Eye-Tracking-Based Dynamic Task Assessment of Post-Stroke Unilateral Spatial Neglect: A Preliminary Study (Postprint)

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Date: 2022-11-16T00:00:00+00:00

Abstract

Background Unilateral spatial neglect (USN) is a common cognitive impairment following stroke that severely impacts patients' functional recovery and quality of life. Therefore, objective assessment is essential for facilitating functional recovery. Objective Eye-tracking-based technology is being explored as a novel assessment tool. Herein, we investigated the feasibility of using eye-tracking-based dynamic tasks to evaluate unilateral spatial neglect in subacute stroke patients. Methods From September 2021 to July 2022, 30 inpatients in the subacute phase of stroke were recruited from the Department of Rehabilitation Medicine at Nanchong Central Hospital. Patients underwent USN clinical scales (the conventional subtests of the Behavioral Inattention Test [BIT-C] and the Catherine Bergego Scale [CBS]) and eye-tracking-based dynamic task assessment. Correlation analysis was performed on the assessment results. Results Left USN patients exhibited a significantly higher proportion of fixation points on the right screen compared to non-USN patients ($Z=-4.776$, $p=0.000$), and a significant difference in fixation point proportion between left and right screens was observed in left USN patients ($Z=-3.49$, $p=0.000$). The conventional subtests of the Behavioral Inattention Test (BIT-C) and eye-tracking-based dynamic task assessment demonstrated high consistency in detecting USN patients (Kappa=0.933, $P=0.000$). Pearson correlation analysis revealed a significant negative correlation between right-side fixation point proportion and total BIT-C score ($r=-0.955$, $p=0.000$). The Catherine Bergego Scale (CBS) and eye-tracking-based dynamic task showed high consistency in assessing USN status (Kappa=0.867, $P=0.000$). Conclusion Eye-tracking-based dynamic task assessment of USN is feasible, yielding results highly consistent with BIT-C and CBS evaluations. Moreover, the assessment process is time-efficient, with high patient engagement and motivation, serving as a valuable supplement to standard USN assessments.

Full Text

Preamble

A Pilot Study of Eye-Tracking-Based Dynamic Tasks to Assess Unilateral Spatial Neglect After Stroke

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Abstract

Background: Unilateral spatial neglect (USN) is one of the common cognitive impairments after stroke, which severely affects functional recovery and quality of life. Therefore, objective assessment is essential to facilitate patients' functional recovery. **Objective:** Eye-tracking-based technology is being explored as a novel assessment tool. Here, we investigate the feasibility of using eye-tracking-based dynamic tasks to assess USN in patients with subacute stroke. **Methods:** From September 2021 to July 2022, 30 inpatients with subacute stroke were recruited from the Department of Rehabilitation Medicine at Nanchong Central Hospital. Patients underwent USN clinical scale assessment (Behavioral Inattention Test-Conventional Subtests and Catherine Bergego Scale) and eye-tracking-based dynamic task evaluation. Correlation analyses were performed on the assessment results. **Results:** Left-sided USN patients showed significantly higher percentages of gaze points on the right screen compared to non-USN patients ($Z = -4.776$, $p = 0.000$), and significant differences existed between left and right screen gaze point percentages in left-sided USN patients ($Z = -3.49$, $p = 0.000$). The Behavioral Inattention Test-Conventional Subtests (BIT-C) and eye-tracking-based dynamic task assessment showed high agreement in detecting USN patients (Kappa = 0.933, $P = 0.000$). Pearson correlation analysis revealed a significant negative correlation between right-side gaze point percentage and total BIT-C score ($r = -0.955$, $p = 0.000$). The Catherine Bergego Scale (CBS) and eye-tracking-based dynamic task also demonstrated high consistency in evaluating whether patients had USN (Kappa = 0.867, $P = 0.000$). **Conclusions:** Eye-tracking-based dynamic task assessment of USN is feasible, with results showing high consistency with both BIT-C and CBS evaluations. The assessment process is time-efficient, highly engaging, and motivating for patients, and can serve as a complement to standard USN assessments.

Keywords: stroke; unilateral spatial neglect; eye-tracking; dynamic task; feasibility study

Introduction

Stroke is the second leading cause of death globally and a major cause of disability, representing a significant international health concern [1]. Approximately one in three stroke survivors is diagnosed with unilateral spatial neglect (USN) [2], which is more common in patients with right hemisphere damage. USN can also be observed in other types of brain injury, with its etiology primarily related to damage in neural networks associated with spatial information processing and attention control [3]. USN is defined as a failure to respond to environmental stimuli from the side contralateral to brain damage in the absence of other sensory or motor deficits [4]. Research indicates that approximately 40% of USN patients continue to experience neglect symptoms [5, 6]. These symptoms disrupt basic self-care activities (such as dressing and grooming), impair postural balance [7, 8], and interfere with reading ability [9, 10]. USN also severely impacts the rehabilitation process for inpatients, leading to prolonged hospital stays [11-13] and increased family burden [14]. Importantly, many USN patients are unaware of their symptoms or potential consequences during the initial disease stage [15-17], preventing them from seeking appropriate treatment or learning compensatory strategies in a timely manner. The profound impact of USN on stroke survivors and their families underscores the necessity of implementing evidence-based assessment and treatment in clinical practice. Objective assessment to determine the presence and severity of USN can help guide multidisciplinary rehabilitation to mitigate or eliminate its adverse effects [18].

Despite extensive research, clinicians have not reached consensus on methods for identifying USN and monitoring post-treatment improvement; accurate and comprehensive assessment of USN remains a major clinical challenge. Clinical assessment of USN typically employs neuropsychological evaluations such as paper-and-pencil cancellation tasks, line bisection tests, and reading tests [18], with ecological assessments like the Catherine Bergego Scale (CBS) [19] serving as complementary evaluation methods.

Eye-tracking technology is being explored as a novel assessment tool. A study on early detection of cognitive decline in mild cognitive impairment and Alzheimer' s disease demonstrated that eye-tracking tests can effectively differentiate cognitive function among normal subjects, Alzheimer' s patients, and those with mild cognitive impairment [20]. Additionally, eye-tracking technology has been applied to USN assessment. Baheux et al. [21] and Broeren et al. [22] used eye-tracking devices to monitor neglect during static tasks, where participants performed line bisection tests and cancellation tests (lines, letters, stars) in a virtual environment (computer). However, static task-based assessments lack dynamic information during evaluation and ecological validity. Gomes Paiva et al. [23] used wearable eye-tracking glasses to study the time patients spent exploring left and right target stimuli while walking in real environments, yet most acute and subacute phase patients are typically unable to walk in real-world settings.

Therefore, we explored the use of eye-tracking technology in dynamic tasks to assist in screening and assessing USN in subacute stroke patients. Dynamic tasks allow patients to freely explore dynamic space to search for target stimuli, offering greater ecological relevance while also increasing cognitive demands to some extent [24]. Furthermore, this paradigm, based on eye-movement interaction technology, enables convenient patient assessment, with each dynamic task requiring only two minutes. It can also be applied to populations unable to complete scale assessments due to hand dysfunction. In summary, we hypothesize that this technology has considerable application prospects for USN assessment.

1. Materials and Methods

This study was approved by the Ethics Committee of Nanchong Central Hospital, and informed consent was obtained from all enrolled patients. The study was registered with the Chinese Clinical Trial Registry (ChiCTR2100049482).

1.1 Participants

From September 2021 to July 2022, 30 inpatients with subacute stroke were recruited from the Department of Rehabilitation Medicine at Nanchong Central Hospital. **Inclusion criteria** were: (1) meeting stroke diagnostic criteria with confirmed cerebral hemorrhage or infarction on CT or MRI; (2) age 18-80 years; (3) in the subacute phase of stroke (1-6 months post-onset); (4) Mini-Mental State Examination (MMSE) score $ $10 or able to cooperate with therapists to complete the trial; (5) intact visual field or corrected to normal; (6) stable condition able to complete the test in a sitting position. **Exclusion criteria** were: (1) history of neurological damage or psychiatric disorders; (2) severe comprehensive aphasia making it difficult to follow therapist instructions; (3) severe hearing loss; (4) failure to sign informed consent.

1.2 Methods

Therapists roughly measured peripheral visual fields using confrontational visual field testing (dynamic method). The examiner and subject sat facing each other at eye level, half a meter apart. When examining the right eye, the subject' s right eye and examiner' s left eye fixated on each other, with the opposite eye covered. The examiner moved a finger slowly from the periphery toward the center from various directions at an equal distance between the two individuals; if both saw the finger simultaneously, the visual field was generally considered normal. Cognitive level was assessed using the Chinese version of the Mini-Mental State Examination [25]. General demographic data were collected for all eligible patients who signed informed consent, including age, sex, handedness, days post-stroke, brain lesion location, and cognitive level. Handedness was evaluated using the Edinburgh Handedness Inventory [26].

Paper-and-pencil tests are the most commonly used USN assessment methods in clinical practice. The Behavioral Inattention Test-Conventional Subtests (BIT-C) includes multiple paper-and-pencil test components. The CBS is recommended as the most suitable USN assessment for inpatients [27]. Therefore, we selected these two assessment methods as standards for comparison with eye-tracking-based dynamic task evaluation results. All patients completed BIT-C, CBS, and eye-tracking-based dynamic task assessments within one week. Researchers recorded assessment results and any adverse reactions during evaluation. Results were categorized into three groups: eye-tracking dynamic task assessment, BIT-C, and CBS.

1.3.1 Eye-Tracking-Based Dynamic Task Assessment

Eye-tracking-based dynamic task assessment was performed using a high-performance eye-tracking device ([Figure 1: see original paper], Hangzhou Jizhi Medical Technology Co., Ltd., Model: JZ-RZ-20US) for eye movement analysis. Each subject sat 60 cm from the device, holding handrails on both sides to maintain relatively fixed posture during task completion (if subjects could not grasp with one or both hands, family members assisted in posture stabilization), ensuring no large upper body or head movements. Therapists adjusted subject positioning so their eyes could be detected by the device ([Figure 1: see original paper]). Before assessment began, subjects completed device calibration by fixating on three calibration points on the display (twice). The eye-tracking device below the monitor uses pupil-corneal reflection technology, offering high precision, non-contact, and non-invasive advantages. Two regions of interest (ROI) were set on the left and right sides of the screen. The device automatically provided percentage values for gaze points (eye search and fixation) on the left and right screen areas. We manually divided the screen into four zones (divided by connecting the upper and lower quarter points: left-inner, left-outer, right-inner, right-outer, [Figure 2: see original paper]). Patients were classified based on gaze point spatial distribution: non-USN patients (gaze points distributed across all four zones) and USN patients (gaze points not distributed across all four zones).

The "shooting insects" task (bilateral, simple level) within the cognitive rehabilitation training and assessment system was selected as the dynamic task. During assessment, insects randomly appeared on the left and right sides of the computer monitor, moving upward from the bottom. Subjects were instructed to search for target stimuli (insects) on the monitor and shoot them by fixating on them until the assessment ended; the total assessment duration was two minutes. Before formal assessment, therapists explained requirements and methods, and patients had one practice opportunity. The practice ended once the therapist confirmed the patient understood the method, after which formal assessment began.

A professional rehabilitation therapist (DJ) conducted all eye-tracking-based dynamic task assessments, with therapist (DJ) blinded to patients' clinical assessment results.

1.3.2 Clinical Scale Assessment

The Catherine Bergego Scale (CBS) is an ecological assessment tool for unilateral spatial neglect with good reliability and validity [28]. The scale consists of 10 items including grooming, dressing, eating, mouth cleaning, gaze direction, limb awareness, auditory attention, collisions, spatial orientation, and item searching. Each item is scored from 0 (normal) to 3 (severe unilateral neglect). Based on total scores, neglect severity is divided into three levels: 1-10 (mild neglect), 11-20 (moderate neglect), and 21-30 (severe neglect).

The Behavioral Inattention Test-Conventional Subtests (BIT-C) includes widely used paper-and-pencil tests [29]: (a) line, letter, and star cancellation tests; (b) figure and shape copying; (c) line bisection; and (d) representational drawing. The sum of scores from each test yields a total BIT-C score ranging from 0 to 146. The cutoff value for BIT-C is 129; scores below 129 diagnose USN, with lower scores indicating more severe neglect.

(a) In cancellation tests, target stimuli were presented on A4 paper (210mm × 297mm). Patients were required to cross out all lines, letters "E" and "R", and all small stars. There was no time limit, and the number of missed targets was recorded. Maximum scores for these cancellation tests were 36, 40, and 54, with cutoff values of 34, 32, and 51, respectively.

(b) In figure and shape copying, subjects copied three figures (a four-pointed star, a cube, a flower) and three line-drawn figures onto A4 paper. The maximum score was 4, with a cutoff value of 3.

(c) In line bisection, three 20-cm horizontal lines were presented on A4 paper. Patients were asked to locate spatially distributed horizontal lines and mark each line as accurately as possible at its midpoint. Scores from 0 to 3 were assigned based on the distance between the mark and each line's midpoint (0-1cm = 3 points; 1-2cm = 2 points; 2-3cm = 1 point; >3cm = 0 points). The maximum score was 9, with a cutoff value of 7.

(d) In representational drawing, patients were asked to draw a clock, a person, and a butterfly from memory on A4 paper. Each drawing was scored based on symmetry (0 = asymmetric, 1 = symmetric). The maximum score was 3, with a cutoff value of 2.

A professional rehabilitation therapist (XYL) conducted all clinical assessments, with therapist (XYL) blinded to patients' eye-tracking dynamic assessment results.

1.4 Statistical Methods

SPSS 25.0 was used for statistical analysis. Continuous variables with normal distribution were expressed as mean ± standard deviation (x ± s), while skewed distributions were expressed as median (interquartile range). Normality tests were performed on eye-tracking dynamic task assessment data to determine distribution. If normally distributed, independent samples t-tests were used to analyze differences in right (left) side gaze point percentages between USN and non-USN patients; otherwise, Mann-Whitney U tests were used. If normally distributed, paired samples t-tests were used to analyze differences in left-right gaze point percentages within USN (or non-USN) patients; otherwise, Wilcoxon signed-rank tests were used. Pearson correlation analysis was used to examine the relationship between right-side gaze point percentage and total BIT-C score. Cohen' s Kappa consistency test from paired chi-square analysis was used to analyze relationships between BIT-C, CBS assessment results, and eye-tracking dynamic task assessment results. $P < 0.05$ was considered statistically significant.

2. Results

Thirty patients with subacute stroke were ultimately included in data analysis, including 19 males and 11 females, aged 34-78 years with a mean age of (60.27 ± 11.51) years. Most participants were right-handed (96.7%). One subject (Patient 24) could not complete the MMSE assessment due to motor aphasia but was able to cooperate with therapists to complete the trial. General demographic data of subjects are summarized in .

Table 1. General Demographic Data of Subjects

Demographic Characteristics (N=30)	Value
Age (years)	60.27 ± 11.51
Sex (male/female)	19/11
Handedness (right/left/ambidextrous)	29/0/1
Days post-stroke	69.23 ± 40.73
Lesion location (right hemisphere/left hemisphere/bilateral)	19/5/6
MMSE (N=29)	23.93 ± 4.79

Note: Values expressed as mean ± standard deviation; MMSE = Mini-Mental State Examination

2.2 Eye-Tracking Dynamic Task Assessment Results

Eye-tracking dynamic task results () showed that among 30 patients, 14 were classified as left-sided USN patients: 3 had gaze points distributed only in the right-outer zone, 8 in both right-inner and right-outer zones, and 3 in left-inner plus right-inner and right-outer zones. The remaining 16 patients were non-USN, with gaze points distributed across all four zones. USN patients showed significantly higher right-screen gaze point percentages than non-USN patients (Z = -4.776, p = 0.000), and significant differences existed between left and right screen gaze point percentages in USN patients (Z = -3.49, p = 0.000), indicating that left-sided USN patients tended to search for and shoot insects on the right screen while neglecting left space during dynamic tasks ().

Table 2. Clinical Evaluation Results of Subjects

Patient	Lesion Location	BIT-C	CBS	Eye-Tracking Dynamic Task
1	Right frontotemporal-occipital, insular and basal ganglia regions	USN	USN	USN
2	Bilateral centrum semiovale, basal ganglia regions	USN	USN	USN
3	Right frontotemporal-parietal region	USN	USN	USN
4	Right frontotemporal-occipital-parietal-insular, basal ganglia-external capsule region	USN	USN	USN
5	Right frontotemporal-occipital, insular region	USN	USN	USN
6	Bilateral basal ganglia regions	USN	USN	USN
7	Right frontotemporal-parietal region	USN	USN	USN
8	Right basal ganglia region	USN	USN	USN
9	Right basal ganglia-external capsule region	USN	USN	USN
10	Right frontotemporal-parietal region	USN	USN	USN

Patient	Lesion Location	BIT-C	CBS	Eye-Tracking Dynamic Task
11	Right parietal, basal ganglia region	USN	USN	USN
12	Right basal ganglia region	USN	USN	USN
13	Right frontotemporal-parietal region	USN	USN	USN
14	Right frontotemporal-parietal region	USN	USN	USN
15	Right frontotemporal-parietal, basal ganglia region	USN	USN	USN
16	Left temporal-basal ganglia, external capsule region	USN	USN	USN
17	Right temporal, external capsule-lateral ventricle region	Non-USN	Non-USN	Non-USN
18	Left insular, frontotemporal-parietal region	Non-USN	Non-USN	Non-USN
19	Right pons, left cerebellar hemisphere and vermis	Non-USN	Non-USN	Non-USN
20	Right frontoparietal, basal ganglia-external capsule region	Non-USN	Non-USN	Non-USN
21	Right frontotemporal-occipital-parietal region	Non-USN	Non-USN	Non-USN
22	Right frontotemporal-parietal region	Non-USN	Non-USN	Non-USN

Patient	Lesion Location	BIT-C	CBS	Eye-Tracking Dynamic Task
23	Right frontotemporal-parietal region	Non-USN	Non-USN	Non-USN
24	Left lateral ventricle region	Non-USN	Non-USN	Non-USN
25	Right basal ganglia-external capsule region	Non-USN	Non-USN	Non-USN
26	Left basal ganglia region, lateral ventricle region	Non-USN	Non-USN	Non-USN
27	Bilateral parietal-occipital, thalamus	Non-USN	Non-USN	Non-USN
28	Bilateral frontoparietal-temporal, centrum semiovale, lateral ventricle	Non-USN	Non-USN	Non-USN
29	Right basal ganglia region	Non-USN	Non-USN	Non-USN
30	Left basal ganglia region	Non-USN	Non-USN	Non-USN

Note: BIT-C = Behavioral Inattention Test-Conventional Subtests, CBS = Catherine Bergego Scale, USN = Unilateral Spatial Neglect

Table 3. Comparison of Left and Right Side Gaze Points in Eye-Tracking Dynamic Task Assessment

Group	Right Gaze Point Percentage	Left Gaze Point Percentage	Z-value	p-value
USN patients	100% (98.25%, 100%)	0% (0%, 1.5%)	-3.49	0.000
Non-USN patients	50.56% ± 6.56%	48.44% ± 6.56%	0.648	0.527

Note: Normally distributed data expressed as mean ± standard deviation;

skewed distribution data expressed as median and interquartile range; USN = Unilateral Spatial Neglect

2.3 Clinical Scale Assessment Results

All patients completed BIT-C and CBS assessments, with detailed results shown in . BIT-C results identified 15 patients with scores below 129 as USN patients, while the remaining 15 with higher scores were classified as non-USN. CBS assessment revealed 16 patients with varying degrees of USN, with the other 14 classified as non-USN.

2.4 Correlation Analysis

Eye-tracking-based dynamic task assessment identified 14 patients as left-sided USN and 16 as non-USN. BIT-C results diagnosed 15 patients as left-sided USN and 15 as non-USN. Only one patient with mild neglect (BIT-C score of 113) was classified as non-USN on the eye-tracking dynamic assessment task. BIT-C and eye-tracking-based dynamic task assessment showed high agreement in detecting USN patients (Kappa = 0.933, P = 0.000). Pearson correlation analysis revealed a significant negative correlation between right-side gaze point percentage and total BIT-C score (r = -0.955, p = 0.000), with the scatter plot shown in [Figure 3: see original paper].

CBS results identified 16 patients as left-sided USN and 14 as non-USN. Compared to eye-tracking-based dynamic assessment, CBS additionally detected two patients with mild neglect. Cohen' s Kappa consistency test showed high agreement between the two assessment methods in evaluating whether patients had USN (Kappa = 0.867, P = 0.000).

2.5 Safety and Tolerability

No adverse events occurred or were recorded during the trial. Participants found the eye-tracking-based dynamic task novel and interesting, showing high engagement. The scatter plot of subjects' right gaze point percentage and total BIT-C score is shown in [Figure 3: see original paper].

3. Discussion

Unilateral spatial neglect is a common disabling condition after stroke [30] and can also be observed in other types of brain injury [31, 32]. This study demonstrates that eye-tracking-based dynamic tasks have considerable potential for monitoring USN and guiding rehabilitation in subacute stroke patients. Eye-tracking devices can record the dynamic task assessment process in real-time and visually display eye movement trajectories (search and fixation), enabling clinicians to evaluate patients' visual search patterns and analyze aspects such as time spent exploring left-right space or number of fixations on each side to further identify significant spatial difficulties associated with post-stroke USN.

Clinically, classical paper-and-pencil tests are commonly used to evaluate neglect levels. These simple paper-and-pencil tests focus on assessing neglect patients' ability to search for/delete static stimuli. While they can directly express neglect through reduced target search performance on one side, they rarely provide information about how patients dynamically scan and explore space. Moreover, static paper-and-pencil tests lack real-world relevance. In daily life, we often need to distribute attention across multiple objects and monitor their movement. Therefore, we employed dynamic tasks in this study, allowing subjects to freely search for targets in dynamic space, providing greater ecological validity while monitoring eye search and fixation induced by dynamic targets in dynamic space for USN assessment.

Previous studies have shown that USN patients tend to engage in repetitive behaviors in the ipsilesional space [33] and exhibit ipsilesional attention bias. In typical visual behavior, eye movements and spatial attention are closely related [34], and spatial bias in eye movements (search and fixation) may be a hallmark of USN. In visual search for static stimuli, left-sided USN patients rarely find targets in the left-outer region [35]. Our study found that this visual search bias also exists in dynamic tasks. When performing dynamic tasks, left-sided USN patients spent significantly less time (fixation percentage) in left visual space than right, and showed significant differences from non-USN patients in right-side fixation percentage ($Z = -4.766$, $P = 0.000$). Furthermore, spatial deviation in fixation distribution correlated with neglect severity (as indicated by BIT-C scores). Interestingly, one patient diagnosed with left-sided USN by BIT-C but with mild symptoms (BIT-C score of 113) showed normal fixation point spatial distribution on the eye-tracking dynamic task. This result suggests that as BIT-C scores increase, fixation distribution between left and right visual fields may gradually change. Diagnosis based solely on fixation spatial distribution may not completely accurately identify patients with mild neglect, but overall diagnostic results showed high consistency with BIT-C. Right-side fixation percentage also showed a significant negative correlation with total BIT-C score, with more severely neglectful patients having more fixations in the right visual field, even confined exclusively to the right-outer zone.

Dynamic stimulation paradigms with free eye movement demonstrate greater ecological validity compared to static stimuli. Therefore, we also analyzed consistency between ecological assessment results and eye-tracking-based dynamic task results. We used the Catherine Bergego Scale as the ecological assessment method, which has high sensitivity and was recommended by Azouvi et al. [29] as the most appropriate USN assessment for inpatients. Results showed high consistency between the two assessment methods in evaluating whether patients had USN, with a Kappa coefficient of 0.867. One patient diagnosed with mild neglect on CBS due to neglect of the affected limb was not detected by either eye-tracking dynamic task or BIT-C. This result suggests that visual-based and behavioral observation-based unilateral neglect assessments may yield dissociated results, confirming that USN is a complex neuropsychological syndrome for which no single test can completely and accurately identify the condition

[36].

Based on our findings, we believe that specific directional eye movement characteristics can provide an effective method to quantify neglect symptoms. However, as a pilot study, this research has the limitation of a small sample size, which we are currently addressing through expanded enrollment. Additionally, we primarily investigated eye-tracking-based dynamic task assessment in subacute patients; further research is needed on its sensitivity and reliability in acute or chronic stroke patients. Diagnosing USN based solely on fixation spatial distribution may be insufficient, as evidenced by missed diagnoses of mildly neglectful patients. However, given our small sample size and lack of stratified analysis by neglect severity, we cannot yet determine the sensitivity of eye-tracking-based dynamic tasks for mild neglect. Furthermore, we used a simple-level dynamic task in this study; whether higher difficulty levels (faster target movement, more simultaneous targets) can more sensitively detect mild neglect patients requires further investigation. As a feasibility study, this research lays the foundation for future trials. Future studies should continue exploring eye movement characteristics in USN patients to develop more precise diagnostic criteria.

In summary, this study provides proof-of-concept that eye-tracking dynamic tasks may be feasible for USN assessment. Eye-tracking-based dynamic task evaluation is efficient, simpler, more interesting, and readily accepted by patients. It can be applied to populations unable to complete scale assessments due to hand dysfunction, though it cannot yet fully replace the comprehensive USN assessment provided by the Catherine Bergego Scale (CBS) and Behavioral Inattention Test-Conventional Subtests (BIT-C). Eye-tracking-based assessment warrants further investigation.

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Note: Figure translations are in progress. See original paper for figures.