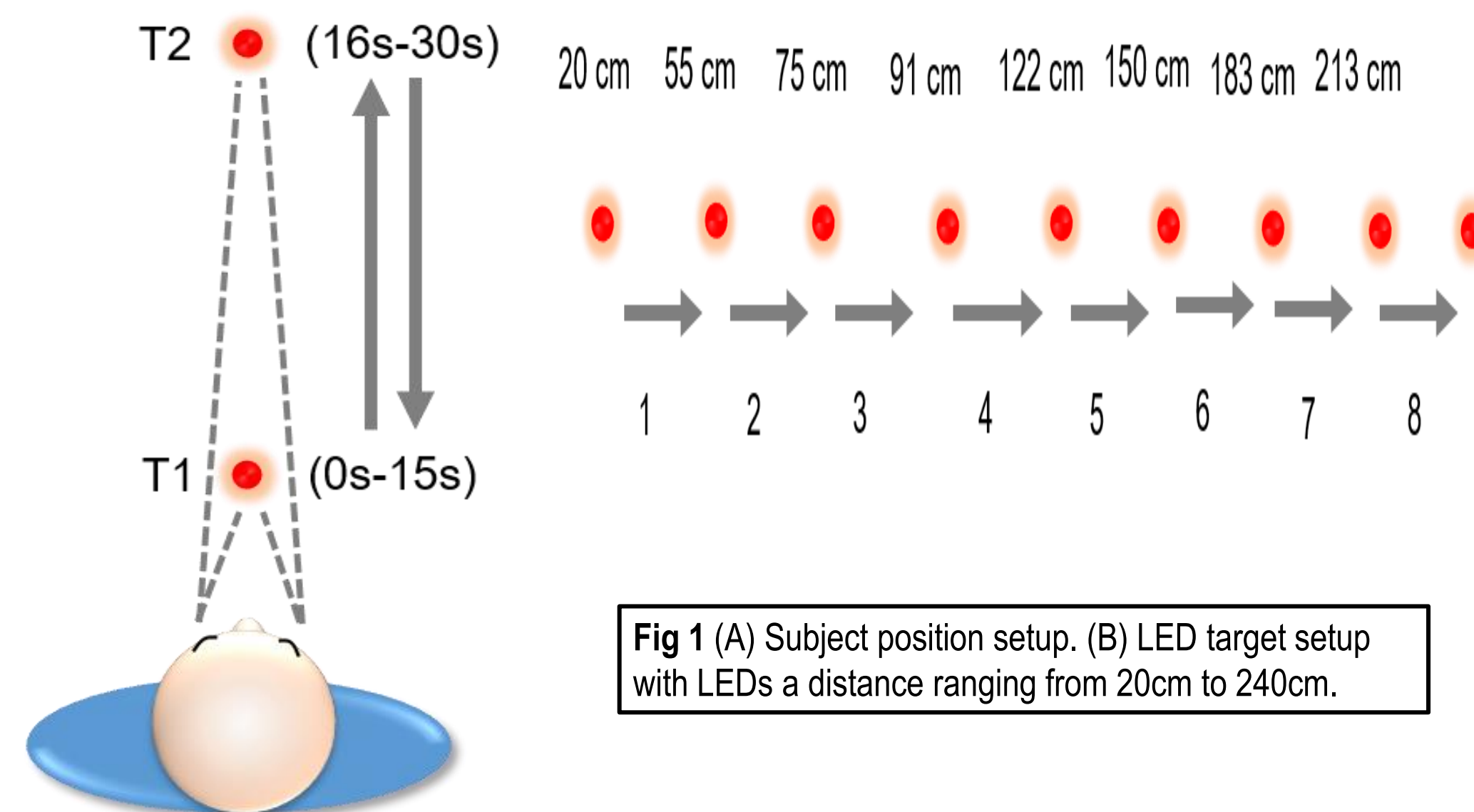


## Introduction

- Parkinson's disease (PD) is the 2nd most common neurodegenerative condition affecting about 10 million individuals worldwide. Visual symptoms in PD are far more common than appreciated and can be due to multiple etiologies. PD subjects have impairment in the simultaneous movement of both eyes in the opposite direction (i.e., vergence) results in compromised depth perception and spatial navigation abnormalities in up to 70% of PD patients. Impaired rapid gaze shifts (i.e., saccades) cause difficulties in reading or scanning the surrounding environment. Misalignment of the two eyes leading to strabismus and abnormal visual fusion also causes diplopia (double vision) in about a third of PD patients, which is a consequence of abnormal vergence.
- The purpose of our study is to examine the correlation between vergence abnormalities and associated strabismus and severity of Parkinson's disease.

## Methods



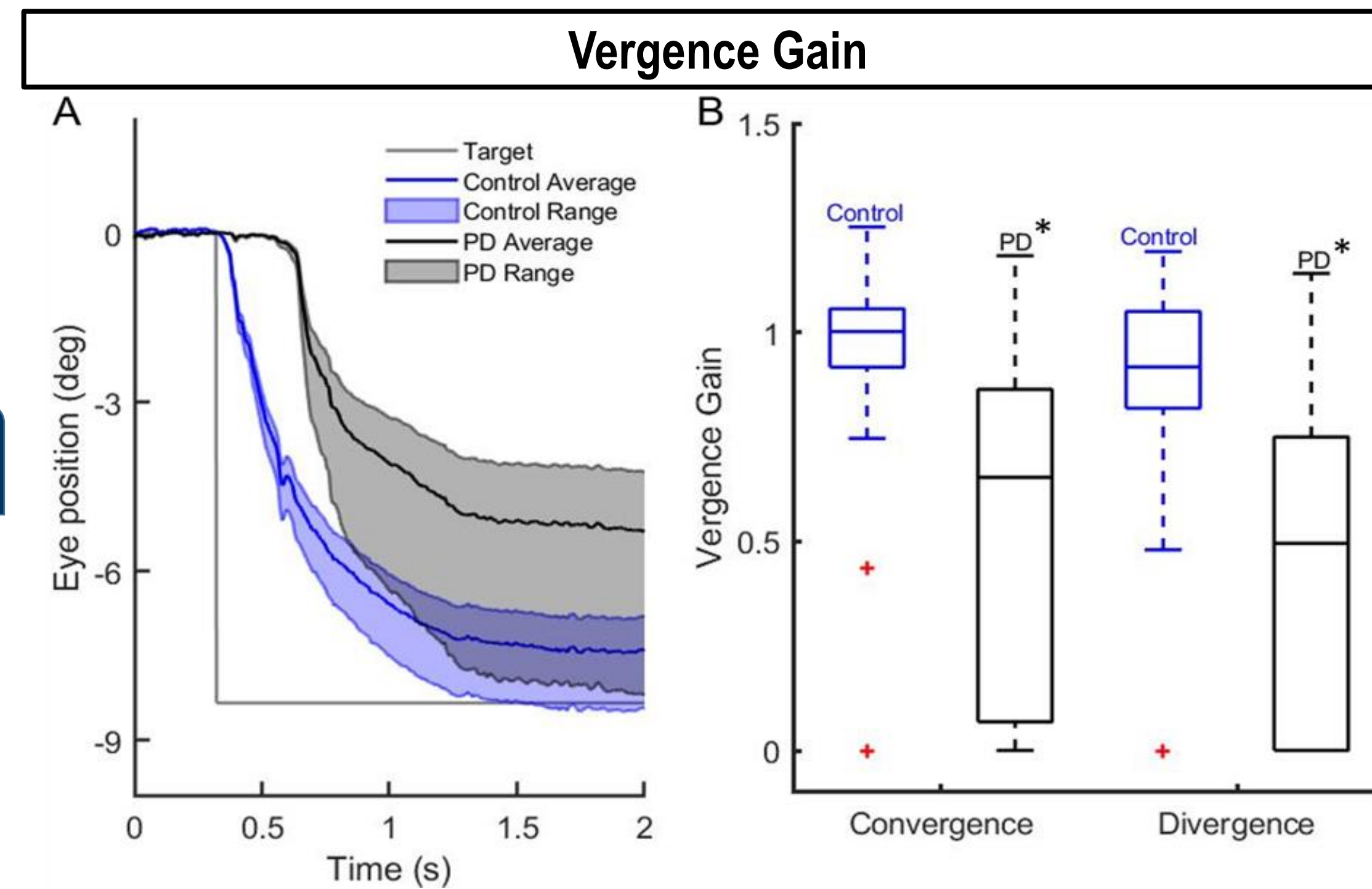
**Fig 1** (A) Subject position setup. (B) LED target setup with LEDs a distance ranging from 20cm to 240cm.

- Subject Selection: 15 patients with idiopathic Parkinson's Disease and 8 healthy age-matched control subjects. All the subjects had a complete eye exam including strabismus measurements.
- Eye movement recording: A high-resolution eye-tracker (EyeLink 1000®, SR Research, Ontario, Canada; spatial resolution of 0.01 degree and temporal resolution of 500Hz) was used to quantify convergence and divergence abnormalities using LED targets placed at distances ranging from 20 cm to 240 cm along the median plane. This video-based eye tracker uses the corneal reflection (first Purkinje image) and the center of the pupil to measure the coordinates of the gaze position. It does not rely on pupil size which may change with light reflex or cognitive processes including thoughts and behaviors. The data was further processed and analyzed using MATLAB (Mathworks, Natick, MA).
- Analysis: We computed the vergence gain (left-right eye amplitude/target amplitude), peak velocities and latencies. The neurologic impairment was quantified using the Unified Parkinson's Disease Rating Scale (UPDRS), disease-duration, Activity-specific Balance Confidence (ABC) scale, and fall frequency.

## References

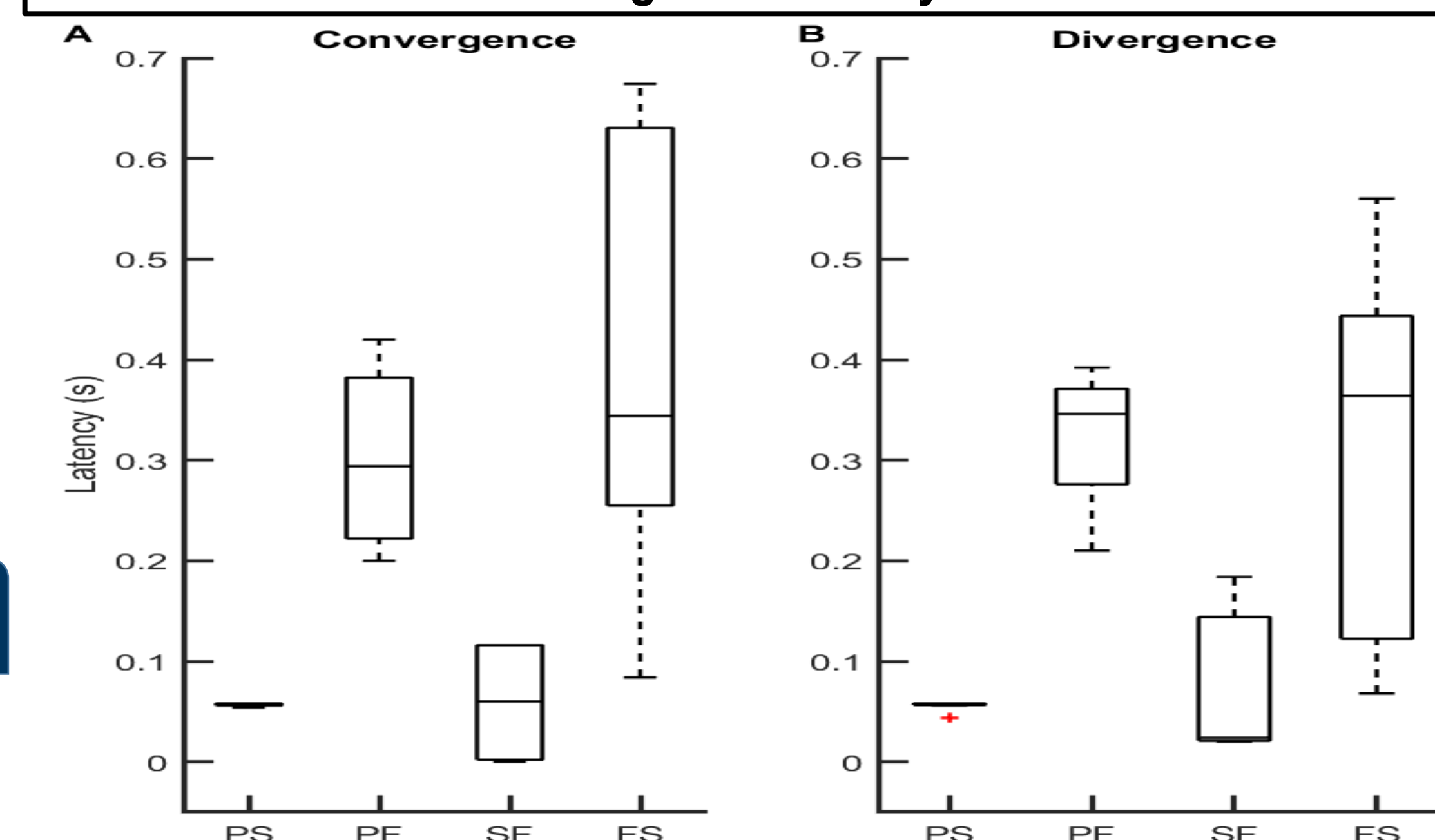
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## Data Analysis



**Fig 2** (A) Summary of eye position trajectory in healthy control (blue trace) and PD subject (black trace). The eye positions are plotted on y-axis while corresponding time is plotted on x-axis. Solid line (black in PD and blue in healthy control) depicts mean eye position from PD subjects and healthy controls who were able to make convergence eye movements. The grey shade (PD) and light blue shade (control) depicts standard deviation. (B) Boxplot depicting vergence gain (plotted on y-axis) grouped by convergence and divergence for both PD (black) and control (blue) subjects. Length of box depicts interquartile interval, whiskers depict range, and horizontal line in the box depicts median value.

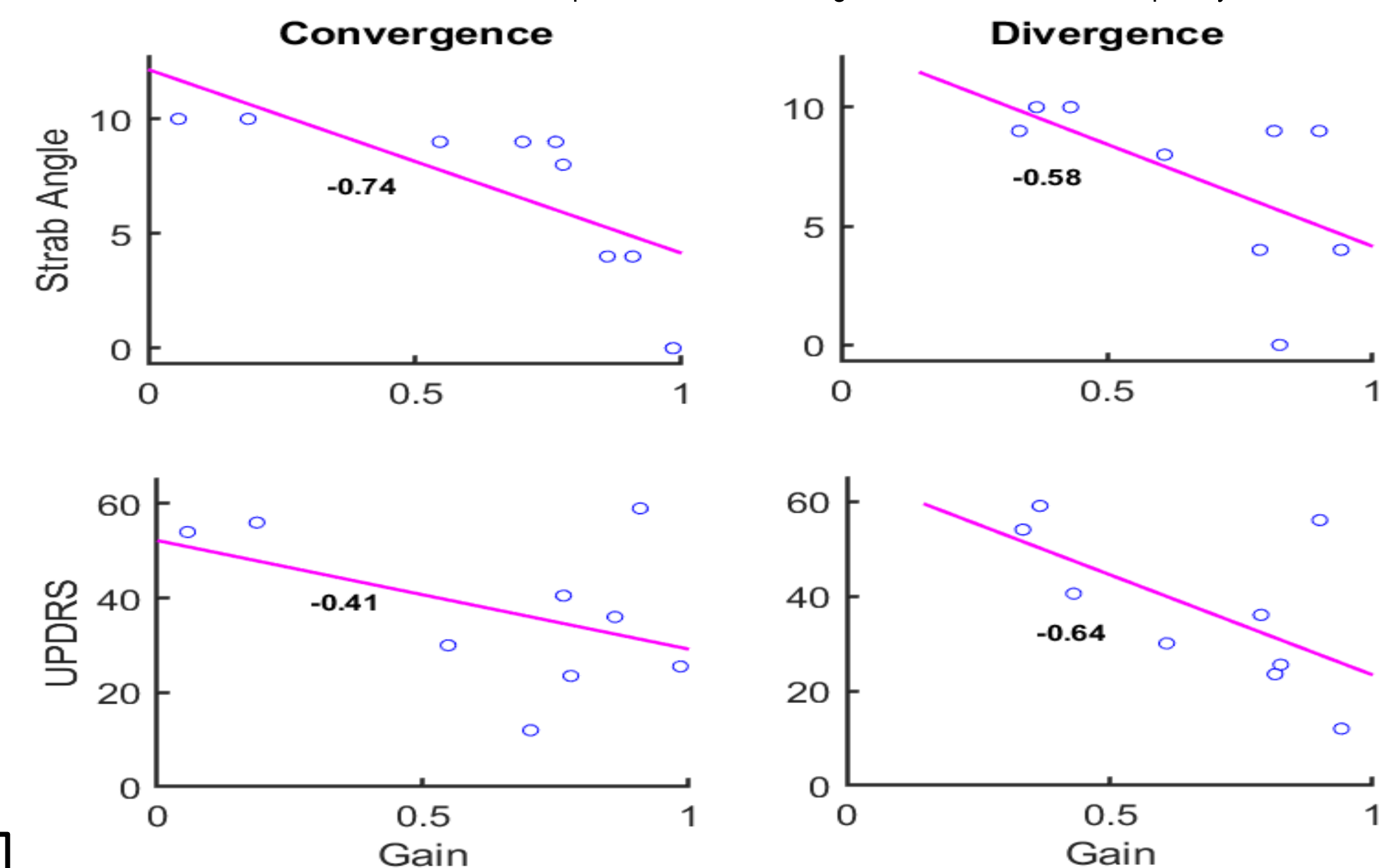
## Vergence Latency



**Fig 3** (A) Comparison of latency in different compensatory strategies. Boxplot depicting vergence latency (plotted on y-axis) are grouped according to movement strategy (pure slow: PS; pure fast: PF; slow fast: SF; and fast slow: FS) in convergence (A) and divergence (B). The box length depicts interquartile interval, whiskers depict range, and horizontal line in the box depicts median value.

## Results

- We found that PD patients had significant impairment of both convergence and divergence compared to controls with reduced vergence gain and peak velocities and prolonged latencies.
- There was a negative correlation between convergence and divergence gains and clinically measured strabismus angles (R-values, convergence=0.74 (strong); divergence=0.58 (moderate)).
- Divergence gain in PD was  $0.58 \pm 0.14$ , significantly lower than controls ( $0.98 \pm 0.13$ , ANOVA,  $p < 0.05$ ).
- Convergence gain was  $0.64 \pm 0.29$ , also significantly lower compared to controls ( $1.09 \pm 0.31$ , ANOVA,  $p < 0.05$ ).
- The reduction in vergence gain also correlated with disease severity measured with UPDRS (R-values, convergence=0.41; divergence=0.64 (moderate in both cases)).
- There was a weak correlation with other parameters such as age, ABC scale, and fall frequency.



## Conclusion

- PD patients have both convergence and divergence insufficiency, which can impact the vision-related quality of life.
- We found a significant reduction in gain of PD subjects as compared to healthy age matched controls. PD patients also have significantly longer latency period as compared to controls. A reduction in vergence gain is correlated with the strabismic angle and UPDRS rating.
- The binocular abnormalities show weak correlation with other parameters such as age, ABC scale and fall frequency.

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