Video-based Analysis of the Blink Reflex in Parkinson’s Disease Patients

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Abstract

We developed a video-based tool to quantitatively assess the Glabellar Tap Reflex (GTR) in patients with idiopathic Parkinson's Disease (iPD) patients as well as healthy age-matched subjects. We also video-graphically assessed the effect of dopaminergic medication on the GTR in iPD patients, as well as frequency and velocity of reflex and non-reflex blinks. The Glabellar Tap Reflex is a clinical sign seen in patients e.g. suffering from iPD. Reliable tools to quantify this sign are lacking.

Methods: We recorded the GTR in 11 iPD patients and 12 healthy controls (HC) with a high-speed camera and a framerate of at least 180 images/s. In these videos, reflex and non-reflex blinks were analyzed for blink count and velocity in an automated fashion.

Results: With our setup, the GTR can be extracted from high-resolution cameras using landmarks of MediaPipe face algorithm. iPD patients did not habituate to the GTR; dopaminergic medication did not alter that response. iPD patients’ non-reflex blinks were higher in frequency and lower in velocity (mean width); dopaminergic medication decreased the frequency and increased the velocity – both in the direction of HC.

Conclusion: We developed a quantitative, video-based tool to assess the GTR and other blinking-specific parameters in HC and iPD patients. Further studies could compare the video data to electromyogram (EMG) data for accuracy and comparability, as well as evaluate the specificity of the GTR in patients with other neurodegenerative disorders, in whom the GTR can also be present.

Significance: The video-based detection of the blinking parameters allows for unobtrusive measurement in patients, a safer and more comfortable option.

1. INTRODUCTION

Idiopathic Parkinson's Disease (iPD) is the most frequent movement disorder and severely affects the patients’ quality of life [1]. Worldwide, 6.1 million individuals suffered from iPD in 2016 [2]. The prevalence increases with age, reaching a maximum in the age group between 80 to 84 years [3]. Patient numbers continue to rise due to the demographic changes. IPD is a chronic progressive disorder: drugs to treat symptoms are available but treatments to stop disease progression are lacking.

IPD patients typically present pathological ways of blinking. Abnormalities are found in the blink rate, reflexive blinking, as well as the voluntary saccades {Agostino, 2008 #21} PMID 18175339. Physiologically, spontaneous blinking is mainly operated by contraction of the orbicularis oculi muscle via facial nerve innervation and simultaneous relaxation of the levator palpebrae muscle {Deuschl, 1998 #9}.

In healthy individuals, blinking occurs with a frequency of 15 to 20 per minute. IPD patients typically show a lower blink rate, often associated with xerophthalmia [4–7], a dryness of the eye which iPD
patients frequently suffer from. However, it has been suggested that iPD patients can be divided into two
groups: one with a low-blinking-rate (mean 5.1 / min) and one with a paradoxically high-blinking-rate
(mean 52.8 / min), which is assumed to be a form of off-state dystonia [8]. While blinking in iPD patients
is typically hypokinetic (low blink rate), bradykinesia (in form of decreased velocity and amplitude) does
not seem to be prevalent [9].

IPD patients also often present with a pathological glabellar tap reflex (GTR). The terms blink reflex (BR),
nasopalpebral reflex, orbicularis oculi reflex, or glabellar tap sign are often used synonymously [10]. The
reflex, first described by Overend in 1896 [11], is a brain stem reflex for protection of the eyes that is
physiologically found in neonates and can be disinhibited due to cerebral impairment as iPD disease [10, 12, 13].

Clinically the GTR presents as reflexive blinking of both eyes in reaction to a light haptic stimulus of the
labellar region, as well as acoustic, optic, or painful stimuli [14, 15].

Electrophysiologically the GTR can be sectioned into an initial proprioceptive and a later nociceptive
component, both of which present as a blink [14]. Electrical stimulation of the ophthalmic nerve creates
an impulse through pons and facial nucleus to the ipsilateral facial nerve; its stimulation causes
contraction in the orbicularis oculi muscle, which can be measured electromyographically, resulting in a
blink [13]. With a latency of 10 to 15ms the ipsilateral R1-response occurs [14, 15]; it is considered
proprioceptive and oligosynaptic [15]. The R2-response follows after a latency of 30 to 35ms as a result
of spinal afferences of the trigeminal nerve that send impulses via formatio reticularis to both nuclei
faciales bilaterally [13]; this component of the GTR is nociceptive and polysynaptic [15]. It is considered a
defensive reflex response to a potentially painful stimulus [14, 15].

Healthy subjects usually habituate to the GTR after the fourth tap [15]. Electromyographically this is
characterized as an increased latency and decreased amplitude of the R2-response [15]. The habituation
might be caused by a decreasing inhibition of the musculus levator palpebrae [16]. Blinking after up to 5
[10], 10 [12], or even 15 taps [17] in response to the glabella tap is considered as adaptation or
habituation in the literature, that means, the Glabella tap reflex is not present.

IPD patients show an increased and prolonged proprioceptive and nociceptive re-action, as well as a lack
of habituation of the nociceptive component [15]. This might be due to a decreased dopamine-inhibition
of the striatum, as dopaminergic nigrostriatal pathways play a role in suppressing nociceptive reflexes
[18]. The continued inhibition of the levator palpebrae muscle might be a result of the substantia nigra's
involvement in the pathogenesis of abnormal eye movement, such as involuntary inhibition of the levator
palpebrae muscle [19].

During a task where concentration on visual input is required, the rate of spontaneous blinks decreases in
order to allow continued visual input during voluntary saccades [20]. In iPD patients, the inhibition of
blinks during voluntary saccades is decreased. Globe et al. even showed an increase in blinking
frequency in iPD patients when they were asked to perform a task that required concentration [21].
Non-contact sensing modalities using cameras have emerged in the past with tremendous success in recent years [22]. These modalities could complement or even replace some of the existing contact-based technologies in the near future. Contactless measurements grant more comfortable diagnostics for patients [23]. Unobtrusive, camera-based technologies have been successfully used various fields, e.g. in vital sign detection in neonates [23] but also in neurodegenerative disorders such as progressive supranuclear palsy (PSP) and the detection of tremor in iPD patients [24, 25].

In this work, we established an algorithm which was able to detect the blink reflex in video recordings. The algorithm was able to detect the “tap” and the “blink” in the classic blink reflex maneuver, as well as provide further information on blink count and velocity. The video-based method can now be used to investigate the GTR in iPD patients and HC to gain further insights into the phenomenon of GTR habituation.

2. METHODS

2.1. Participants

Twelve healthy subjects, termed HC, of both sexes (7 females (58%) and 5 males (42%)) aged 53–84 years (mean 65.7 years) were enrolled. Informed consent was obtained from all participants. Extended participant information is given in Table 1.

Eleven patients with clinically unquestionable iPD (4 females (36%) and 7 males (64%)) aged 52–83 years (mean 66.2 years) participated in the study (see Table 2 for extended information). The patient cohort showed good response to L-Dopa treatment.

Data of two patients and one participant had to be excluded from the analysis as the examiner’s finger was in the glabellar region (within camera frame) throughout the experiment, blocking the automated tap detection.

Disease duration ranged from 3 to 20 years (mean 10 years). The average Hoehn and Yahr (H&Y) stage, a scale including five stages estimating disease severity, was 2.5. The patients scored with a mean of 37.9 points in Part III of the Unified Parkinson's Disease Rating Scale (UPDRS) (min. 22, max. 73). The UPDRS is a multiscale clinical score to describe iPD symptoms severity widely used in iPD research. While scales within the UPDRS describe several symptoms, e.g. non-motor symptoms, part III focuses on motor symptoms. All patients were in-house patients of the University Hospital Aachen enrolled in a 3-week rehabilitation program. Medication was taken according to the regular, individual scheme. The study is purely observational, and it did not interfere with the clinical treatment. The first video was recorded just before the next regular medication intake, and the second video was 30 minutes after. The mean L-Dopa equivalent daily dose among patients was 770.1 mg. The mean dose taken before the second recording was 113.6 mg.
Table 1
Extended Patient Information

<table>
<thead>
<tr>
<th>Patient</th>
<th>Age</th>
<th>Sex</th>
<th>Years Since Disease Onset</th>
<th>L-Dopa Equivalent Doses (mg) Daily</th>
<th>L-Dopa Equivalent Doses (mg) Before the Second Measurement</th>
<th>H&amp;Y</th>
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<tr>
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<td>67</td>
<td>m</td>
<td>7</td>
<td>600</td>
<td>100</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td>68</td>
<td>f</td>
<td>7</td>
<td>1125</td>
<td>150</td>
<td>2</td>
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<td>m</td>
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<td>725</td>
<td>125</td>
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</tr>
<tr>
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<td>52</td>
<td>m</td>
<td>17</td>
<td>785</td>
<td>75</td>
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</tr>
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<td>57</td>
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<td>10</td>
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<tr>
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<td>71</td>
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<td>837</td>
<td>100</td>
<td>3</td>
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<td>7</td>
<td>500</td>
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<tr>
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<td>f</td>
<td>13</td>
<td>632</td>
<td>133</td>
<td>3</td>
</tr>
</tbody>
</table>
### 2.2. Video Recording

We used a Lumix, GH5, Kadoma, Japan (Participant 1) and a Go-Pro HERO 7, San Mateo, CA, USA (all others). The videos were recorded in slow-motion with at least 180 frames/s). Image processing was performed with Python (Python Software Foundation) and Matlab (MathWorks, Massachusetts, USA).

We recorded the videos while examining the subject’s BR clinically. The subjects were seated in a quiet, temperature-controlled room which was lit by regular artificial light, no special lighting was installed. The subjects were directed to watch straight while the examiner (TJ) approached her index finger from above to the subject’s forehead (outside the visual field to eliminate visual threat as a stimulus) and tapped the region between the eyebrows 5 to 8 times (irregular rhythm, slower than 2 times per second). The examiner was wearing a blue/blue-toned glove on her right hand that helped to distinguish the examiner’s finger from the subject’s forehead. The natural reaction to the BR was recorded in the first video.

For the iPD patients we recorded a second video 30 minutes after intake of their L-Dopa medication.

### 2.3. Data Extraction and Processing

This work aims to track and compare the eye blinking of patients (before/after medication) and HC after finger-tapping to the glabellar region, using an automated video-based approach. In this context, we used the AI-based MediaPipe face mesh [26] algorithm to track the eye blinking and the intervention in the

<table>
<thead>
<tr>
<th>Participant</th>
<th>Age</th>
<th>Sex</th>
</tr>
</thead>
<tbody>
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<td>1</td>
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<td>m</td>
</tr>
<tr>
<td>2</td>
<td>84</td>
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<td>f</td>
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<tr>
<td>11</td>
<td>64</td>
<td>f</td>
</tr>
<tr>
<td>ex1</td>
<td>54</td>
<td>f</td>
</tr>
</tbody>
</table>
The MediaPipe face mesh pipeline uses two network models which collaborate. A detector model works on the input image to compute the face locations and passes the information to the 3D face landmark model which creates the 3D mesh with 468 landmarks from those locations. A representation of 468 landmarks, each of which has three coordinates (x, y, and z), is given in Fig. 1 (d, left).

Based on the MediaPipe face mesh landmarks, we defined two regions of interest (ROIs). (I) The glabellar region was defined based on glabellar landmarks from the face mesh. (II) The eye ROI (left or right, depending on the recording angle) was a rectangular ROI defined by the eyelid landmarks covering the eye (pixel values except the eye were set to zero). From the defined ROIs, the information was extracted throughout the experiment. We used two different approaches for the different ROIs. For the glabellar ROI, the blue channel of the color image was used (The examiner was wearing a blue/blue-toned nitril examination glove while applying the stimuli to make the finger more distinguishable from the skin of the subject's forehead) and the pixels were averaged for all sequential frames to create the one-dimensional (1D) tapping signal. Without intervention by the examiner, the skin of the participant/patient represented the average value. During the intervention, the blue glove caused a higher averaged value, so that we were able to detect the timepoint when the tap to the glabella occurred. Sample images of tracked glabellar ROI with and without intervention are given in Fig. 1 (d).

The landmarks from the face mesh algorithm has the sensitivity to track the eyelids. We used the eye ROI based on the eyelid contours and tracked this ROI for all frames. During the tracking, the number of non-zero pixels was noted for all frames and then reversed to create a 1D signal with positive amplitude. When there was no eye-blink, the number of non-zero pixels was relatively high. During the lid closure, the eye ROI shrank down and led to a lower number of non-zero pixels. A sample image of tracked eye ROI is given in Fig. 1 (d).

**Figure 1.** Experimental Setup: The BR was measured clinically in 12 HC and 11 iPD patients and analyzed with a high-resolution camera. (a) The subjects were filmed at a 45° angle, while the examiner performed the GTR. A blue/blue-toned glove was worn for better discrimination in the video analysis; (b) For the HC one video of the GTR was taken. iPD patients were examined before and 30 minutes after the intake of their standard L-Dopa medication. (c-d) In a next step, MediaPipe face mesh algorithm was used for facial landmarks detection. Based on the facial landmarks we defined two ROIs (Glabellar Region and Eye Region), from which information was extracted throughout the experiment, with which we were able to detect the occurrence of blinks and taps.

Next, the signal was set to a common baseline by applying baseline removal of all 1D signals. Following the baseline correction, data were low-pass filtered at 0.75 Hz cut-off frequency. The frequency was determined empirically, to reduce flickering in illumination. An example of extracted 1D tapping and blinking signals are given in Fig. 2 (a).

**Figure 2.** Example Tapping and Blinking Signal: (a) Tapping and blinking signals are visualized throughout the examination of the GTR. Blue peaks show the tapping of the glabella region on the
examinee’s forehead while red peaks visualize when blinks were detected; (b) In order to differentiate blinks as a response to the tapping of the glabella from other blinks, blinks were divided into two groups: reflex blinks, which occurred in the time frame from 50ms prior to until 200 ms after the tapping signal, and non-reflex blinks in between two consecutive taps, but outside of the afore-noted time range. The velocity was defined as the mean width of each blink, which was calculated at half prominence. a.u. = arbitrary unit.

We defined two different blink categories. (I) The reflex blinks which occurred 50ms before to 200ms after the tapping signal and (II) the non-reflex blinks which occurred between two consecutive taps.

For further blink analysis we defined the width at half of the maximum prominence (half-prominence) and the mean number of reflex/non-reflex blinks was noted. Figure 2 (b) shows the example of reflex and non-reflex signals with the calculation of width at half-prominence.

2.4. Statistical Analysis

Manual curation of each video was compiled in a database (Microsoft Excel version 16.42 [Microsoft, Redmond, Washington, USA]). All computations were performed using MATLAB R2019b, The MathWorks, Natick, MA, USA. Statistical analyses were performed using SPSS 28.0, IBM, Armonk, NY, USA Descriptive statistics were applied. For comparison of two metrical scales, Pearson’s correlation coefficient was employed. Significance was defined as p < 0.05. For the statistical analysis of automated video-based approach, Wilcoxon rank sum test were applied using MATLAB R2022b, setting the significance value as p < 0.05.

3. RESULTS

We developed a video-based method to detect the GTR. Therefore, we recorded the GTR of 12 HC (mean 65.7 years of age) for reference and 11 iPD patients (mean 66.2 years of age) on a high-resolution camera taking at least 180 images per second. This frame rate corresponds to one image every 5.6ms. This section presents the results of blink count and velocity of reflex and non-reflex blinks among the groups, as well as the effect of medication on these parameters in iPD patients.

3.1. IPD Patients Showed no Habituation to the GTR Before or After Medication While HC Habituate After Tap Four

As shown in Table 5, for reflex blinks, there is not much change in the values for the patients between before and after medication cases. However, HC showed a decreasing mean number of reflex blinks after taps. Figure 3 (a) visualizes this result.

Figure 3. Mean Number of Reflex Blinks After Taps: (a) We analyzed the mean number of reflex blinks after taps 1–8 in iPD patients before and after medication, as well as in HC. The mean number of reflex blinks did not change significantly in iPD patients before or after medication, while the mean number of
reflex blinks decreased from tap 1 to 8; (b) Here, the distributional results of the mean number of reflex blinks are visualized.

In Fig. 3 (b), Patients with PD had a higher number of reflex blinks, without difference upon levodopa treatment (Fig. 3b). HC had a lower number of reflex blinks compared to the groups of PD patients, but there was no statistical difference between the two cases (p = 1). However, HC had a relatively low median value compared to the two cases with statistically meaningful results (Before-Healthy: p = 1.5540e-04, After-Healthy: p = 1.5540e-04).

3.2. IPD patients had a Higher Count of Non-Reflex Blinks Compared to HC - After Medication the Blink Count Decreased

For the non-reflex blinks, Fig. 4 shows the distributional results.

**Figure 4.** Non-Reflex Blink Count and Tap-Wise Distributions: (a) The figure shows the mean number of non-reflex blinks after taps, comparing iPD patients (before and after medication) and HC. IPD patients showed a higher median value before and after medication compared to HC. The mean number of blinks after medication is lower than before medication, but statistically the difference is not significant. However, the iPD patient’s results differ significantly from those of the HC; (b) The number of blinks of iPD patients before and after medication was calculated after each tap. Before medication there is no increase or decrease in the number of blinks throughout the examination. After medication iPD patients showed a higher number of blinks after the first 2–3 taps. After the third tap the median value decreased or stayed constant.

PD patients showed a higher number of non-reflex blinks and variability compared to HC (Before-Healthy: p = 3.1080e-04, After-Healthy: p = 0.0026). After medication patients had a decreased median value while variability increased. There was no differences in the PD patients before-after levodopa treatment (p = 0.3114) (Fig. 4). Additional information on blink count is shown in Table 5.

3.3. Mean Width of Reflex Blinks did not Differ Significantly Among the Groups

As shown in Tables 3 and 4, patients and participants showed different blinking patterns for reflex and non-reflex blinks. As for reflex-blinks, iPD patients showed higher median value and variability before medication compared to HC. After medication patients experienced increased median value while variability decreased. No statistically significant difference was observed between patients and HC before and after medication (p: 0.4363, 0.1135 respectively). Figure 5 visualizes the mean peak width of reflex and non-reflex blinks among the three groups.
Table 3
Averaged Blinking Width Information of Patients

<table>
<thead>
<tr>
<th>Patient</th>
<th>Mean Width of Reflex Blinks (s)</th>
<th>Mean Width of Non-reflex Blinks (s)</th>
</tr>
</thead>
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<tr>
<td></td>
<td>Before Medication</td>
<td>After Medication</td>
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<tr>
<td>9</td>
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<td>0.250</td>
</tr>
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</table>

* nan: there is no blinking.

Table 4
Averaged Blinking Width Information of Healthy Controls

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<thead>
<tr>
<th>Participant</th>
<th>Mean Width of Reflex Blinks (s)</th>
<th>Mean Width of Non-reflex Blinks (s)</th>
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<tbody>
<tr>
<td>1</td>
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* nan: there is no blinking.
Table 5
Averaged Number of Blinking Information

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<th>Tapping Number</th>
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<th>Mean Number of Non-reflex Blinks</th>
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Figure 5. Patient/Participant-Wise Comparison of Mean Peak Width Distributions of Reflex and Non-Reflex Blinks: Reflex blinks: IPD patients had an insignificantly higher median value and a higher reflex time to the tap compared to HC; this effect is slightly enhanced by medication. After medication iPD patients had a significantly higher mean width than HC. Non-reflex blinks: IPD patients presented with a higher median value than HC. After medication the median value of the mean width decreased.

3.4. IPD Patients Showed Slower Non-Reflex Blinks Than HC - Medication Increased the Mean Width of Non-Reflex Blinks in iPD Patients

As for non-reflex blinks, compared to HC, iPD patients had a higher median value before medication. After medication, the median value decreased while variability seemed to increase. However, there was no statistical difference between before/after medication cases (p: 0.8148) and HC in terms of non-reflex blink widths (p: 0.8594, and 0.6943 respectively).

4. DISCUSSION

We developed a videographic tool to quantitatively assess the GTR in iPD patients as well as HC. With this tool we were able to successfully identify habituation to the GTR as well as quantify the blink count and the velocity of blinks. We were also able to study the effect of dopaminergic medication on iPD patients’ reflex and non-reflex blinking.

The results showed that the iPD patients in our cohort did not habituate to the GTR. However, the intake of dopaminergic medication did not affect the reaction to the tap in this group. Other studies suggested that dopaminergic medication can lead to a reversal of the glabellar response [27]. A study by Klawans
and Goodwin showed a reversal to a normal clinical GTR response in 50% of iPD patients after being treated with L-Dopa for three months or longer [27]. The likelihood of reversing the GTR was observed to decrease with a higher Hoehn and Yahr stage as well as a longer disease duration; patients whose GTR was reversed also had a good clinical response to L-Dopa overall [27]. However, the authors studied the effect of dopaminergic medication on the GTR over a longer period of time, not the initial change after the intake of medication.

HC habituated after the fourth tap. These results are in line with the Simpson Angus Scale, in which the GTR is used as one of ten items to evaluate the severity of iPD; here up to 5 consecutive blinks after tapping are considered a normal response [28].

Before medication, the iPD patients blinked more frequently in between the taps as compared to the HC. Dopaminergic medication decreased the frequency of non-reflex blinks (closer to the HC).

As hypomimia and low blink rate are typical symptoms of iPD, we expected the iPD patients to show a lower frequency of non-reflex blinks as compared to the HC. Nevertheless, a decreased blink rate has been reported in healthy subjects while performing a task that required concentration and during voluntary saccades [20, 29]. Contrary to that, Golbe et. al found an increased blink rate of iPD patients during voluntary horizontal eye movements [21]. As dopamine is associated with attention and cognitive functioning [30], reduced dopamine levels in iPD patients might affect the ability to suppress blinking during a task where concentration is required. Increased blink rate has also frequently been reported in patients with dry eye, a condition associated with autonomic dysfunction in iPD [5, 31]. In our patient cohort, a multifactorial effect on their blink rate can be assumed.

We defined velocity as the inverse of the mean peak width (see Fig. 2). With respect to the reflex blinks, there was no significant difference between iPD patients and HC. When we analyzed the non-reflex blinks, iPD patients before medication blinked slower than the HC.

After medication, the velocity of reflex blinks decreased slightly - the iPD patients’ reflex blinks slowed down after the intake of dopaminergic medication. However, the velocity of non-reflex blinks increased after medication and the blinking behavior was more similar to the HC.

From a common clinical perspective, dopaminergic medication should increase the velocity of movements. The increase in velocity of the non-reflex blinks is explained by the effect of the dopaminergic medication. For the reflex blinks, we see a counterintuitive decrease in velocity after medication. As reflexive blinking is increased in iPD patients, the decrease in velocity of reflex-blinks after medication might be explained as a reduction of excitability of the GTR.

Unobtrusive measurements are regarded safer and more comfortable [23, 32]. They do not require electrodes or any adhesives. Beside patient comfort and examination of the GTR, other scenarios of use are possible, e.g. detection of sleepiness indicated by slowing of the blink frequency in car drivers [33].
We developed a tool to quantitatively assess the GTR. This tool is contactless and easily accessible; unlike the conventional form of measurement (EMG) it does not require electrical stimulation, which makes it more comfortable for the examinee. The algorithm could be used to support early diagnosis of iPD, preferably combined with further videographic tools for common parkinsonian symptoms such as tremor [25].

Despite our pilot sample size, we could showcase the robust results of our algorithm.

For further research, comparing the videographic assessment of the GTR to the data collected with the EMG might deliver information about the accuracy of the video data and algorithm.

5. CONCLUSIONS

We developed a quantitative, video-based tool to assess the GTR and other blinking-specific parameters (frequency and velocity) in HC as well as in iPD patients before and after medication. This tool can now be used as an easy, quick, and comfortable yet accurate method to examine blinking behavior in a clinical or scientific setting. Further studies could focus on the comparability of the video data to the EMG data of the GTR and on the applicability of this method on patient groups suffering from other neurodegenerative disorders.

ABBREVIATIONS

GTR: Glabellar Tap Reflex; iPD: Idiopathic Parkinson's Disease; HC: Healthy Controls; EMG: Electromyogram; BR: Blink Reflex, PSP: Progressive Supranuclear Palsy; H&Y: Hoehn and Yahr; UPDRS: Unified Parkinson's Disease Rating Scale; ROIs: Regions of Interest; 1D: One-Dimensional

DECLARATIONS

Author Contributions: AKB drafted the design of the study and wrote the manuscript. GG performed the analysis and wrote the manuscript. TSJ performed the measurement, prepared the analyses, and wrote the manuscript. BG, MHGM and MD advised on the design of the study. JBS and MD supervised the study and reviewed the manuscript. CHA performed the analyses and wrote the manuscript. All authors have read and agreed to the published version of the manuscript.

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Data Availability Statement: Data sharing is not available. Videos cannot be shared due to privacy reasons. Extracted primary data are shown in supplementary tables.

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**Figures**
Experimental Setup: The BR was measured clinically in 12 HC and 11 iPD patients and analyzed with a high-resolution camera. (a) The subjects were filmed at a $45^\circ$ angle, while the examiner performed the GTR. A blue/blue-toned glove was worn for better discrimination in the video analysis; (b) For the HC one video of the GTR was taken. iPD patients were examined before and 30 minutes after the intake of their standard L-Dopa medication. (c-d) In a next step, MediaPipe face mesh algorithm was used for facial
landmarks detection. Based on the facial landmarks we defined two ROIs (Glabellar Region and Eye Region), from which information was extracted throughout the experiment, with which we were able to detect the occurrence of blinks and taps.

Figure 2

Example Tapping and Blinking Signal: (a) Tapping and blinking signals are visualized throughout the examination of the GTR. Blue peaks show the tapping of the glabella region on the examinee's forehead while red peaks visualize when blinks were detected; (b) In order to differentiate blinks as a response to the tapping of the glabella from other blinks, blinks were divided into two groups: reflex blinks, which occurred in the time frame from 50ms prior to until 200 ms after the tapping signal, and non-reflex blinks in between two consecutive taps, but outside of the afore-noted time range. The velocity was defined as the mean width of each blink, which was calculated at half prominence. a.u. = arbitrary unit.
Figure 3

Mean Number of Reflex Blinks After Taps: (a) We analyzed the mean number of reflex blinks after taps 1-8 in iPD patients before and after medication, as well as in HC. The mean number of reflex blinks did not change significantly in iPD patients before or after medication, while the mean number of reflex blinks decreased from tap 1 to 8; (b) Here, the distributional results of the mean number of reflex blinks are visualized.

Figure 4

Non-Reflex Blink Count and Tap-Wise Distributions: (a) The figure shows the mean number of non-reflex blinks after taps, comparing iPD patients (before and after medication) and HC. iPD patients showed a higher median value before and after medication compared to HC. The mean number of blinks after
medication is lower than before medication, but statistically the difference is not significant. However, the iPD patient’s results differ significantly from those of the HC; (b) The number of blinks of iPD patients before and after medication was calculated after each tap. Before medication there is no in- or decrease in the number of blinks throughout the examination. After medication iPD patients showed a higher number of blinks after the first 2-3 taps. After the third tap the median value decreased or stayed constant.

Figure 5

Patient/Participant-Wise Comparison of Mean Peak Width Distributions of Reflex and Non-Reflex Blinks: Reflex blinks: IPD patients had an insignificantly higher median value and a higher reflex time to the tap compared to HC; this effect is slightly enhanced by medication. After medication iPD patients had a significantly higher mean width than HC. Non-reflex blinks: IPD patients presented with a higher median value than HC. After medication the median value of the mean width decreased.