnaires were designed for the present study, which enable the systematic collection of subjective facial emotion recognition. The *Self-Assessment Questionnaires Emotion Recognition Accuracy* and *Time* thus documented the self-assessment of facial emotion recognition of the six basic emotions (anger, disgust, fear, joy, sadness and surprise) [51].In order to be able to look at the evaluation in a differentiated way, one questionnaire each was developed for the accuracy and time of facial emotion recognition. The questionnaires assess a possible change between pre-morbid to current abilities per basic emotion. These were the questions of the questionnaires in each case: *How well do you recognise the following feelings in other people's faces?* One of three answer options each could be selected. For *Accuracy*, the patient evaluated whether the respective basic emotion is *more difficult*, *just as well as* or *easier* recognised than before stroke. For *Time*, the patient indicated whether the basic emotion is detected *slower*, *as fast as* or *faster* than before the stroke. For deteriorations (response options *more difficult* or *slower)* a score of -1 was assigned. If the patient did not notice any changes (response options *just as well as* or *just as fast as)* no points (0) were calculated. For improvements (answer options *easier* or *faster)* the patient achieved a score of +1, resulting in a score between -6 and +6 per questionnaire.

*Sunnybrook Facial Grading System for diagnosing facial paresis*

In order to answer the main research question, all patients were examined in a standardised way to identify a possible facial paresis. Only this allowed to divide the patients into the study group (participants with central facial paresis) or the control group (participants without central facial paresis). The *Sunnybrook Facial Grading System* [52][53]is used for the standardised assessment for diagnosing a facial paresis or paralysis, respectively. This measurement method is explicitly recommended [54]. It is also considered the current standard in the evaluation of facial paresis [55] and was used in various studies (e.g. [54] [56] [57] [58] [59] [60] [61] [62] ). Ross et al. [52] published the original version of the *Sunnybrook Facial Grading System* in 1996, which was implemented in the present study (German version [53]). For this purpose, a video was made of each patient with an *Apple iPod touch* (camera at right angles, at the individual height of the chewing plane, 150 cm from the patient's chin), in which the patients were asked in a standardised manner to show their face in rest or to perform an arbitrary movement with their face (raise eyebrows, close eyes gently, smile with open mouth, show teeth, pucker lips). The videos were evaluated by a speech-language therapist (see also appendix B).

*2.3 Statistical analysis*

Two-factorial ANOVAs with post-hoc t-tests were performed with the factors *group* (with vs. without facial paresis) as between-subject factor and *modality* (facial vs. auditory emotion recognition) as within-subject factor. Accuracy and time of emotion recognition were considered as dependent variables. In order to compare the empirical data of the present study with the normative data of healthy controls (without stroke and without facial paresis) which were already available, a series of t-tests were subsequently performed separately both for accuracy and time. So, to compare the facial emotion recognition und auditory emotion recognition in accuracy and time between patients and healthy persons’ normative data, t-tests were performed for one sample. For the comparison between patients with and without facial paresis, two-factorial ANOVAs and (post-hoc) t-tests for independent samples were run. T-test for dependent samples were done to compare facial emotion recognition and auditory emotion recognition in patients with and without facial paresis. To analyse the subjective emotion recognition in accuracy and time, one-sample t-tests were conducted. To compare accuracy and time, t-tests for dependent samples were performed.

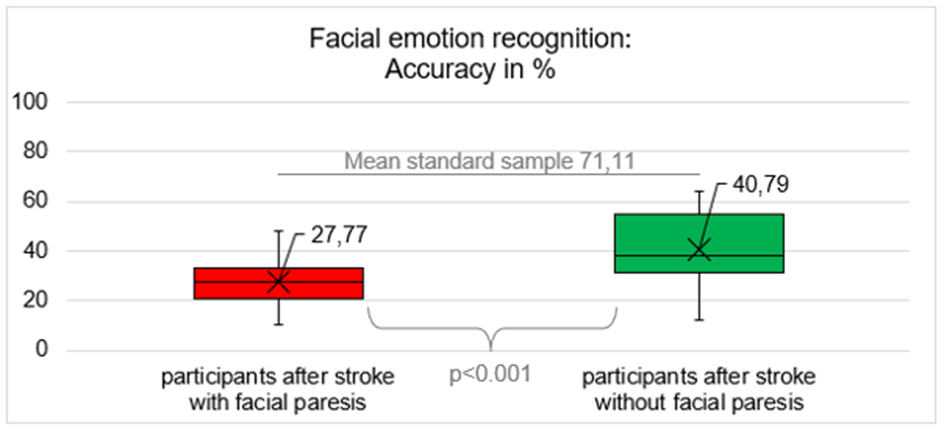
Benjamini -Hochberg-Correction was applied, if more than one t-test was conducted.

3. Results

The results of the objective (accuracy and time) and subjectively perceived success of emotion recognition are summarised in figures 1 to 4 and table A4 (appendix A).

*Accuracy of facial emotion recognition (figure 1)*

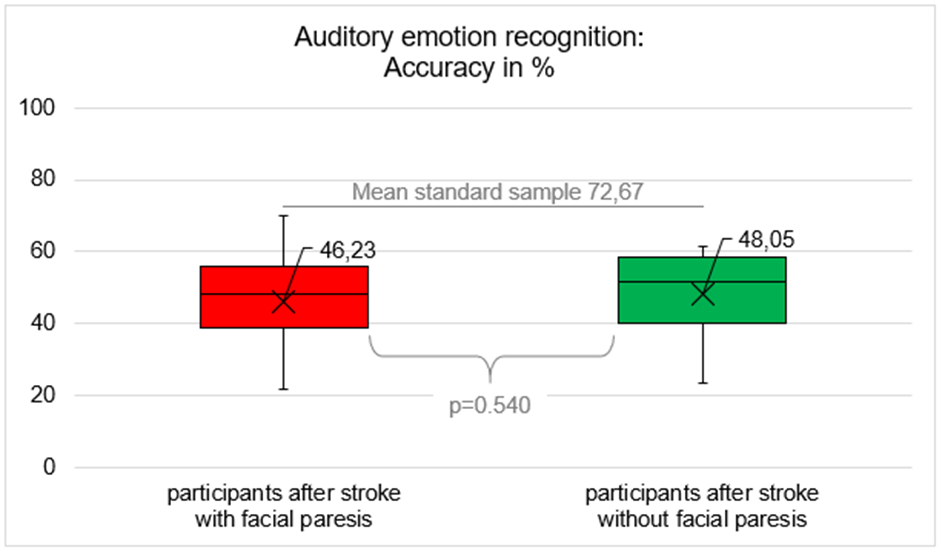
The results by the ANOVA of accuracy were main effect *group* F(1;61)=6.620; p=0.013; main effect *modality* F(1;61)=96.535; p<0.001 and interaction effect *group x modality* F(1;61)=18.330; p<0.001], which means that participants with central facial paresis recognised visually presented basic emotions significantly worse (reduced accuracy), compared to participants without facial paresis [t(49.425)=-3.767; p<0.001; after correction p=0.002] and compared to healthy controls [t(33)=-22.888; p<0.001; after correction p=0.002] . Participants without facial paresis recognised visually presented basic emotions significantly worse (reduced accuracy) compared to healthy controls [t(28)=-10.476; p<0.001; after correction p=0.002].



**Figure 1.** Accuracy of facial emotion recognition (mean, median, interquartile range). Participants after stroke with facial paresis performed significantly worse compared to healthy controls (p<0.001) and compared to participants after stroke without facial paresis (p<0.001). The data for healthy controls were not collected in this study but were taken from [46] [47]. So, no information on the actual distribution of the data is available but only the mean as indicator of the central tendency. Therefore, the figures only contain two box plots, not three.

*Accuracy of auditory emotion recognition (figure 2)*

Participants with central facial paresis recognised auditory presented basic emotions significantly worse (reduced accuracy) compared to healthy controls [t(33)=-13.258; p<0.001; after correction p=0.002]. Participants without facial paresis recognised auditory presented basic emotions significantly worse (reduced accuracy) compared to healthy controls [t(28)=-11.259; p<0.001; after correction p=0.002]. Participants with vs. without central facial paresis did not differ significantly in auditory emotion recognition (accuracy) [t(61)=0.616; p=0.540; after correction p=0.540].

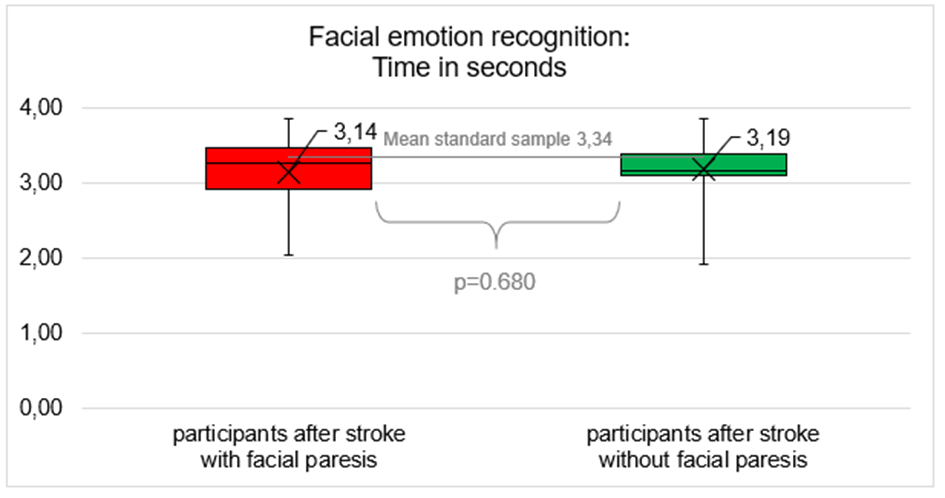
** **Figure 2.** Accuracyof auditory emotion recognition (mean, median, interquartile range). Participants after stroke with facial paresis performed significantly worse compared to healthy controls (p<0.001) but did not differ significantly compared to participants after stroke without facial paresis (p=0.540). The data for healthy controls were not collected in this study but were taken from [45]. So, no information on the actual distribution of the data is available but only the mean as indicator of the central tendency. Therefore, the figures only contain two box plots, not three.

*Comparison of accuracy of facial and auditory emotion recognition*

Participants with central facial paresis recognised visually presented basic emotions significantly worse (reduced accuracy) than auditorily presented basic emotions [t(33)=-11.252; p<0.001; after correction p=0.002]. Participants without facial paresis recognised visually presented basic emotions significantly worse (reduced accuracy) than auditorily presented basic emotions [t(28)=-3.485; p=0.002; after correction p=0.002].

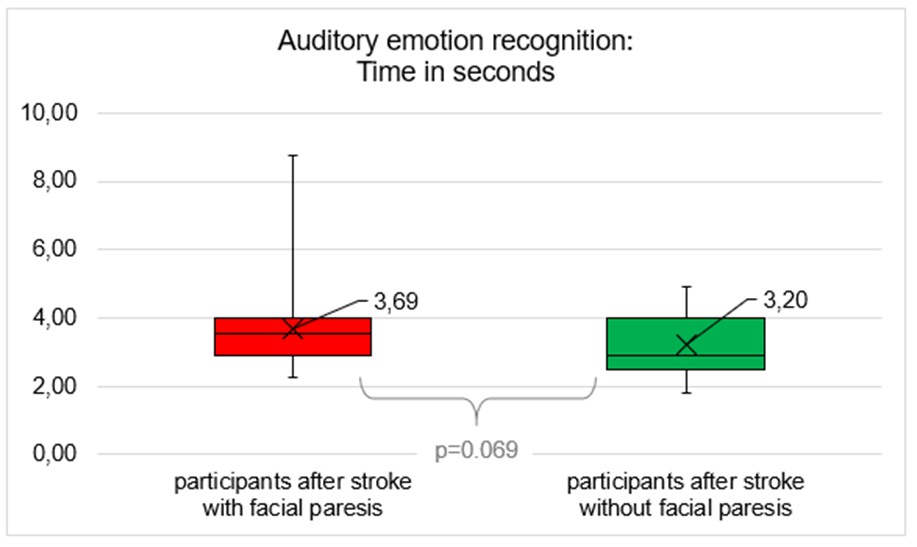
*Time of facial emotion recognition (Figure 3)*

The results by the ANOVA of accuracy were a main effect of *group [*F(1;61)=2.797; p=0.100], a main effect of *modality [*F(1;61)=3.311; p=0.074], and interaction effect *group x modality [*F(1;61)=3.148; p=0.081)], which means that participants with central facial paresis did not recognise visually presented basic emotions significantly more slowly (reduced time) compared to participants without facial paresis [t(61)=0.414; p=0.680; after correction p=0.680]. Participants with central facial paresis recognised visually presented basic emotions significantly (not significantly after correction) faster (increased time) compared to healthy controls [t(33)=-2.442; p=0.020; after correction p=0.060]. Participants without facial paresis recognised visually presented basic emotions significantly faster (increased time) compared to healthy controls [t(28)=-2.390; p=0.024; after correction p=0.036].

**Figure 3:** Average time of facial emotion recognition (mean, median, interquartile range). Participants after stroke with facial paresis performed significantly faster compared to healthy controls (p=0.02) but did not differ significantly compared to participants after stroke without facial paresis (p=0.68). The data for healthy controls were not collected in this study but were taken from [46] [47]. So, no information on the actual distribution of the data is available but only the mean as indicator of the central tendency. Therefore, the figures only contain two box plots, not three.

*Time of auditory emotion recognition (Figure 4)*

Participants with vs. without central facial paresis did not differ significantly in the average time of auditory emotion recognition [t(61)=-1.851; p=0.069].

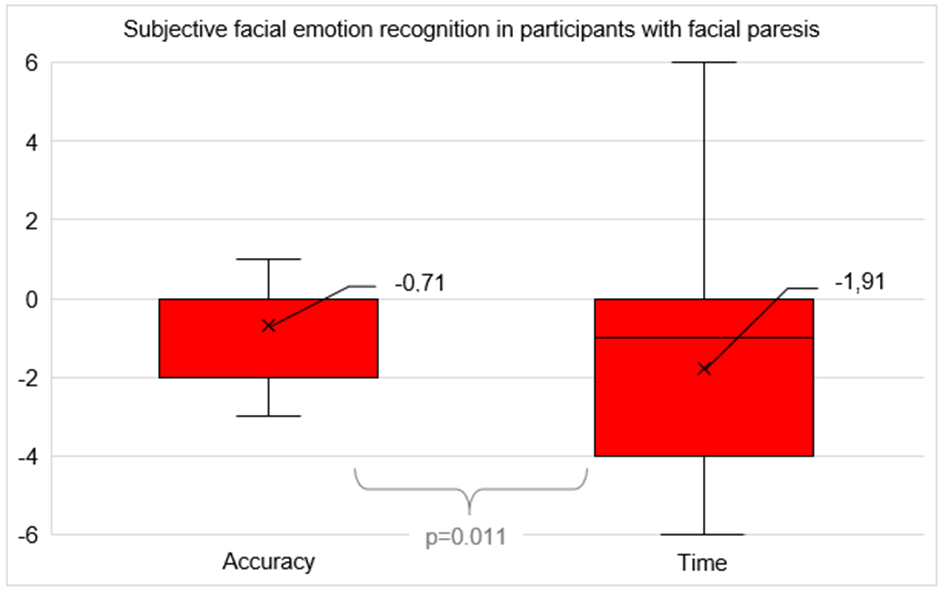
**Figure 4:** Average time of auditory emotion recognition (mean, median, interquartile range). Participants after stroke with facial paresis did not differ significantly compared to participants after stroke without facial paresis (p=0.069).

*Comparison of time of facial and auditory emotion recognition*

Participants with central facial paresis recognised visually presented basic emotions significantly (not significantly after correction) faster (increased time) than auditorily presented basic emotions [t(33)=-2.269; p=0.030; after correction p=0.060]. Participants without facial paresis recognised visually presented basic emotions not significantly different than auditorily presented basic emotions [t(28)=-0.041; p=0.968; after correction p=0.968].

*Subjective judgement of emotion recognition from the perspective of participants with central facial paresis (Figure 5)*

Both the average accuracy of facial emotion recognition (mean=-0.71±1.90) was perceived as significantly limited [t(33)=-2.167; p=0.038; after correction p=0.038] as well as the time of facial emotion recognition (mean=-1.91±2.90) was subjectively perceived as significantly limited [t(33)=-3.849; p=0.001; after correction p=0.003]. Participants with central facial paresis judged themselves as significantly more restricted in their time of facial emotion recognition than in their accuracy [t(33)=2.689; p=0.011; after correction p=0.017].

**Figure 5:** Accuracy and time in subjective facial emotion recognition (mean, median, interquartile range) in participants after stroke with facial paresis. Participants felt significantly more restricted in time compared to accuracy (p=0.011).

*Further analysis*

In order to verify that the identified pattern is reasonable on the basis of these results, the following further control calculations were made.

A correlation calculation (Pearson's product moment correlation) between objective accuracy and objective time of facial emotion recognition for patients with and without central facial paresis was done. The accuracy and the time of facial emotion recognition in patients with central facial paresis positive correlate with each other, (r=0.729; p<0.001). The average accuracy and the average time of facial emotion recognition in patients without facial paresis do not correlate significantly with each other (r=0.291; p=0.126).

Furthermore, a correlation calculation (Pearson's product moment correlation) between objective facial emotion recognition, accuracy and severity of facial paresis using the Sunnybrook Facial Grading System across all patients (with and without facial paresis) was performed. The average accuracy of facial emotion recognition and the severity of facial paresis correlate significantly positively with each other (r=0.31; p=0.014).

Moreover, a one tailed *t-*Tests for independent samples for facial emotion recognition in accuracy showed no significant difference in patients with left sided facial paresis (Mean=26.44±11.49) and right sided facial paresis (Mean=29.25±10.69), t(32)=-0.734; p=0.234. Another one tailed *t-*Tests for independent samples for facial emotion recognition in time showed no significant difference in patients with left sided facial paresis (Mean=3.12±0.48) and right sided facial paresis (Mean=3.17±0.47), t(32)=-0.322; p=0.375.

Also, a Chi-square test to compare the number of patients with limitations in general mental capacity between both groups (table A5, appendix A) was done. Both groups are comparable with x²(1, n=63)=0.204; p=0.651. Another Chi-square test to compare the number of patients with aphasia between both groups (table A6, appendix A) was done. Both groups are comparable with x²(1, n=63)=1.546; p=0.214.

Additionally, univariate and multivariate regressions with emotion recognition (facial and auditory in accuracy and time) as dependent variable and predictors diagnosis of facial paresis, sex, age, subjective judgement, general mental capacity and time post onset were conducted (table A7, and table A8, appendix A). Patients with facial paresis recognised visually presented basic emotions significantly worse (reduced accuracy) compared to patients without facial paresis calculated by means of univariate regression (beta=-0.444; p<0.001), as well as by multivariate regression (beta=-0.353; 0.003).

4. Discussion

This study investigated the Visual Facial Emotion Recognition (VFER) in patients with(out) central facial paresis vs. healthy individuals. The results of our study show that participants with central facial paresis have significantly less average accurate emotion recognition in the facial modality compared to the auditory modality. The less accurate VFAR in facial paresis but not in auditory emotion recognition may be supported by changes in the facial feedback mechanism. Clinically this means that an VFAR in persons which has a limited facial mimicry like central facial paresis patients in contrast auditory performance does appear to be affected by the facial paresis [36]. Taking into account that we did not test facial mimicry itself (i.e. facial muscle activity was not measured during the emotion recognition task), but facial emotion recognition, facial paresis deduces to be one factor influencing the accuracy of objective facial emotion recognition which may be supported by changes in the facial feedback mechanism. This may be an indication that accuracy of objective facial emotion recognition is limited especially when facial feedback is altered by facial paresis. Auditory performance does not appear to be affected by the facial paresis (for a similar finding cf. [36]). Besides facial paresis, also stroke could be one factor influencing the accuracy of objective facial emotion recognition in our sample. All participants (with and without facial paresis) had at least one stroke. Since stroke may also cause deficits in emotion recognition [43], our examined patient groups may be affected as well. These two potential factors (altered facial feedback and altered central processing due to stroke) indicate the relevance and need to also study patients without stroke but with limited facial feedback, for example patients with peripheral facial palsy.

Our results uncover significantly deficits in the accuracy of facial emotion recognition while other studies did not report any differences, e.g. [27] [28] [34]. This fact may be due to the large sample size (participants with facial paresis: n=34; participants without facial paresis: n=29) and the inclusion of different phases post onset with a wide range since the stroke (day 5 up to day 6361 post onset). However, previous studies reported significant limitations in the average time of facial emotion recognition, e.g. [27] [28], while the participants in this present study showed faster reaction times. This in turn could indicate that the participants after stroke replied *quick and dirty* [63], while they suffered from other impairments like deficits in attention, concentration and memory [64] in addition to the facial paresis after stroke. In order to investigate a possible systemic connection between the fast, inaccurate responses, the significant positive correlation between objective accuracy and objective time of facial emotion recognition in patients with facial paresis provide further insights. I.e. the faster a patient with facial paresis responded, the less accurate was the response. Whereas no correlation was found for patients without facial paresis. This could indicate, that the patients with facial paresis themselves were aware of their deficit in the time of facial emotion recognition (as reported in the *Self-Assessment Questionnaires Emotion Recognition)* but wanted to show their best performance in the test situation and therefore answered as quickly as possible.

The participants with facial paresis subjectively felt limited in both parameter accuracy and time in VFAR. They stated that they were impaired in time more than in accuracy. The participants felt that facial emotion recognition had slowed down considerably since the stroke and was somewhat less accurate. These results provide a new insight into subjective emotion recognition as it was not considered in previous studies. However, the clinical measurement gave contradictory results and showed that the patients were clear less accurate but faster. Thus, the visual and auditory performance appears to be partially controversial to the subjectively perceived performance.

In the present study, we considered facial and auditory emotion recognition difference in the results. This may support for example FFH as mentioned before. Nevertheless, it should be noted that a large part of human emotion is communicated via face and voice with respect to the literature. To the best knowledge of the authors, this is the first clinical study which combines two different modalities in a clinical setting [65]. The mentioned factors (limitations like deficits in attention, concentration and memory [64] besides facial paresis and emotion recognition) influence both the study results and the everyday communication of the patient groups. Although for stroke patients their survival is of primary importance [66], participation is also highly relevant, in particular in the post-acute and chronic phase [67]. Since both groups of patients had a significantly reduction in the accuracy of facial and auditory emotion recognition compared to healthy subjects, intervention recommendations for both groups and both modalities are required. Although there is limited evidence for FFH [68], FHH can be used as an explanation for assessment and rehabilitation [69].

*Relevance of assessment of emotion recognition*

The described results not only provide evidence for the FFH and effects of stroke, but also have implications for the treatment of patients with central facial paresis after stroke. Already in 2013, Dobel et al. [69] called for the examination of facial emotion recognition in patients with facial paresis using basic emotions [69]. In summary, the present study supports this demand and once again advocates it.

Since the accuracy of facial emotion recognition can be impaired, especially in patients after stroke with facial paresis, appropriate assessment and therapy is recommended for this patient group. Deficits should be assessed, because the performance limitations may have negative consequences for communication and increase over time. If the performance of emotion recognition remains deficiently impaired, this can lead to a construct of disorders like alexithymia (the inability to recognise or describe one's own emotions) [11] [70]. For example, if sadness is misinterpreted not adequately the patient may reacts defensively and thus not appropriate to the situation [6]. The effects of facial emotion recognition are therefore far-reaching and decisive for adequate social contacts. The partially controversial results of objective measurement and subjective assessment of facial emotion recognition in participants with facial paresis require detailed and individual examination in clinical practice. It is not sufficient to either ask the patient for his or her opinion *or* to carry out an objective diagnosis. Both options should be taken, and the results should be compared.

In addition, the lack of disease insight to be expected according to the available results (comparison between clinical measurement and subjective assessment) must become part of the therapy in order to show the patient the relevance of the therapy of facial emotion recognition. This should not underestimate the importance of considering the individual wishes and goals of the patient and including them in the sense of joint decision-making [71]. The basis for this is the tripartite evidence-based practice[71] [72]. It ensures not only the effectiveness and efficiency of therapy, but also therapy motivation and transfer into the patient's every-day life [71].

*Limitations of the study*

The composition of the sample may be considered a limiting factor of the study. A larger and more representative, homogeneous sample tested on the same time post onset after stroke and subdivided according to the subtypes of central facial paresis (voluntary and involuntary central facial paresis [73]) would therefore be desirable for future studies. For a more precise observation of the lesion localization and comparability of patients, imaging with detailed description of affected brain areas. Also, statistical adjustment for different stroke locations and lesion sizes would be beneficial, because differences in emotion recognition could depending on affected hemisphere [43]. Despite the possibly different lesion locations and lesion sizes, the results in facial emotion recognition show significant differences between the patient groups. Since significant effects can already be observed in our sample, we expect similar or stronger effects from a more selected sample with stricter inclusion criteria in further studies. Also, a strong and reliable test battery to assess cognitive capacity (see [74]) is needed to differentiate deficits in emotion recognition and limitations on general mental capacity after stroke. Because emotion perception depends on general mental capacity [74] [75] [76], any emotion perception test measures general mental capacity to some degree also. For the presented study, there was a comparable number of patients with limitations in mental capacity, and aphasia proven by Chi-square tests. In future studies, comparability should be extended and improved by standardised diagnostic.

However, the significant positive correlation calculation between objective facial emotion recognition accuracy, and severity of facial paresis using the *Sunnybrook Facial Grading System* across all patients points to facial paresis as the main differentiator between the two patient groups. Thus, the higher the accuracy of facial emotion recognition, the higher the score on the *Sunnybrook Facial Grading System.* That is, facial competence correlates with accuracy in facial emotion recognition, or the lower the facial competence, the worse the accuracy in facial emotion recognition. Also, significant univariate and multivariate regressions documented the relation of facial emotion recognition accuracy and facial paresis. These results demonstrate the influence of facial paresis on facial emotion recognition once more, but only in accuracy. No significant differences were detected in objective facial emotion recognition accuracy, and time between patients with left or right sided facial paresis. If one hemisphere is dominant for emotion processing, [43] patients with lesion in this dominant hemisphere with contralateral facial paresis [25], could be possibly more affected. We cannot confirm this hypothesis and previous research in facial palsy, where patients with left sided facial palsy showed less performance in facial emotion recognition compared to patient with right sided facial palsy [29]. But our results are in line with findings on patients with Parkinson’s Disease, where facial asymmetry is not related to hemispheric dominance for emotion processing [77]. For this, further evidence is needed to inspect possible differences in facial emotion recognition and expression depending on affected side of the facial palsy and hemisphere.

A perfect comparability of the standard data to the sample cannot be guaranteed without gaps, e.g. due to the age of the participants (for example e.g. *Montreal Affective Voices* validation sample with an average age 23.3±3 years [45]vs. patients with facial paresis average age 62.6±9.3 years and patients without facial paresis average age 58.4±10.7 years). Also, it must be noted that only a small sample size of normative data (n=29) was used for the auditory emotion recognition *(Montreal Affective Voices)* [45]*.* Furthermore, the measurement of auditory and facial emotion recognition is not completely comparable. Especially with regard to the time of emotion recognition, it should be noted, for example, that the response modes differed (selecting option on screen vs pointing to a surface) or that the number of items and response options were not identical. As a consequence, for further research, norm data from healthy individuals should be collected a new with an extended comparability to the patient groups. Also, the measurements of the facial and auditory emotion recognition tasks should be made even more comparable.

The separate presentation of facial and auditory items in emotion recognition should also be critically questioned. Facial and auditory expressions are not necessarily independent and influence their recognition mutually. For example, a facial expression is generated by moving the mouth while a vocal expression is taking place [1]. However, a separation of the modalities, i.e. just visual or just auditory impressions, seemed to make sense in this study in order to differentiate and compare the performances. In order to be able to answer the question reliably, it seems unavoidable. At the same time, however, this separate type of emotion recognition is far removed from everyday life and thus reduces the external validity. Equally adapted to optimal experimental conditions, the offer of static photographs instead of everyday situations also appears as material [78]. A person is able to show up to 8000 different emotional facial expressions with his or her face [17]. However, it should be critically noted that our study only examined the emotion recognition in basic emotions and thus minimized the requirements compared to non-verbal communication in everyday life. It should be noticed here that basic emotions can be regarded as the basis for far more complex emotions or emotional states [8]. Yet, since even the emotion recognition of the comparatively primitive basic emotions [8] was assessed as limited in the present study, an even worse performance can be assumed for more complex emotions.

5. Conclusions

From this study one may conclude that

* participants after a stroke with central facial paresis were significantly less accurate in visually recognising basic emotions compared with stroke patients without facial paresis and a sample of healthy controls.
* auditory emotion recognition was in both stroke groups less accurate than in the control sample.
* the facial emotion recognition in accuracy of participants with central facial paresis was significantly worse than the auditory accuracy of emotion recognition.
* because visual emotion recognition was clear worse as auditory emotion recognition in participants with facial paresis, facial mimicry plays probably an important role in communication with patients after stroke.
* The results of our observational study may support the overall effects of stroke on emotion recognition as well as FFH which is a practical and appropriate model implemented in clinical assessments and interventions.
* Future research should investigate patients with facial palsy without stroke to further describe the impact of facial feedback on emotion recognition.

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**Institutional Review Board Statement:** All subjects gave their informed consent for inclusion before they participated in the study.The study was conducted according to the guidelines of the Declaration of Helsinki, and the protocol was approved by the Ethics Committee of Medical Faculty at RWTH Aachen University, Germany (protocol code EK 271/18, 11 December 2018).

**Informed Consent Statement:** Informed consent was obtained from all subjects involved in the study.

**Data Availability Statement:** The data presented in this study are available on request from the corresponding author. The data are not publicly available due to the data were collected within a large research project that has not yet been completed.

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**Appendix A**

**Table A1:** Sociodemographic information to gender, age, education and handedness of the study group and control group.

|  |  |  |
| --- | --- | --- |
| **Sociodemographic**  **information** | **Study group**  **Patients with facial paresis**  **n=34** | **Control group**  **Patients without facial paresis**  **n=29** |
| Gender | Male: n=18; 53%  Female: n=16; 47% | Male: n=20; 69%  Female: n=9; 31% |
| Age in years | mean=62.65±9.26  min=39  max=81 | mean=58.38±10.72  min= 35  max=83 |
| Education | No school degree:  n=4; 11.77%  Sec. school certificate:  n=9; 26.47%  Medium maturity:  n=12; 35.29%  High school:  n=9; 26.47% | No school degree:  n=0  Sec. school certificate:  n=6; 20.69%  Medium maturity:  n=15; 51.72%  High school:  n=8; 27.59% |
| Handedness | Left: n=0  Right: n=33; 97.06%  Left and right: n=1; 2.94% | Left: n=1. 3.45%  Right: n=27; 93.10%  Left and right: n=1; 3.45% |

Note: n describes the number of participants.

**Table A2:** Lesion information to time post onset on examination for this study, type of lesion (ischaemic, hemorrhagic or both), affected hemisphere, quantity (number of lesions), limitations in general mental capacity after stroke, and aphasia.

|  |  |  |
| --- | --- | --- |
| **Lesion** | **Study group**  **Patients with facial paresis**  **n=34** | **Control group**  **Patients without facial paresis**  **n=29** |
| Time post onset  in days (in years;months)  Phase post onset  (Acute: ≤6 weeks  Post-acute: <1 year  Chronic: ≥1 year) | mean=1558 (4;3) ± 2112 (5;9)  min=5  max=6361 (17;5)  Acute: n=11; 32.35%  Postacute: n=6; 17.65%  Chronic: n=17; 50.00% | mean=1359 (3;9) ± 2702 (7;5)  min=13  max=11398 (31;2)  Acute: n=11; 37.93%  Postacute: n=3; 10.34%  Chronic: n=15; 51.72% |
| Type | Ischemic: n=27; 79.41%  Hemorrhagic: n=5; 14.71%  Ischemic  and hemorrhagic:  n=1; 2.94%  n.a.: n=1; 2.94% | Ischemic: n=21; 72.41%  Hemorrhagic: n=6; 20.69%  Ischemic  and hemorrhagic:  n=1; 3.45%  n.a.: n=1; 3.45% |
| Hemisphere | Left: n=12; 35.29%  Right: n=13; 38.24%  Left and right:  n=0  n.a.: n=9; 26.47% | Left: n=15; 51.72%  Right: n=6; 20.69%  Left and right:  n=2; 6.90%  n.a.: n=6; 20.69% |
| Quantity | 1x: n=22; 64.71%  2x: n=8; 23.53%  3x: n=1; 2.94%  4x: n=1; 2.94%  n.a.: n=2; 5.88% | 1x: n=25; 86.21%  2x: n=2; 6.90%  3x: n=1; 3.45%  4x: n=0  n.a.: n=1; 3.45% |
| Limitations in general mental capacity after stroke | n=16; 47.06% | n=12; 41.38% |
| Aphasia | n=6; 17.65% | n=9; 31.03% |

Note: n.a. means no information was given. N describes the number of participants.

**Table A3:** Facial paresis information to diagnosis from the patient’s perspectives and from the patient’s therapist perspective according to the participant, diagnosis via Sunnybrook Facial Grading System [52] [53] done as a part of this study by a logopaedic examiner and severity classification via House & Brackmann Facial Nerve Grading System [79] as well as affected side of the face, time post onset on examination for this study, and already perceived therapy until the examination for this study.

|  |  |  |
| --- | --- | --- |
| **Facial paresis** | **Study group**  **Patients with facial paresis**  **n=34** | **Control group**  **Patients without facial paresis**  **n=29** |
| Diagnosis facial paresis from the patient‘s perspective | Facial paresis: n=21; 61.76%  - Left: n=9; 26.47%  - Right: n=12; 35.29%  None facial paresis: n=13; 38.24% | Facial paresis: n=10; 34.48%  - Left: n=2; 6.90%  - Right: n=8; 27.58%  None facial paresis: n=19; 65.52% |
| Diagnosis facial paresis from the therapist’s perspective (physiotherapy or speech and language therapy) | Facial paresis: n=11; 32.35%  - Left: n=4; 11.76%  - Right: n=6; 17.65%  - n.a. to the affected side:  n=1; 2.94%  None facial paresis: n=2; 5.88%  n.a.: n=21; 61.77% | Facial paresis: n=0  None facial paresis: n=6; 20.69%  n.a.: n=23; 79.31% |
| Diagnosis facial paresis  *Sunnybrook Facial Grading System* (total score 0-100) | mean=73.12±8.34  min=54  max=83  Grade II: n=24; 70.59%  Grade III: n=10; 29.41%  Left:  - Grade II: n=11; 61.11%  - Grade III: n=7; 38.89%  Right:  - Grade II: n=13; 81.25%  - Grade III: n=3; 18.75% | mean=91.21±3.46  min=87  max=100  Grade I: n=29; 100% |
| Time post onset  in days (in years;months)  Phase post onset  (Acute: ≤6 weeks  Postacute: <1 year  Chronic: ≥1 year) | mean=827 (2;3) ± 1606 (4;5)  min=5  max=5852 (16;0)  Acute: n=14; 41.18%  Postacute: n=5; 14.71%  Chronic: n=7; 20.59%  n.a.: n=8; 23.53% | mean=2207 (6;1) ±3709 (10;2)  min=35  max=11398 (31;2)  Acute: n=3; 10.35%  Postacute: n=1; 3.45%  Chronic: n=9; 31.03%  n.a.: n=16; 55.17% |
| Non-pharmaceutical Therapy  At the time of the  examination (current)  Start  Frequency  Duration  Therapist  Content  Self-exercises | Yes: n=9; 26.47%  No: n=25; 73.53%  From the stroke to latest post-acute phase  Isolated therapy units up to 1-3x/week  Max. 3.5 months  12x logopaedic therapy,  2x physiotherapy,  1x physical therapy  Exercises for facial expression, oral motor skills, articulation, Proprioceptive Neuromuscular Facilitation, massage  Exercises for facial expression, oral motor skills, articulation, massage, sensitivity training | Yes: n=0  No: n=29  From the stroke to latest post-acute phase  Individual therapy units up to 2x/week  Max. 6 months  5x logopaedic therapy,  1x physiotherapy,  1x n.a.  Exercises for facial expression, oral motor skills, articulation, stretching M. buccinator  Exercises for facial expressions, oral motor skills |

Note: n.a. means no information was given. N describes the number of participants.

**Table A4:** The results of the objective (accuracy and time) and subjectively perceived success of emotion recognition are summarised.

|  |  |  |  |
| --- | --- | --- | --- |
| **Emotion recognition** | **Study group**  **Patients with facial paresis**  **n=34** | **Control group**  **Patients without facial paresis**  **n=29** | **Healthy controls** |
| Objective facial emotion recognition via *CRAFTA Emotion Program,* Accuracy in % | mean=27.77  sd=11.04  min=10.00  max=48.00 | mean=40.79  sd=15.59  min=12.00  max=64.00 | mean=71.11  sd=7.53  min=45.00  max=88.00  n=147 [46] [47] |
| Objective facial emotion recognition via *CRAFTA Emotion Program,* Time in sec. | mean=3.14  sd=0.47  min=2.04  max=3.86 | mean=3.19  sd=0.34  min=1.91  max=3.86 | mean=3.34  sd=0.66  min=1.94  max=5.58  n=147 [46] [47] |
| Objective auditory emotion recognition via *MAV,* Accuracy in % | mean=46.23  sd=11.63  min=21.67  max=70.00 | mean=48.05  sd=11.78  min=23.34  max=61.67 | mean=72.67  sd=11.99  min=56.00  max=86.00  n=29 [45] |
| Objective auditory emotion recognition via *MAV,* Time in sec. | mean=3.69  sd=1.20  min=2.25  max=8.75 | mean=3.20  sd=0.88  min=1.80  max=4.90 | n.a. [45] |
| Subjective facial emotion recognition via *Self-Assessment Questionnaires Emotion Recognition Accuracy* | mean=-0.71  sd=1.90  min=-6.00  max=6.00 | mean=-0.03  sd=1.32  min=-2.00  max=6.00 | n.a. |
| Subjective facial emotion recognition via *Self-Assessment Questionnaires Emotion Recognition Time* | mean=-1.91  sd=2.90  min=-6.00  max=6.00 | mean=-1.00  sd=2.52  min=-6.00  max=6.00 | n.a. |

Note: n.a. means no information was given. N describes the number of participants.

**Table A5:** Facial paresis and general mental capacity information are summarised.

|  |  |  |
| --- | --- | --- |
|  | **Study group**  **Patients with facial paresis**  **n=34** | **Control group**  **Patients without facial paresis n=29** |
| With limitations in general mental capacity | n=16 | n=12 |
| Without limitations in general mental capacity | n=18 | n=17 |
| Type of limitations in general mental capacity | Memory: n=10  Concentration: n=9  Slowdown: n=3  Fatigue: n=2  Complex thinking: n=1  Neglect on spec: n=1  Orientation in time: n=1  Orientation in place: n=1  Overall deterioration: n=1  Acalculia: n=0  Arousal: n=0  Inner unrest: n=0 | Memory: n=8  Concentration: n=5  Slowdown: n=1  Fatigue: n=2  Complex thinking: n=0  Neglect on spec: n=0  Orientation in time: n=0  Orientation in place: n=0  Overall deterioration: n=0  Acalculia: n=1  Arousal: n=1  Inner unrest: n=1 |

Note: N describes the number of participants. For limitations in general mental capacity, multiple deficits types per participant are possible. For this, n describes the number of limitations per group.

**Table A6:** Facial paresis and aphasia information are summarised.

|  |  |  |
| --- | --- | --- |
|  | **Study group**  **Patients with facial paresis**  **n=34** | **Control group**  **Patients without facial paresis n=29** |
| With aphasia | n=6 | n=9 |
| Without aphasia | n=28 | n=20 |

Note: N describes the number of participants.

**Table A7:** Univariate regression analysis

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Accuracy of facial emotion recognition** | | | | |
|  | **Standardised Beta** | **95.0% Confidence interval** | | **p value** |
|  |  | **Lower bound** | **Higher bound** |  |
| **Diagnosis of**  **facial paresis** | -0.444 | -19.762 | -6.295 | <0.001 |
| **Time of facial emotion recognition** | | | | |
| **Diagnosis of**  **facial paresis** | -0.053 | -0.253 | 0.166 | 0.680 |
| **Accuracy of auditory emotion recognition** | | | | |
| **Diagnosis of**  **facial paresis** | -0.079 | -7.733 | 4.091 | 0.540 |
| **Time of auditory emotion recognition** | | | | |
| **Diagnosis of**  **facial paresis** | 0.231 | -0.040 | 1.033 | 0.069 |

**Table A8:** Multivariate regression analysis

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Accuracy of facial emotion recognition** | | | | |
|  | **Standardised Beta** | **95.0% Confidence interval** | | **p value** |
|  |  | **Lower bound** | **Higher bound** |  |
| **Diagnosis of**  **facial paresis** | -0.353 | -16.920 | -3.787 | 0.003 |
| **Sex** | 0.022 | -6.306 | 7.615 | 0.851 |
| **Age** | -0.393 | -0.891 | -0.256 | <0.001 |
| **Subjective judgement**  **Accuracy** | -0.014 | -2.359 | 2.110 | 0.911 |
| **Subjective judgement**  **Time** | 0.032 | -1.197 | 1.542 | 0.802 |
| **Limitations in general mental capacity** | 0.054 | -5.213 | 8.392 | 0.641 |
| **Time post onset acute, postacute, chronic** | -0.227 | -7.417 | 0.128 | 0.058 |
| **Time of facial emotion recognition** | | | | |
| **Diagnosis of**  **facial paresis** | -0.029 | -0.248 | 0.201 | 0.834 |
| **Sex** | -0.173 | -0.383 | 0.093 | 0.228 |
| **Age** | -0.186 | -0.018 | 0.003 | 0.167 |
| **Subjective judgement**  **Accuracy** | 0.013 | -0.073 | 0.080 | 0.935 |
| **Subjective judgement**  **Time** | 0.057 | -0.038 | 0.055 | 0.715 |
| **Limitations in general mental capacity** | 0.076 | -0.170 | 0.295 | 0.593 |
| **Time post onset acute, postacute, chronic** | -0.252 | -0.242 | 0.016 | 0.085 |
| **Accuracy of auditory emotion recognition** | | | | |
| **Diagnosis of**  **facial paresis** | 0.015 | -4.900 | 5.596 | 0.895 |
| **Sex** | 0.082 | -3.638 | 7.488 | 0.491 |
| **Age** | -0.428 | -0.747 | -0.239 | <0.001 |
| **Subjective judgement**  **Accuracy** | -0.160 | -2.894 | 0.678 | 0.219 |
| **Subjective judgement**  **Time** | 0.106 | -0.646 | 1.542 | 0.416 |
| **Limitations in general mental capacity** | 0.068 | -3.859 | 7.015 | 0.563 |
| **Time post onset acute, postacute, chronic** | -0.374 | -7.750 | -1.720 | 0.003 |
| **Time of auditory emotion recognition** | | | | |
| **Diagnosis of**  **facial paresis** | 0.227 | -0.074 | 1.052 | 0.088 |
| **Sex** | -0.050 | -0.706 | 0.489 | 0.717 |
| **Age** | 0.153 | -0.011 | 0.044 | 0.232 |
| **Subjective judgement**  **Accuracy** | 0.184 | -0.073 | 0.310 | 0.220 |
| **Subjective judgement**  **Time** | -0.033 | -0.131 | 0.104 | 0.825 |
| **Limitations in general mental capacity** | -0.173 | -0.959 | 0.209 | 0.203 |
| **Time post onset acute, postacute, chronic** | 0.205 | -0.083 | 0.565 | 0.141 |

**Appendix B**

*Additional information on data collection*

Each patient was examined once. The patient was first informed about the study and data privacy. After the declaration of informed consent, an anamnesis took place (see tables A1 to A3, appendix A) before the examination was conducted. All data were collected by the same examiner. All participants received the same standardised verbal instruction to perform the following tasks.

*Facial emotion recognition: CRAFTA Emotion Program*

The *CRAFTA Emotion Program (CRAFTA Facemirroring Assessment and Treatment Software)* [49]measured the objective facial emotion recognition in accuracy and time [47] [49]. Portraits of people, each showing a basic emotion with their face, were presented on a *lenovo yoga 500* 14” touch screen. The person was first shown in a neutral position (one second) before changing to an emotional facial expression (basic emotion). Six additional answer options are displayed on the right side of the screen according to the basic emotions [47].

By selecting an answer option (in 85% [n=54] of cases via touch screen, in 6.35% [n=4] of cases via touch pen due to hemiparesis, in 7.95% [n=5] via mouse due to hemiparesis), the program recorded the accuracy (right or wrong answer) as well as the reaction time (in seconds). Immediately afterwards, the next screen appeared. In a standardised test, a total of 42 images of three different adult women and three different men (one person per picture) in the same order, were presented. Each basic emotion was shown seven times (six basic emotions x seven images = 42 images). The time limit to respond was maximal 10 seconds. If there is no response within this time, this was considered to be an exceeded response time and therefore *unanswered* and start with the next emotion. The objective facial emotion recognition was so measurable in accuracy and time [47]. After testing, the program reproduces an overview of the time and accuracy of all the emotions together and separately and the time and exchange emotion, if available of all 42 pictures.

A pre-test with ten items was performed. The pre-test ensured that the task was understood [48]. Questions of the patient regarding the test procedure were answered. However, no assistance was given with regard to the content of the test.

For the *CRAFTA Emotion Program,* normal values of 147 healthy subjects are available. Accuracy in %: mean=71.11±7.53; min=45.00; max=88.00. Time in seconds: mean=3.34±0.66; min=1.94; max=5.58 [46] [47](see also figure 1 and 3 and table A4, appendix A).

*Auditory emotion recognition: Montreal Affective Voices*

As stimuli for the auditory emotion recognition, a part of the *Montreal Affective Voices (MAV)* [45]was used. These are emotional, non-linguistic, vocal expressions on /a/ (to be compared with a as in *apple,* British English). Five women and five men each presented the six basic emotions with their voice once each [45], so that in the present study a total of 60 (= ten persons x six basic emotion) items were used.

For the presentation of the *MAV,* a software was available which, in addition to the accuracy of emotion recognition, also checks the intensity of the emotion, but neglects the time [80]. For the present study, which examined the accuracy and time of emotion recognition, the procedure must therefore be adapted. For this purpose, a specially programmed experiment with the software *PsychoPy,* version 3.0.0b9 [50] was used, which on the one hand reproduces the *MAV* and on the other hand records the selected response option and reaction time. The sound was given once [80] via standard headphones [45]. The sequence of stimuli was randomised and standardised presented in the same order for all participants.

The participant was then asked to assess the emotion by selecting a response option [81]. Following the original software [80], the participant selected one of the response options (one of the six basic emotions or *neutral/unknown)* by pointing at a surface (A4 size). Ten seconds of time were available to respond for one task.

As in objective facial emotion recognition, a pre-test with ten items (initially randomised, later presented in the same order) was performed too. In addition, the examiner checked that the headphones are comfortably fitted. The volume was adjusted individually [45]. Questions of the patient regarding the test procedure were answered. However, no assistance was given with regard to the content of the test.

Standard values are available for accuracy (in %) of emotion recognition: mean=72,67±11.66; min=56.00; max=86.00 (see also figure 2 and table A4, appendix A). However, no data were collected on time [45]. As proposed by Belin et al. [45] and explained above, *MAV* (selected items and adapted to the circumstances of this study) were used. The *MAV* as material for auditory emotion recognition are explicitly recommended for comparison with facial emotion recognition. They are particularly well suited, since only the auditory modality is addressed. Furthermore, the *MAV* do not contain any linguistic information, which excludes distortion or aggravated conditions for patients with aphasia [45]. Mild aphasia was not necessarily a criterion for exclusion in this study (see table 1*).*

*Sunnybrook Facial Grading System for diagnosing facial palsy*

With the *Sunnybrook Facial Grading System,* the face was rated in three areas by comparing the affected side of the face with the intact side. This resulted in three values: (1) *Resting Symmetry Score* (symmetry at rest), (2) *Voluntary Movement Score* (symmetry of voluntary movements) and (3) *Synkinesis Score* (synkinesis). From these three scores a *total score* (0-100 points) was calculated. The lower the *total score*, the more pronounced the facial paresis respectively paralysis. The authors did not give any recommendation for a further classification into degrees of severity or from which point value the diagnosis *facial palsy* is actually made [52] [53]. For the present study, however, an unambiguous diagnosis of the presence of a facial paresis seemed indispensable to classify the participants into the appropriate target or control group (with or without facial paresis). The severity classification of the present study was therefore based on the procedures of *House Brackman Facial Nerve Grading System* [79]and *Facial* *Nerve Grading System 2.0* [55]. For these measuring instruments, the total value to be achieved is divided into six groups or grades (degree I: normal function up to degree VI: total paralysis) [79] [55]. This classification was also used in the present work. For this purpose, the maximum *total score* (100 points) to be achieved in the *Sunnybrook Facial Grading System* was divided by six and thus into six equally sized areas (100-84 points: normal function, no facial paresis; 83-67: light facial paresis; 66-50 moderate facial paresis; 49-33 medium facial paresis; 32-16 severe facial paresis; 15-0 complete facial paresis respectively paralysis). After the *total score* hasbeen evaluated by the logopaedic examiner, the severity level could be determined. According to this definition a facial paresis from grade II (≤83 points) was presented. This in turn implied an admission of a natural portion of asymmetry in the face and is consistent with previous research [82].

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