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I spy with my little eye:

The detection of changes in emotional faces and the influence of facial feedback in Parkinson's disease

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Abstract

Background: Parkinson's disease (PD) is a progressive neurodegenerative disorder that affects the motor system but also involves deficits in emotional processing such as facial emotion recognition. In healthy participants, it has been shown that facial mimicry, the automatic imitation of perceived facial expressions, facilitates the interpretation of the emotional states of our counterpart. In PD patients, recent studies revealed reduced facial mimicry and consequently reduced facial feedback, suggesting that this reduction might contribute to the prominent emotion recognition deficits found in PD.

Methods: We investigate the influence of facial mimicry on facial emotion recognition. Twenty PD patients and 20 healthy controls (HC) underwent a classical facial mimicry manipulation (holding a pen with the lips, teeth or non-dominant hand) while performing an emotional change detection task with faces.

Results: As expected, emotion recognition was significantly influenced by facial mimicry manipulation in HC further supporting the hypothesis of facial feedback and the related theory of embodied simulation. Importantly, patients with PD generally and independent from the facial mimicry manipulation were impaired in their ability to detected emotion changes. Our data further show that PD patients facial emotional recognition abilities are completely unaffected by mimicry manipulation, assuming that PD patients cannot profit from an artificial modulation of the already impaired facial feedback.

Conclusions: These findings suggest that it is not the hypomimia and the absence of the facial feedback per se, but a disruption of the facial feedback loop, which leads to the prominent emotion recognition deficit in PD patients.

Introduction

Parkinson's disease (PD) is a progressive neurodegenerative disorder. During the course of the disease, the loss of dopaminergic neurons in the substantia nigra pars compacta causes the prominent motor symptoms of PD, comprising bradykinesia, rigidity, postural instability and rest tremor(1). These motor symptoms result in difficulties and limitations in daily routines. Among these motor symptoms, facial bradykinesia circumscribes impairments in emotional, spontaneous as well as voluntary facial movements(2). Facial bradykinesia is often perceived as 'masked face' (hypomimia) and significantly influences the quality of life and social well-being(3, 4). Apart from these impairments in self-expressing emotions by facial movements, patients with PD experience difficulties in perceiving and recognizing emotional expressions(5). Previous studies reveal that, in contrast to healthy controls, PD patients are impaired in the explicit categorization of emotional expressions in faces(6, 7) (for a review see (3)). These difficulties in facial emotion recognition have already been associated with problems of facial mimicry as a result of facial bradykinesia(8).

The link between facial mimicry and the recognition of facial expressions of others plays an important role in theories of embodied simulation. According to such theories, emotional expressions are decoded, processed, interpreted and finally understood by simulating them. Thus, when observing emotional expression of others, facial and body gestures are adapted by contracting the corresponding muscles. This simulation occurs automatically and by feedback processes that trigger the simulation of the equivalent motor, somatosensory and affective state(9).

The inter-relation between mimicry and emotional face processing has been repeatedly investigated by actively manipulating the process of mimicry. Using this approach several studies demonstrate that facial mimicry influences the perception accuracy of facial

expressions on a behavioral(10), as well as on an electrophysiological level(11). Further, facial mimicry manipulation affects the change detection of facial expressions(12, 13) and even the automatic unconscious processing of emotional faces(14).

Analogously, in patients with PD is has been shown that the discrimination as well as the recognition of facial expressions of emotions positively correlated with voluntary facial muscle control, supporting the embodied simulation account (15)·(16).

As PD patients frequently exhibit impairments in their mimicry as well as in their recognition abilities of emotional facial expressions, they offer a good model to investigate the influence of facial mimicry on the processing of facial emotions. The present study investigates the influence of facial mimicry manipulation on the detection of changes in emotional expressions in PD patients and in healthy controls. Mimicry manipulation was implemented by different pen holding conditions, as originally described by Strack, Martin and Stepper(17). Holding a pen with the teeth activates the zygomaticus major muscle, which is activated while smiling. In contrast, holding a pen with the lips prevents smiling and instead induces a frown by activating the orbicularis oris muscle. Holding the pen with the non-dominant hand allows free mimicry and thus serves as control condition.

In accordance with previous studies, we expect a general deficit in detecting changes in emotional expressions in patients with PD. Further, we assume that facial mimicry manipulation influences change detection in both healthy controls and patients with PD. In particular, in line with our previous findings(12) we expected happy facial expressions to be perceived sooner (change from neutral expression) and longer (change to neutral expression) while participants hold the pen with their teeth compared to the control hand-condition. In contrast, while holding the pen with the lips, participants will detect sad faces earlier (changes from neutral expressions) and perceive them longer (changes to neutral expressions). Further,

we expect that the deficit of change detection of PD patients will improve with emotion-congruent facial mimicry manipulation. The expected results would further support the embodied simulation account where facial mimicry plays a crucial role in the process of facial emotion recognition. Moreover, they would provide first evidence that reduced facial mimicry in PD patients highly contributes to the prominent emotion recognition impairments.

Materials and methods

Participants

Forty-six participants (24 PD patients, 22 healthy controls, HC) took part in the study. All participants were recruited from the Department of Neurology at the University of Magdeburg. Groups were matched for sex, age and educational level. PD patients were diagnosed with idiopathic Parkinson's by a neurologist of the department. All participants completed the Beck Depression Inventory-II (BDI-II) (18) and the German version of the Snaith-Hamilton-Pleasure Scale (SHAPS- D(19)). Exclusion criteria for the present study included any reported psychiatric or neurological disease other than PD, BDI-II scores above 19 and SHAPS-D scores greater than two. Six participants were excluded from analysis due to scores exceeding the BDI-II cut-off threshold for mild depressive symptom (one HC, three PD) or exceeding ± 2 standard deviations from the mean level of the group in the main task (one HC, one PD). This resulted in 20 participants for each group. Table 1 shows demographic and clinical characteristics for both groups. All participants had normal or corrected to normal vision. All patients remained on their prescribed dopaminergic medication and were tested during the ON state of their medication cycle. The local Ethical Committee of the University Magdeburg approved the experimental procedures. All participants were naïve to the aim of the study and

provided informed consent. The study was conducted in accordance with the Declaration of Helsinki.

– Please insert Table 1 here –

Stimuli and procedure

Visual stimuli consisted of 24 different characters (12 female, 12 male) each displaying three different emotional expressions (neutral, happy, sad) taken from the Karolinska face database(20). To control for low-level visual influence the hair region was cut off and the background of all images was gray scaled. Additionally, mean luminance and contrast of all images was equalized with the SHINE toolbox for MATLAB(21). For each character, six different emotional change sequences were created with java psychomorph (version 6(22)). These emotional change sequences included 40 frames each of morphs from neutral to happy, happy to neutral, neutral to sad and sad to neutral facial expressions for quantitative changes and changes from happy to sad and sad to happy facial expressions for the qualitative changes. The experimental procedure consisted of 144 different morph sequences (24 characters x 6 emotional change sequences). Visual stimuli were presented on a computer screen (Samsung SyncMaster SA450, 22') located in front of the observer at a viewing distance of 90cm.

Facial mimicry manipulation was conducted following Strack, Martin and Stepper(17) by applying three different pen holding conditions. Holding a pen with the teeth innervates facial muscles activated while smiling, while holding the pen with lips inhibits those facial muscles and instead activated the the orbicularis oris muscle used for frowning. Holding the pen with the non-dominant hand allows free mimicry and serves as a control condition.

After experimental instructions and completing questionnaires, participants sat in a comfortable chair in a dimly lit room. To investigate the influence of facial mimicry on the detection of emotional changes, participants underwent the different pen holding conditions in pseudorandomized order in three separate blocks. Each block consisted of a familiarization task and the emotional change detection task. In the familiarization task, emotional faces were introduced to the observer to exclude any novelty effects during the emotional change detection task. Eight different characters (four female) were randomly presented, each displaying all three emotional expressions resulting in 24 trials. Participants had to indicate the emotional expression of a face by pressing one of three colored keys that matched one of the displayed labels under the face (three-forced-choice response format, see Figure 1). The subsequent emotional change detection task consisted of 48 morph sequences (six possible emotional changes, eight characters), with randomly selected order of morph sequences within each block. The playback of these sequences was self-paced – by pressing the space bar participants navigated forwards through the morph sequences. Each morph sequence comprised 40 frames and with every button press the initial emotion changed stepwise into another one. As soon as a change of the initial emotional expression was detected, participants pressed the enter button. Subsequent to this change detection, participants had to indicate the initial and the end emotion of the previously displayed morph sequence by pressing one of the three corresponding colored keys. After this, the next trial started (see Figure 1).

The familiarization task and the emotional change detection task were available in four different versions, pseudorandomly assigned between the participants. The versions of the familiarization and the emotional change detection task differed in key allocations to the emotional labels and the assignment of characters to the different blocks.

– Please insert Figure 1 here –

Data analysis

Statistical analyses were performed with IBM SPSS-Software 26. In order to investigate the differential influence of facial mimicry manipulation (FMM) on the ability to detect changes of facial emotional expressions between PD patients and the control group, results of the quantitative (changes from neutral to happy, happy to neutral, neutral to sad and sad to neutral) and qualitative (changes from happy to sad and sad to happy) morph sequence changes were analyzed separately. We averaged the frame number at which the emotion change was detected, separately for each participant and morph sequence. For the quantitative morph sequences these numbers were entered into a repeated measures (RM)-ANOVA with within-participant factors facial muscle manipulation *FMM* (hand vs. lips vs. teeth) and *morph sequence* (neutral – happy vs. happy – neutral vs. neutral – sad vs. sad – neutral) and the between-participant factor *group* (HC vs. PD). Analogously, the critical frame numbers of qualitative morph sequence were analyzed with the within-subject factors *FMM* (hand vs. lips vs. teeth) and *morph sequence* (happy – sad vs. sad – happy) and the between-subject factor *group* (HC vs. PD). In case of sphericity violations, data were Greenhouse-Geisser adjusted. Significant interactions were further examined using paired *t* tests. In order to further confirm the absence of an effect, we provide confidence intervals (CI) for the differences between the tested means for the emotional change detection task. The CIs provide information whether H_0 can be rejected or whether it should be retained. Granted that the CI did not entail the value of zero effect (0) H_0 can be rejected, conversely, if the calculated CI includes 0 we can assume that the treatment has no effect of practical importance(23, 24). Additionally, to further confirm the absence of

an effect in PD, we performed Bayesian Repeated Measures ANOVAs with the two within-subjects factors FMM and morph sequence, using JASP(25).

Quantitative morph sequences

The results of the quantitative morph sequences are depicted in Figures 2A and 3. (for complete statistic see Table S1-S7). RM-ANOVA revealed a significant *group* effect ($F_{1,38} = 21.674$, $P < .001$, $\eta_p^2 = 0.363$) due to more frames required for change detection for PD patients ($M = 26.54$, $SE = 0.84$) compared to the control group ($M = 20.93$, $SE = 0.86$, $t(19) = -4.073$, $P = .001$, $d = -1.247$, 95%$CI = -8.491 <= \mu_1 - \mu_1 <= -2.727$) (see Figure 2A).

– Please insert Figure 2 here –

Most importantly, the ANOVA showed a significant *FMM* x *morph sequence* x *group* interaction ($F_{3.502,133.062} = 4.849$, $P = .002$, $\eta_p^2 = 0.113$). To further examine the significant *FMM* x *morph sequence* x *group* interaction two additional 3 (*FMM*) x 4 (*morph sequence*) RM-ANOVAs were conducted for HC and PD patients separately. Notably, only HC showed a significant interaction between *FMM* and *morph sequence* ($F_{2.181,41.432} = 8.341$, $P = .001$, $\eta_p^2 = 0.305$), while this interaction effect was absent for PD patients ($F_{6,114} = 0.672$, $P = 0.672$, $\eta_p^2 = 0.034$) (see Figure 3). In particular in HC, for neutral – happy morph sequences, holding the pen with the lips ($M = 14.99$, $SE = 1.08$) significantly increased the detection time for happy faces compared to the hand ($M = 12.39$, $SE = 0.94$, $t(19) = -2.804$, $P = .011$, $d = -0.573$, 95%$CI = -4.541 <= \mu_1 - \mu_1 <= -0.659$) and teeth condition ($M = 10.62$, $SE = 1.15$, $t(19) = 4.684$, $P <$

.001, d = 0.876, 95%CI = 2.417 <= μ_1 - μ_1 <= 6.321), while holding the pen with the teeth significantly decreased detection time of happy faces compared to the hand condition (t(19) = 2.563, P = .019, d = 0.376, 95%CI = 0.325 <= μ_1 - μ_1 <= 3.213)(see Figure 3A). In contrast, when happy faces changed to neutral faces, the lip condition (M = 24.29, SE = 1.32) significantly decreased change detection time compared to the hand (M = 27.76, SE = 1.28, t(19) = 2.835, P = .011, d = 0.597, 95%CI = 0.909 <= μ_1 - μ_1 <= 6.041) and teeth condition (M = 27.73, SE = 0.97, t(19) = -2.766, P = .012, d = -0.663, 95%CI -6.038 <= μ_1 - μ_1 <= -0.837)(see Figure 3B). Further, change detection for sad – neutral morph sequences was significantly increased while participants held the pen with the lips (M= 25.89, SE = 1.53) compared to holding the pen with the teeth (M = 22.17, SE = 1.83, t(19) = 2.786, P = .012, d = 0.493, 95%CI = 0.926 <= μ_1 - μ_1 <= 6.524) (see Figure 3D). In contrast, as shown in Figures 3E-H, facial feedback manipulation was absent in the PD group. Bayesian analysis revealed substantial evidence for the absence of an interaction between these two factors, (BF=0.023) (for complete Bayesian statistic see Table S5).

– Please insert Figure 3 here -

In summary, HC generally outperformed PD patient in their ability to detect changes of facial emotional expressions. Additionally, HC showed the expected effect of facial muscle manipulation on the emotional change detection for the presented quantitative morph sequence, while there was no effect in patients with PD (see Figure 3 and Table S6).

Qualitative morph sequences

Figures 2B and 4 illustrate the results of qualitative morph sequences (for complete statistic see Table S8-S11). As for the quantitative morph sequences, analysis revealed a significant *group* effect ($F_{1,38}$ = 8.275, P = .007, η_p^2 = 0.179), due to more sequences required for change detection for PD patients (M = 25.49, SE = 0.79) compared to healthy controls (M = 22.21, SE = 0.82, $t(19)$ = -2.838, P = .011, d = -0.91, 95%, CI = -5.705 <= μ_1 - μ_1 <= -0.862) (see Figure 2B). Most notably, the interaction between *FMM* X *morph sequence* X *group* reached significance ($F_{2,76}$ = 4.018, P = .022, η_p^2 = 0.096). In order to examine this interaction effect, two separate ANOVAs with *FMM* and *morph sequence* as within-subject factors were conducted, separately for HC and PD participants. Again, while an interaction effect was absent for PD ($F_{2,38}$ = 0.792, P = 0.460, η_p^2 = 0.040, BF=0.16, indicating strong to moderate evidence for the absence of an interaction (for complete Bayesian statistic see Table S10) (see Figure 4C, D), there was a significant interaction between *FMM* and *morph sequence* in the control group ($F_{2,38}$ = 3.529, P = .039, η_p^2 0.157). This interaction effect was driven by the influence of *FMM* on happy – sad morph sequences: compared to the lips condition (M = 24.14, SE = 1.18) emotional changes from happy to sad faces were detected later in the teeth condition (M = 26.97, SE = 1.20, $t(19)$ = -2.812, P = .011, d = -0.53, 95%CI = -4.940 <= μ_1 - μ_1 <= -0.724)(see Figure 4A).

– Please insert Figure 4 here –

In summary, results demonstrate that emotional change detection in healthy controls is systematically influenced by facial muscle manipulation. During the lip-condition, changes from neutral to happy and sad to neutral were detected later, while changes from happy to

neutral expressions were detected earlier. Analogously, during the teeth condition changes from neutral to happy were detected earlier and changes from happy to sad expressions later. In contrast, patients with PD generally detected emotional changes in facial expressions later and -importantly- their emotional change detection was completely unaffected by facial mimicry manipulation.

Discussion

The correct interpretation of emotional facial expressions forms an essential aspect of human social interactions and is partly implemented by imitating the perceived emotional expression (facial mimicry). The resulting facial feedback activates related affective and cognitive mental states(26).

In the present study, we demonstrate the systematic impact of facial mimicry manipulation on healthy participants' ability to recognise emotional facial expressions, supporting the facial feedback hypothesis and the related theory of embodied simulation. Additionally, we showed that patients with PD generally and independently of the facial mimicry manipulation, are impaired in their ability to detected emotion changes. Finally, our data show that PD patients' facial emotional recognition abilities were completely unaffected by mimicry manipulation, assuming that PD patients cannot profit from an artificial modulation of their already impaired facial feedback.

Our results are generally consistent with several studies showing that PD patients have deficits in the recognition and processing of facial emotional expressions(3, 5, 27). An impaired dopamine transmission in the limbic system of the midbrain has been assumed to explain these deficits in the recognition of facial emotions in PD. In particular, amygdala impairments that

can bee seen from the early stages of disease progression might explain these emotional deficits (for a detailed review see Argaud et al.(3)). It might be worth mentioning that emotion recognition deficits in PD have been related to dopaminergic medication as well. However, results are inconsistent with some studies reporting detrimental effects(28, 29) while others show beneficial effects of L-Dopa on emotion recognition(30, 31), suggesting that L-Dopa partially restores amygdala response but in dependence of disease progression(32). Furthermore, also malfunctioning neural synchronizations within and between the basal ganglia have been discussed as a neurophysiological underpinning of these deficits in PD(33). Finally, impaired emotion recognition in PD patients has been also repeatedly related to a reduced facial emotional expressivity (spontaneous as well as controlled)(15, 16, 34, 35). Thus, the emotion recognition impairments observed in patients with PD might partially result from missing facial feedback. If this were the case, the specific facial mimicry manipulation used in the present study should enhance facial feedback in PD patients and by this improve their recognition of congruent facial emotions. Interestingly, in the present study we show that facial mimicry manipulation influenced the change detection only in healthy controls, but not in PD patients. The performance of PD patients was completely unaffected by mimicry manipulation. This unexpected effect clearly suggests that in PD, not only facial mimicry itself, but also further aspects of facial feedback processing are impaired, so that facial feedback information cannot be further processed. This implies a disruption of the facial feedback loop. Apart from the classical brain regions involved in the processing of facial expressions of emotions (e.g., amygdala, insula and limbic system(36)) theories of embodied simulation assume that the simulation process activates a network of multiple neural regions. A possible mechanism is provided by a specialized mirror neuron system (MNS)(37-39). Neurophysiological and brain-imaging studies suggest that the human MNS is located within a fronto-parietal MNS network(40). Importantly, recent data demonstrate that PD patients show impaired activation

of this MNS during the processing of facial expressions(41) and consequently link impaired emotion recognition in PD to this hypo activity in the fronto-parietal MNS network. Apart from the fronto-parietal MNS, also the somatosensory cortex (especially the right somatosensory cortex) is involved in facial expression recognition(42-44). It is assumed that the generated proprioceptive feedback is transmitted to and processed within the somatosensory cortex(45). Accordingly, the somatosensory cortex allegedly plays an important role in understanding the facial expressions of others, potentially by simulating emotional expressions and experiencing the emotional states of others(46). One assumption is that while observing facial emotional expressions the activation of congruent facial muscles may lead to an activation of somatosensory representation of the emotional states related to those facial movements(47). Interestingly, in PD patients, during facial emotion recognition, brain potentials to fearful faces were not generated within amygdala and visual cortex as they are in healthy controls, but within the somatosensory cortex(48, 49). The authors assume that this somatosensory activity represents a compensatory mechanisms that would also account for diminished visual discrimination while late cortical evaluative processes are intact in PD(50). An unimpaired emotion recognition with simultaneous compromised early visual discrimination could be suggestive of compensatory functions of the somatosensory, premotor and prefrontal areas. Altogether, these studies are in favor of an intact functioning or rather an overfunctioning of the somatosensory cortex in patients with PD. Thus, consequently, the missing facial mimicry manipulation effect in PD patients in the present study is probably not a result of an absent processing of the facial feedback signal within the somatosensory cortex. However, in contrast to the present research, the studies by Yoshimura, Kawamura, Masaoka and Homma(48) and Wabnegger et al.(49) investigated only negative emotions and the latter study only included patients in the OFF dopaminergic state. Additionally, both studies report no impairments of emotion recognition in their patient group whereas we found a clear impaired performance in

the detection of emotional changes in PD patients. Thus, further studies are necessary to investigate the processing within the somatosensory cortex during facial emotion recognition.

Finally, the facial feedback loop might be also disrupted at a processing stage where the integration of the visual information and the facial feedback information takes place. The process of multisensory integration involves the integration of complex sensory information of different modalities into a unique percept(51). It has been demonstrated that the basal ganglia play a pivotal role in this integration process(52). As basal ganglia undergo considerable structural changes due to loss of dopaminergic neurons in substantia nigra in PD(1) it is not surprising that PD patients have difficulties in multisensory integration processes(53-55). Accordingly, following the result of the present study we assume that the degeneration of dopaminergic neurons in the basal ganglia results in a modified integration process of the facial feedback that potentially explains the lacking influence of facial feedback on emotional change detection in PD. However, future studies are needed with focus on this assumption.

It should be mentioned that a recent multi-lab study provided strong evidence that facial mimicry can amplify and initiate feelings of happiness, supporting the hypothesis that facial feedback is one component of the peripheral nervous system contributing to emotional experience (56). Importantly, under more liberal inclusion criteria, this study also provided strong evidence of a facial feedback effect in the pen-in-mouth task. However, the effect in the pen-holding task was substantially smaller than under free facial mimicry or facial action conditions. The authors assume that this attenuation might be related to the fact that inferential processes are minimized in the pen task or that pen-in-mouth manipulations create less prototypical emotional expression. Accordingly, a more direct facial feedback manipulation – mimicking facial expressions (facial mimicry) or voluntary facial action - may well have been able to induce a facial feedback effect in the patients as well.

Taken together, the present results confirmed that PD patients have difficulties to detect emotional changes in facial expressions. Furthermore, we affirmed that facial mimicry manipulation systematically influences emotional change detection in healthy controls. Moreover, we demonstrate for the first time, that in patients with PD emotional change detection was completely unaffected by facial mimicry manipulation. These data indicate that it is not the hypomimia and the absence of the facial feedback per se, but a disruption of the facial feedback loop, which leads to this prominent deficit in these patients. As the reduced facial mimicry as well as the impairment of emotion recognition considerably influence the social well-being and the quality of life of those patients further studies are indispensable to investigate the facial feedback processes in PD.

Data availability

The data that support the findings of this study are openly available in OSF at https://osf.io/tjbzk/?view_only=9c4c3623312546e9b70f81a2807c143a.

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Tables

Table 1: Sample characteristics of Parkinson's disease patients and healthy controls

	Parkinson's Disease (n = 20, 10 female)	Healthy controls (n = 20, 10 female)
Age (years)	70.85 ± 6.7	69.75 ± 5.02
BDI-II[a]	8.7 ± 4.59	5.7 ±4.46
SHAPS-D[b]	0.45 ±0.80	0.11 ± 0.31
Disease Duration (years)	13.3 ± 16.83	
LED (mg)[c]	543.75 ± 222.35	

[a]Beck Depression Inventory. [b]German version of the Snaith-Hamilton-Pleasure-Scale. [c]daily levodopa dose equivalent.

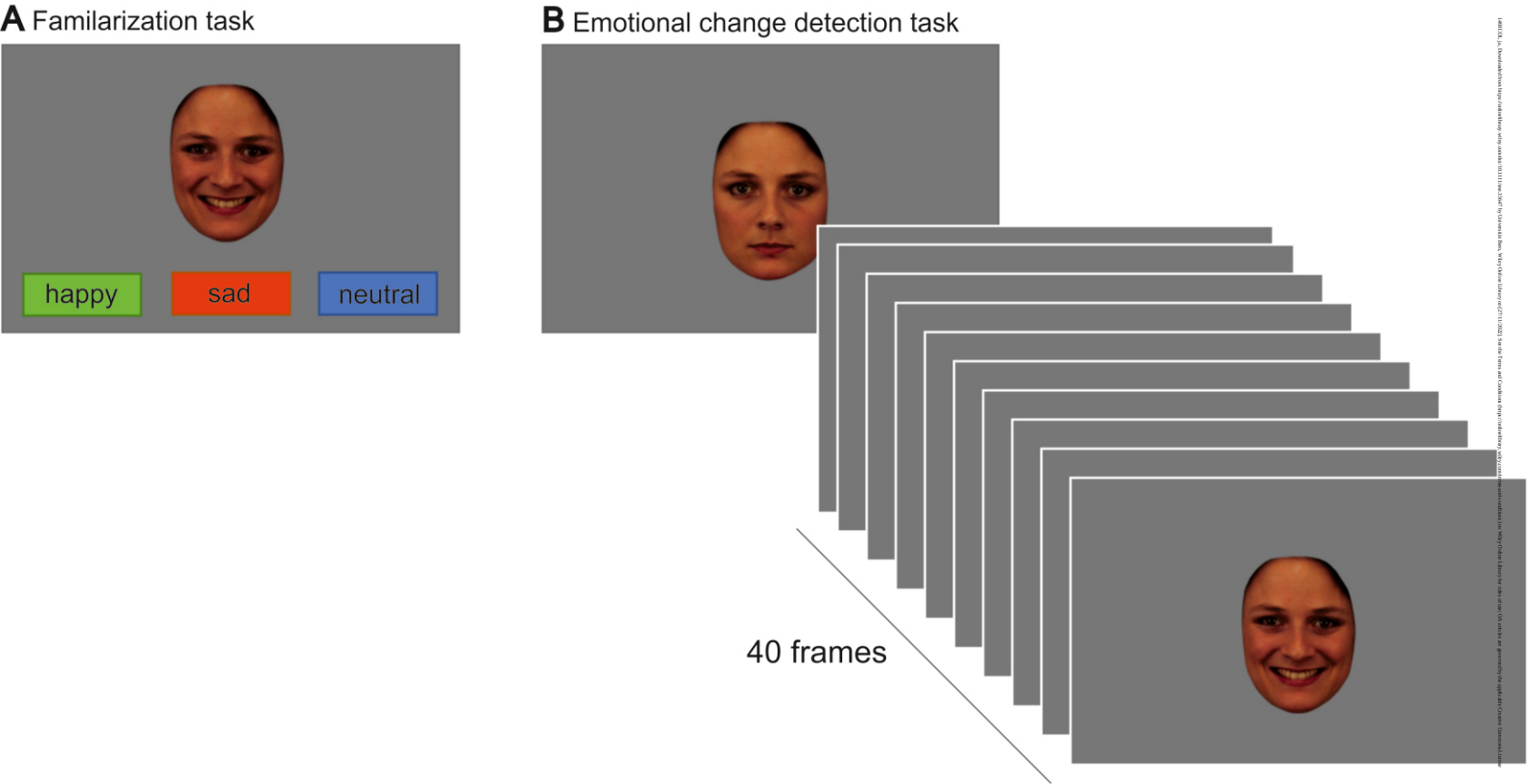
Figure legends

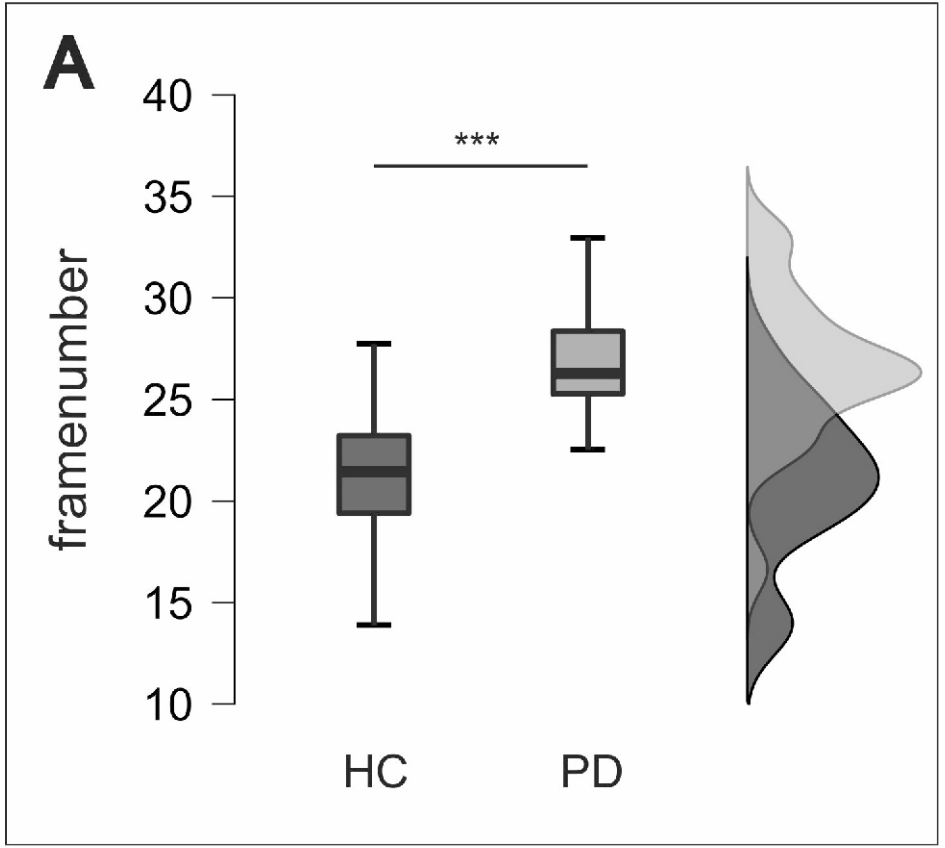
Figure 1: Trial procedure for one block. Each block started with a familiarization task (**A**). During this task, facial stimuli were introduced to the participants, who indicated the presented emotion by pressing one of three colored keys of the keyboard. The familiarization task was followed by the emotional change detection task (**B**). Here participants saw a face whose emotional expression slightly changed into another emotion by each pressing of the space bar. Whenever the initial emotion changed into a new emotion they pressed the enter key and the next trial started.

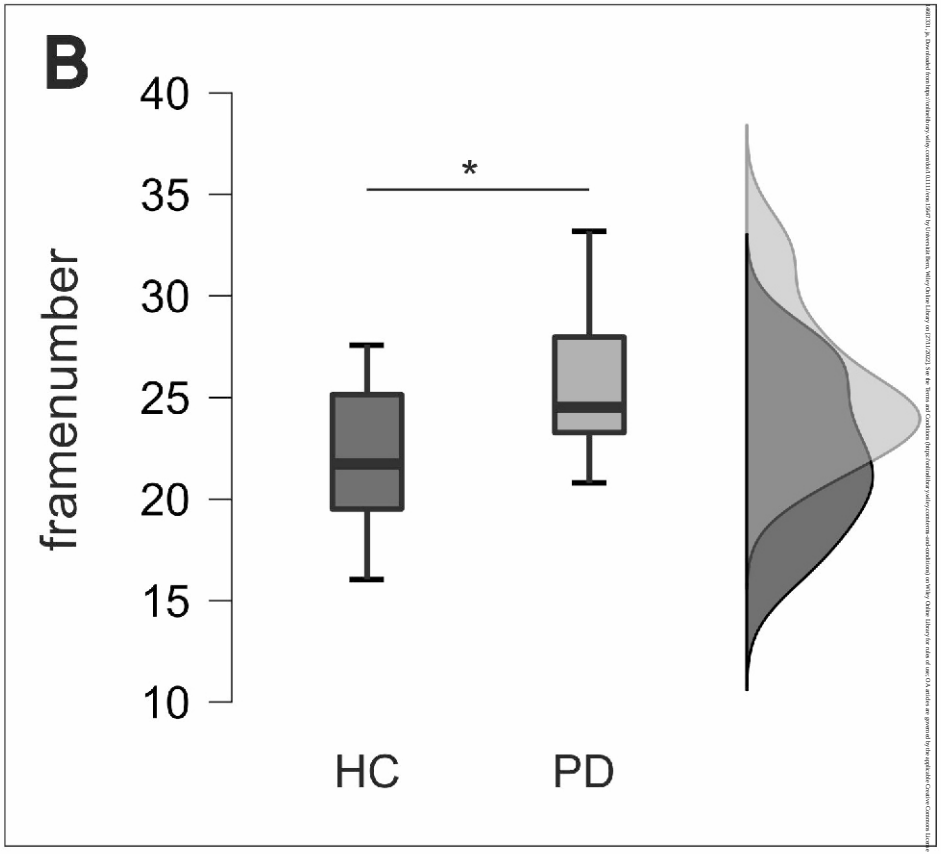
Figure 2: Box plots for (A) quantitative and (B) qualitative morph sequences. Group effect: Parkinson's disease patients need significantly more frames to detect emotional change. *** $p \leq .001$, * $p < .05$.

Figure 3: Boxplots of quantitative morph sequences for healthy controls (A-D) and Parkinson's disease patients (E-H). (**A-D**) The ability to detect changes in facial emotional expressions was significantly influenced by the different mimicry conditions. (**E-H**) Facial mimicry manipulation did not influence the detection change of facial emotional expressions in Parkinson's disease patients. grey – hand, orange – lip, blue – teeth condition, *** $p \leq .001$, * $p < .05$

Figure 4: Boxplots of qualitative morph sequences for healthy controls (A, B) and Parkinson's disease patients (C, D). (**A**) The teeth condition significantly increased the perception of happy faces compared to the lip condition. **(B)** There was no influence of facial mimicry manipulation for sad – happy morph sequences. (**C, D**) Parkinson's disease patients did not have any influence of facial muscle manipulation during the emotional change detection task of qualitative morph sequences. *p < .05


A Familarization task
happy
sad
neutral
B Emotional change detection task
40 frames


A
framenumber
40
35
30
25
20
15
10
***
HC
PD


B
framenumber
40
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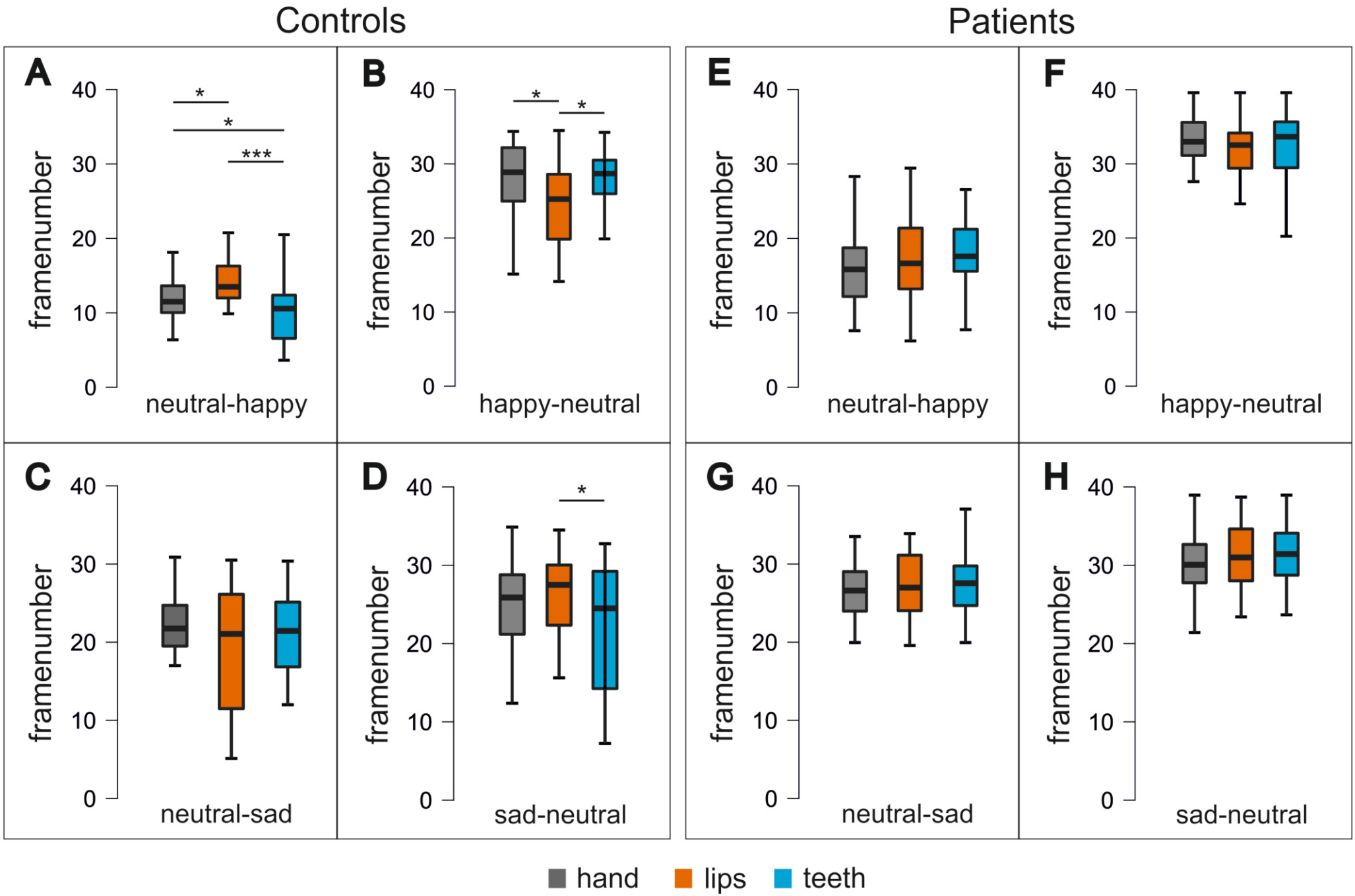
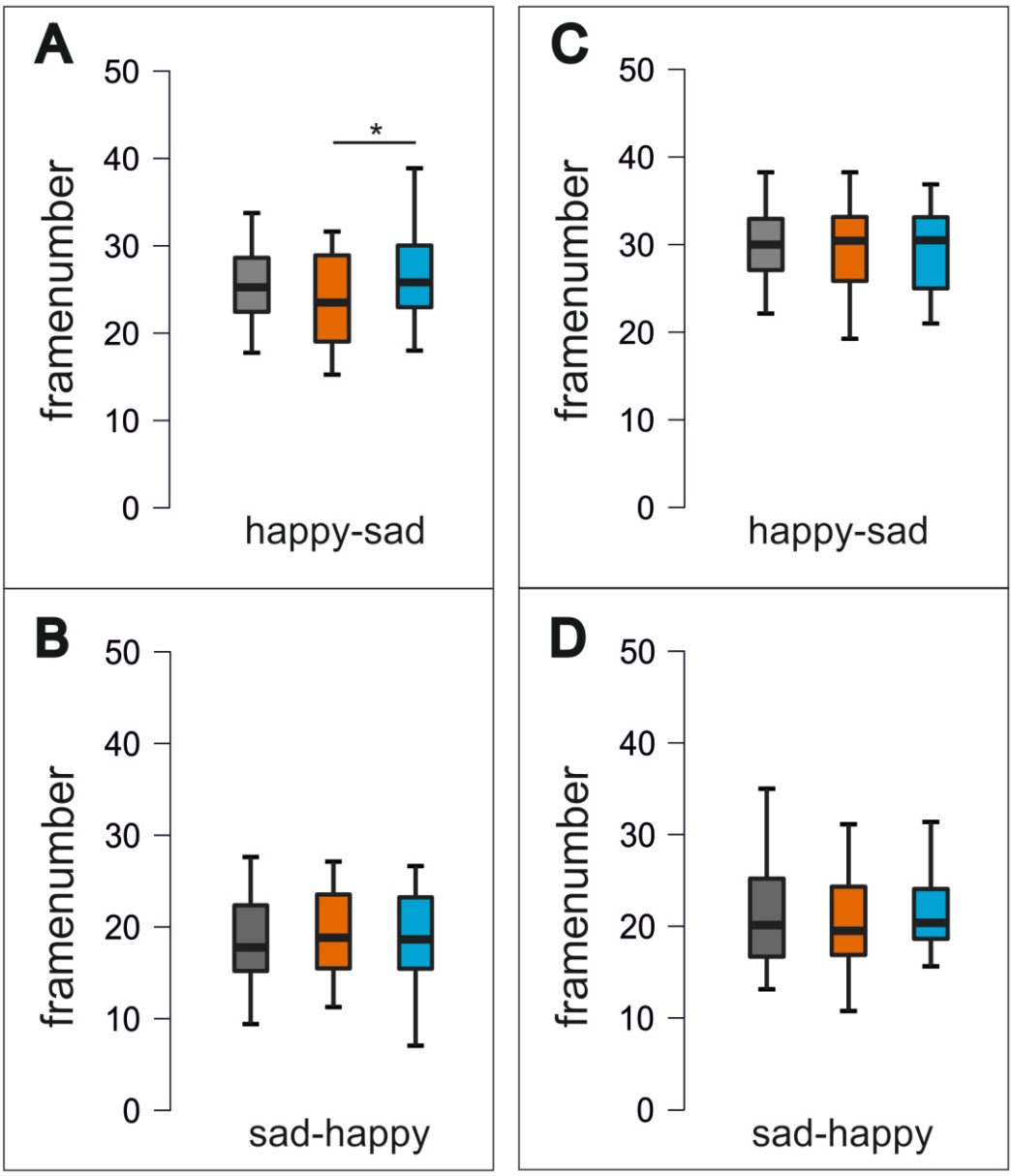
HC
PD





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PD: Parkinson´s Disease

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