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# Evaluation of the Validity and Psychometric Properties of the Persian Version of the Brain Fog Questionnaire

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A B S T R A C T

**Purpose:** The primary aim of this study was to examine the psychometric properties (validity and reliability) of the Persian version of the Brain Fog Scale in an Iranian student population.

**Methods and Materials:** This research was a cross sectional, descriptive analytical study. A sample of 300 students from Islamic Azad University, Qom Branch, was selected using convenience sampling. In addition to the Brain Fog Scale (BFS), participants completed measures for convergent validity (Cognitive Load Questionnaire and General Health Status) and divergent validity (Meal Frequency and Physical Activity Questionnaire). Data were analyzed using SPSS (version 27) and AMOS (version 24).

**Findings:** Confirmatory factor analysis supported the three factor structure of the scale (mental fatigue, reduced cognitive sharpness, and confusion) with very good fit indices (CFI = 0.96, RMSEA = 0.045, $\chi^2$/df = 2.3). The instrument demonstrated excellent internal consistency with Cronbach's alpha = 0.935 for the total scale and 0.785 to 0.876 for the subscales. Test retest reliability was confirmed with a correlation coefficient of 0.942, indicating high temporal stability. A significant positive correlation between brain fog scores and cognitive load (r = 0.284) and a significant negative correlation with general health status (r = -0.202) supported the instrument's convergent validity. The questionnaire also successfully discriminated scores across educational levels, with doctoral students reporting higher brain fog scores than undergraduate and master's students.

**Conclusion:** Overall, the findings indicate that the Persian version of the Brain Fog Scale (BFS) is a valid, reliable, and culturally appropriate tool for assessing brain fog symptoms in the Iranian student population. This study confirms the scale's three factor structure and supports its use in future research and clinical assessments.

***Keywords:*** *Brain Fog Scale; cognitive disorder; COVID 19; cognitive load; validity; reliability.*

## 1. Introduction

Brain fog has increasingly emerged as a pressing interdisciplinary concern across neuroscience, psychology, and clinical medicine, reflecting a constellation of subjective and objective cognitive disturbances that span attention, memory, executive functioning, processing speed, and mental clarity. Although the term lacks formal diagnostic recognition, scholars consistently highlight its disruptive nature and its growing prevalence across diverse clinical and non-clinical populations. Contemporary neurocognitive literature describes brain fog as a complex, multidimensional cognitive disruption marked by impaired information processing, slowed thinking, reduced memory retrieval, and fluctuations in mental energy, often accompanied by a subjective sense of cognitive inefficiency (Lucius, 2021; McWhirter et al., 2023). These experiences are frequently embedded within broader biopsychosocial processes, illustrating that brain fog is not a singular deficit but rather a heterogeneous cognitive syndrome with diverse etiologies and symptom profiles.

A substantial body of recent literature has attributed the rise in reported brain-fog symptoms to the global impact of the COVID-19 pandemic. Numerous studies have documented persistent cognitive impairment among individuals who experienced SARS-CoV-2 infection, even months after recovery, placing "post-COVID cognitive dysfunction" at the forefront of public health discourse (Aghajani Mir, 2024; Nouraeinejad, 2023). Evidence suggests that neuroinflammatory processes, mitochondrial dysregulation, vascular injury, and autonomic dysfunction may underpin long-lasting cognitive sequelae associated with COVID-19. A growing subset of research highlights structural and functional abnormalities in patients with persistent cognitive symptoms, including blood-brain-barrier compromise and sustained systemic inflammation (Greene et al., 2024). These biological disruptions add compelling weight to the argument that post-COVID cognitive impairment resides not solely within subjective experience, but also in measurable neural alterations.

At the phenomenological level, qualitative studies have offered valuable insight into how individuals articulate their lived experiences of brain fog. Many report difficulties "keeping up" with mental tasks, managing multiple stimuli, and maintaining sustained concentration—issues that impede daily functioning and erode confidence in cognitive capabilities (Callan et al., 2022). Such first-person accounts provide a crucial complement to biomedical findings by illuminating the subjective distress and functional limitations associated with cognitive clouding. Importantly, these perspectives highlight cognitive overload and emotional fatigue as common companions to brain fog, demonstrating the need for multidimensional assessment tools capable of capturing both subjective and objective manifestations.

Although post-COVID conditions have elevated brain fog to global prominence, research clearly demonstrates that the phenomenon predates the pandemic and occurs across many chronic medical conditions. For example, chronic fatigue syndrome presents cognitive slowing, attentional lapses, and memory impairment long recognized as central components of the illness (Ocon, 2013). Individuals with postural orthostatic tachycardia syndrome (POTS) similarly describe fluctuating cognitive symptoms influenced by autonomic instability (Ross et al., 2013). Cancer-related cognitive impairment—often labeled "chemo brain"—is another well-documented construct in which survivors experience diminished executive functioning and memory deficits associated with treatment regimens (Bernstein et al., 2017; Gu et al., 2024). Evidence likewise indicates cognitive impairment among individuals with autoimmune or inflammatory disorders such as systemic lupus erythematosus (Mackay, 2015) and celiac disease (Makhlouf et al., 2017). These conditions provide compelling cross-clinical evidence that brain fog is not merely a byproduct of psychological stress or acute infection but may arise from diverse biological pathways including immune dysregulation, metabolic disruption, inflammatory responses, and neurovascular abnormalities.

Additionally, hormonal transitions, nutritional deficiencies, sleep disturbances, and thyroid dysfunction have been identified as contributors to brain-fog-like cognitive disturbances. In particular, hypothyroidism appears to produce cognitive clouding that patients often describe in terms strikingly similar to post-viral brain fog (Ettleson et al., 2022). The convergence of these findings suggests that brain fog constitutes a shared cognitive phenotype emerging from multiple physiological, psychological, and environmental sources—each presenting unique challenges for clinical assessment and therapeutic intervention.

Growing recognition of this complexity has prompted significant efforts to develop conceptual models and robust measurement instruments capable of capturing the multidimensional nature of brain fog. Researchers emphasize the importance of distinguishing between


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subjective cognitive complaints and objective neuropsychological deficits, noting that the relationship between the two may vary depending on underlying pathology, individual coping strategies, and contextual demands (Kverno, 2021). Structural equation modelling and other advanced psychometric approaches have further contributed to clarifying the latent structure of cognitive symptoms, enabling the identification of core dimensions that underlie diverse presentations (Kline, 2011). These insights have laid the groundwork for new assessment tools designed to enhance the precision, sensitivity, and cross-cultural applicability of brain-fog measurement.

Among contemporary measurement tools, the Brain Fog Scale (BFS) represents one of the most systematic attempts to operationalize the multifaceted phenomenon. Developed through a rigorous scale-construction process that integrated conceptual clarity with empirical factor validation, the BFS delineates brain fog into distinct but interrelated components including mental fatigue, reduced cognitive sharpness, and confusion (Atik & Manav, 2023; Debowska et al., 2023). Subsequent validation studies have reinforced the robustness of this factor structure, confirming the scale's reliability and construct validity across diverse populations. The BFS's emphasis on capturing subjective cognitive experience while maintaining psychometric rigor positions it as an important instrument for both research and clinical practice.

A complementary direction in recent scholarship involves disentangling subjective cognitive complaints from objective neurocognitive functioning. Although subjective experiences of "mental cloudiness" do not always correspond directly to measurable performance deficits, emerging evidence suggests a meaningful connection between perceived cognitive impairment, emotional distress, and behavioral functioning. Studies have shown that subjective brain fog is a significant predictor of functional impairment, even when objective testing yields borderline or normal results (Alim-Marvasti et al., 2024). These findings reinforce the importance of assessing subjective cognitive symptoms not as secondary or peripheral experiences, but as central indicators of broader neuropsychological and psychosocial functioning.

Recent neuroimaging studies have highlighted biomarkers and neural patterns consistent with altered connectivity, inflammation, and disrupted metabolism in individuals reporting persistent cognitive impairment. This growing body of evidence underscores the need for combining subjective assessment tools with emerging objective indices to form a comprehensive understanding of cognitive dysfunction (Delgado-Alonso et al., 2025). By offering converging evidence across multiple levels of analysis—behavioral, experiential, and neural—researchers are increasingly well-positioned to build integrative models of brain fog that align with evolving clinical realities.

Students comprise an especially relevant population for brain-fog research due to their heavy reliance on sustained concentration, working memory, and high-level reasoning. Cognitive difficulties at this developmental stage may impair academic performance, exacerbate stress responses, and diminish psychological well-being. Emerging international evidence suggests strong associations between cognitive symptoms, fatigue, mood disturbances, and environmental stressors in student groups (Anderson et al., 2022; Butardo et al., 2022). Understanding brain fog in this population is therefore not only theoretically important but also practically consequential for educational support systems, mental-health interventions, and broader policy considerations.

Furthermore, chronic diseases and lifestyle factors appear to interact with stress and high cognitive load to intensify cognitive symptoms among young adults. Research indicates that elevated cognitive load is consistently associated with worsened subjective cognitive functioning, suggesting that individuals with pre-existing vulnerabilities may experience amplified brain-fog symptoms under academic pressure (Ceban et al., 2021). These associations underscore the need for instruments that can sensitively capture variations in cognitive functioning within high-demand contexts.

At the same time, the global literature reveals that brain fog is a dynamically evolving construct—shaped by shifting health patterns, societal stressors, and scientific understanding. Although foundational work has shed light on some of the biological, psychological, and social contributors to cognitive clouding, much remains unknown regarding cross-cultural differences, prevalence trends, and risk factors among younger adult populations. In studies comparing clinical and non-clinical cognitive disturbances, it has been shown that symptom presentation and severity may vary depending on demographic and contextual factors, suggesting the importance of localized research initiatives (Mitchell & Woods, 2001). Likewise, clinical studies on post-infectious and treatment-related impairments continue to highlight the broad variability in cognitive trajectories, reflecting the complex interplay of individual and environmental influences (Mackay, 2015).


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Given these considerations, the validation of culturally adapted cognitive-assessment tools represents a critical step toward strengthening clinical and research infrastructures. Rigorous psychometric work ensures that instruments measure intended constructs consistently and accurately across groups, enabling meaningful comparison, early detection of impairment, and reliable evaluation of intervention outcomes. As researchers increasingly emphasize the need for precision in cognitive-health assessment, particularly in the wake of global health crises, developing validated instruments in diverse cultural contexts becomes essential to global scientific advancement (Ettleson et al., 2022; McWhirter et al., 2023).

Despite global progress, the Iranian context lacks a validated Persian version of one of the most widely used brain-fog measures—the Brain Fog Scale (BFS). Establishing such a tool would create new opportunities for clinical screening, longitudinal monitoring, cross-cultural research, and evidence-based academic support services. Given the substantial cognitive load experienced by students and the widespread influence of post-COVID conditions, psychometric evaluation of the BFS is both timely and necessary. The availability of a validated Persian instrument would enable more accurate assessment of cognitive symptoms, facilitate early detection of impairments, and support future neuropsychological and epidemiological research.

The aim of this study is to translate, culturally adapt, and psychometrically validate the Persian version of the Brain Fog Scale (BFS) among Iranian university students.

## 2. Methods and Materials

### *2.1. Study Design and Participants*

The present study was a descriptive-analytical, psychometric investigation with a cross-sectional design, conducted to examine the psychometric properties (validity and reliability) of the Persian version of the Brain Fog Scale (BFS) in an Iranian student population. The statistical population comprised all students enrolled at Islamic Azad University, Qom Branch, during the 2024-2025 academic year. From this population, 300 participants were selected using a convenience sampling method. This sample size was judged appropriate based on commonly recommended criteria for factor analysis (a minimum subject-to-item ratio of 10:1 or 20:1).

Data collection instruments in this study included the following procedures and measures:

- Content and face validity: Initially, content and face validity were evaluated by a panel of experts (clinical psychology, psychometrics, and neuroscience). Necessary revisions to the translation were made based on the panel's feedback.
- Construct validity: Construct validity was assessed using confirmatory factor analysis (CFA) implemented in AMOS version 24 to test and confirm the proposed three-factor structure.
- Convergent and discriminant validity: These were examined via Pearson correlation analyses between BFS scores and scores on related instruments.

To assess reliability:

- Internal consistency was estimated using Cronbach's alpha for the total scale and for each subscale.
- Test–retest reliability was evaluated by re-administering the questionnaire after a two-week interval to a subsample of 40 participants, and the intraclass correlation coefficient (ICC) was calculated.

### *2.2. Measures*

Brain Fog Scale (BFS): The Brain Fog Scale (BFS) was originally developed by Debouska et al. (2023) to assess symptoms associated with brain-fog disorder. The scale comprises 23 items covering three primary components: mental fatigue, reduced cognitive sharpness, and confusion. Responses are given on a five-point Likert scale ranging from Never (1) to Always (5). During the localization and psychometric evaluation of the Persian version, a forward translation followed by a back-translation was performed by two independent translators. The final version was conceptually and linguistically approved by a committee of psychology and language experts. The scale's internal consistency (Cronbach's alpha) for the total measure was estimated at 0.85. Test–retest reliability over a two-week interval for the subscales was reported as an average 0.45, indicating moderate temporal stability. For convergent validity, BFS scores were correlated with the Cognitive Load Questionnaire and the General Health Questionnaire, showing significant positive associations. For discriminant validity, measures of nutrition and physical activity were used, and the observed correlations supported satisfactory construct separation. The proposed three-factor structure was examined via CFA in AMOS, and fit indices such as RMSEA, CFI, and $\chi^2$/df supported model adequacy.

Cognitive Load Questionnaire: The Cognitive Load Questionnaire is a self-report instrument designed to


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measure perceived mental and processing load during cognitive tasks. It contains 8 items covering three components: intrinsic load, extraneous load, and overall load. Responses use a five-point Likert scale from Strongly Disagree to Strongly Agree. In the Persian version used in this study, forward and back translations followed international standards and face validity was confirmed by experts. Psychometric analysis yielded a Cronbach's alpha of 0.87 for the total scale, indicating good internal consistency. Convergent validity with the BFS was confirmed: higher cognitive load scores were associated with increased brain-fog symptoms. CFA supported the original three-factor structure in the Iranian student sample, with fit indices indicating acceptable model fit.

General Health Questionnaire (GHQ): The General Health Questionnaire (GHQ), developed by Goldberg and Williams, is a screening tool for psychological symptoms in the general population. The version used in this study includes 12 items with four response options ranging from Less than usual to More than usual. The scale comprises two main factors: positive mental health and psychological distress. The Persian GHQ has been widely used in Iran and its psychometric properties are well established. In the present study, Cronbach's alpha for the total scale was 0.89. The positive correlation between GHQ scores and BFS scores supported convergent validity. CFA confirmed the two-factor structure, and indices such as CFI, GFI, and RMSEA indicated good model fit.

Healthy Lifestyle Questionnaire (Physical Activity and Nutrition): To assess discriminant validity, the study employed a Healthy Lifestyle Questionnaire consisting of two subscales: physical activity and dietary pattern. This instrument evaluates individuals' behavioral habits related to physical health and uses a five-point Likert response format. Internal consistency for the physical activity and nutrition subscales in the study sample was 0.75 and 0.72, respectively. Negative correlations between scores on this questionnaire and BFS scores provided evidence of desirable discriminant validity for the BFS.

### *2.3. Data Analysis*

Data were analyzed using SPSS version 26 and AMOS version 24. In addition to descriptive statistics, the analyses included Pearson correlations, independent-samples t-tests, Cronbach's alpha, and model fit indices (e.g., RMSEA, CFI, GFI, $\chi^2$/df). All analyses aimed to determine the instrument's construct validity, convergent and discriminant validity, and reliability.

## 3. Findings and Results

For descriptive evaluation of the Brain Fog Scale (BFS) items, indices such as mean, standard deviation, skewness, and kurtosis were calculated. Item standard deviations ranged from 1.32 to 1.89. Skewness and kurtosis statistics for all items fell within acceptable limits (absolute skewness < 3 and absolute kurtosis < 8), supporting the univariate normality assumption according to Kline's (2011) criteria.

To assess the assumption of no multicollinearity among variables, Tolerance and Variance Inflation Factor (VIF) statistics were examined. All tolerance values exceeded 0.10 and all VIF values were below 3, indicating no problematic multicollinearity among the variables. These results permitted the application of more advanced analyses, such as confirmatory factor analysis.

**Table 1**

*Descriptive statistics: mean standard deviation skewness kurtosis*

| Item No. | Item (English) | Mean | Standard Deviation | Skewness | Kurtosis |
|---|---|---|---|---|---|
| 1 | My thinking speed has decreased | 1.57 | 0.984 | 0.173 | -0.376 |
| 2 | I feel my mind is tired | 2.26 | 1.037 | -0.103 | -0.538 |
| 3 | I feel a little fatigued | 2.47 | 0.962 | -0.211 | -0.693 |
| 4 | I easily lose my concentration | 2.22 | 1.069 | -0.051 | -0.811 |
| 5 | I get irritated more quickly than before | 2.17 | 1.147 | -0.116 | -0.836 |
| 6 | I feel drowsy | 2.21 | 1.113 | -0.005 | -0.878 |
| 7 | I have difficulty learning and remembering new information | 1.89 | 1.122 | 0.112 | -0.651 |
| 8 | Sometimes I forget names of objects or some words | 1.77 | 1.065 | 0.203 | -0.353 |
| 9 | I have difficulty with logical thinking | 1.32 | 1.018 | 0.679 | 0.103 |


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|---|---|---|---|---|---|
| 10 | It has become difficult for me to concentrate | 1.96 | 1.064 | 0.120 | -0.711 |
| 11 | I cannot think clearly and distinctly | 1.67 | 1.083 | 0.249 | -0.809 |
| 12 | Finding the right words to express my thoughts is difficult for me | 1.83 | 1.147 | 0.130 | -0.899 |
| 13 | Organizing my thoughts seems difficult | 1.90 | 1.066 | 0.141 | -0.668 |
| 14 | Sometimes I feel my mind is blank | 1.43 | 1.115 | 0.418 | -0.624 |
| 15 | I have difficulty understanding words while reading | 1.43 | 1.084 | 0.483 | -0.392 |
| 16 | It is difficult for me to understand others' speech | 1.01 | 0.943 | 0.878 | 0.627 |
| 17 | I often get lost in daydreams | 2.28 | 1.233 | -0.231 | -0.985 |
| 18 | I feel somewhat detached from reality | 1.63 | 1.257 | 0.306 | -0.996 |
| 19 | Sometimes I feel confused | 2.09 | 1.053 | -0.105 | -0.581 |
| 20 | I experience a state where my thoughts seem to have stopped | 1.34 | 1.040 | 0.441 | -0.423 |
| 21 | I feel lost | 1.34 | 1.218 | 0.746 | -0.319 |
| 22 | Sometimes I get distracted and feel like I'm living in my own world | 1.71 | 1.235 | 0.266 | -0.931 |
| 23 | I feel my thoughts move very quickly | 1.88 | 1.149 | 0.057 | -0.811 |

To evaluate the factorial validity of the Persian version of the Brain Fog Scale (BFS), confirmatory factor analysis (CFA) was conducted within a structural equation modeling framework. The aim of this analysis was to assess the instrument's conceptual structure and to test the validity of the proposed three-factor model based on its theoretical components. Maximum likelihood (ML) estimation was used to obtain model parameters.

In the first step, model adequacy was examined by comparing the independence model—in which all observed variables are assumed to be uncorrelated—with the proposed structural model. The independence model showed very poor fit: \ $\chi^2 = 724.27$ ،df = 15 ،$\chi^2/df = 48.29$ ،$p < 0.001$) $p < 0.001$/, indicating its inability to account for the relationships among variables and thereby supporting the superiority of the hypothesized model.

Because there is no universal agreement on a single preferred fit index, a set of commonly used fit statistics was evaluated simultaneously following Arbuckle and Wothke's approach. The indices considered included chi-square, the chi-square to degrees of freedom ratio ($\chi^2/df$), the Goodness-of-Fit Index (GFI), the Comparative Fit Index (CFI), the Adjusted Goodness-of-Fit Index (AGFI), and the Root Mean Square Error of Approximation (RMSEA).

Next, the proposed three-factor model—comprising mental fatigue, cognitive performance decline, and confusion—was tested. CFA results indicated acceptable fit to the collected data, with fit indices as follows: $\chi^2 = 212.34$ ، df = 79 ،$\chi^2/df = 2.67$ ،GFI = 0.94 ،AGFI = 0.91 ،CFI = 0.96 & RMSEA = 0.065. Factor loadings ranged from 0.59 to 0.82, indicating that items made substantial contributions to their respective factors. These findings support the acceptable fit of the conceptual model to the empirical data.

**Table 2**

*Goodness-of-fit indices and factor loadings for competing measurement models*

| Competing models | $\chi^2$ | $\chi^2/df$ | GFI | AGFI | CFI | RMSEA | Loadings |
|---|---|---|---|---|---|---|---|
| Independence model | 724.27 | 48.29 | 0.50 | 0.31 | 0.00 | 0.38 | - |
| Two-factor model | 212.34 | 2.67 | 0.94 | 0.91 | 0.96 | 0.065 | 0.59 – 0.82 |



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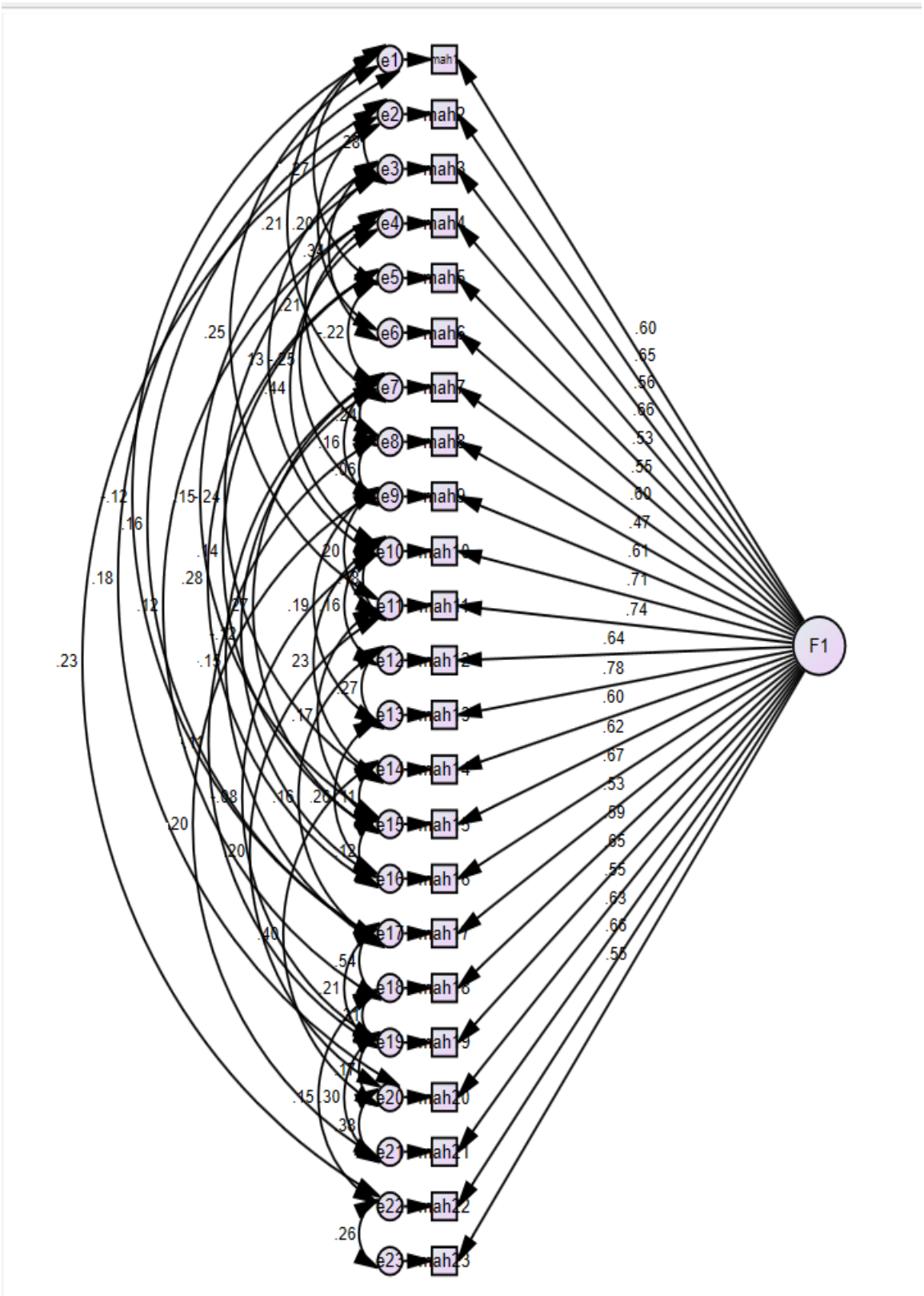
**Figure 1**

*Confirmatory factor analysis model of the Brain Fog Scale items with standardized coefficients (modified model).*



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The results showed that all regression weights (factor loadings) were statistically significant ($p < 0.001$). The obtained factor loadings ranged from 0.62 to 0.87, indicating strong associations between the items and their respective factors.

Item–total correlations ranged from 0.54 to 0.73. In every case, Cronbach's alpha decreased when any single item was removed, which supports the importance of each item within the overall scale structure. Cronbach's alpha coefficients were 0.85 for the Mental Fatigue factor, 0.83 for the Reduced Cognitive Sharpness factor, and 0.80 for the Confusion factor.

**Table 3**

*Cronbach's alpha item-total correlations alpha-if-item-deleted for three-factor model*

| Component | Item | Factor loading | Item–total correlation | Alpha if item deleted |
|---|---|---|---|---|
| Mental fatigue | 1 | 0.72 | 0.64 | 0.83 |
| Mental fatigue | 2 | 0.76 | 0.66 | 0.82 |
| Mental fatigue | 3 | 0.70 | 0.60 | 0.84 |
| Mental fatigue | 4 | 0.75 | 0.65 | 0.83 |
| Mental fatigue | 5 | 0.73 | 0.63 | 0.83 |
| Mental fatigue | 6 | 0.71 | 0.61 | 0.83 |
| Mental fatigue | 7 | 0.69 | 0.60 | 0.84 |
| Reduced cognitive sharpness | 8 | 0.74 | 0.66 | 0.80 |
| Reduced cognitive sharpness | 9 | 0.77 | 0.68 | 0.79 |
| Reduced cognitive sharpness | 10 | 0.75 | 0.65 | 0.80 |
| Reduced cognitive sharpness | 11 | 0.78 | 0.67 | 0.80 |
| Reduced cognitive sharpness | 12 | 0.82 | 0.69 | 0.79 |
| Reduced cognitive sharpness | 13 | 0.79 | 0.68 | 0.80 |
| Reduced cognitive sharpness | 14 | 0.74 | 0.65 | 0.81 |
| Reduced cognitive sharpness | 15 | 0.70 | 0.61 | 0.82 |
| Reduced cognitive sharpness | 16 | 0.68 | 0.60 | 0.83 |
| Reduced cognitive sharpness | 17 | 0.66 | 0.59 | 0.83 |
| Mental confusion | 18 | 0.69 | 0.60 | 0.82 |
| Mental confusion | 19 | 0.67 | 0.59 | 0.82 |
| Mental confusion | 20 | 0.62 | 0.54 | 0.83 |
| Mental confusion | 21 | 0.65 | 0.57 | 0.82 |
| Mental confusion | 22 | 0.63 | 0.56 | 0.83 |
| Mental confusion | 23 | 0.68 | 0.60 | 0.82 |

Cronbach's alpha (total scale): 0.89.

Range of factor loadings: 0.62 to 0.82.

Item–total correlations: All items > 0.54, indicating acceptable alignment of items with the overall scale.

Alpha if item deleted: Alpha decreased when any item was removed, indicating that no item reduces the scale's reliability; each item contributes positively to internal consistency.

A multi-group confirmatory factor analysis (MG-CFA) was conducted to examine the stability of the factor structure of the Persian Brain Fog Scale (BFS) across gender groups. The primary aim was to evaluate the degree of measurement and structural equivalence of the instrument between female and male students.

In the first step, the configural invariance model—imposing no constraints on factor loadings, error variances, or covariances—was estimated. The results indicated good fit for this baseline model in both groups. These findings suggest that the three-factor configuration of the scale is



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equivalent across genders and that both groups share the same basic factor structure.

In the second step, metric invariance was tested by constraining factor loadings to be equal across the two groups. The analysis showed that imposing this constraint did not produce a significant deterioration in model fit; the chi-square difference was non-significant. Therefore, items load on the underlying factors with comparable strength in both female and male students.

In the third step, error invariance was examined by constraining measurement error variances to equality across groups. With these constraints in place, the model continued to show acceptable fit, supporting equivalence of item error variances between genders.

Finally, structural invariance was assessed by constraining factor variances and covariances to be equal across groups. Comparison of the constrained and unconstrained models revealed no significant difference, indicating that the pattern of relationships among the BFS factors is similar for female and male students.

Taken together, these results indicate that the Persian BFS is a valid and reliable instrument for use across both gender groups and that scores can be meaningfully compared between female and male students.

**Table 4**

*Multi-group CFA results for female and male students*

| Model | $\Delta\chi^2$ | $\Delta$df | P |
|---|---|---|---|
| Model with constrained factor loadings | 1.75 | 4 | 0.89 |
| Model with constrained error terms | 3.01 | 5 | 0.77 |
| Model with constrained factor variances and covariances | 2.45 | 7 | 0.81 |

To examine the criterion and concurrent validity of the Persian version of the Brain Fog Scale (BFS), correlations between BFS scores and scores on the Cognitive Load Scale were analyzed. Because cognitive load is a theoretically related construct to brain fog, a significant relationship between the two instruments was expected.

Pearson correlation analysis showed a positive and statistically significant association between the total brain-fog score and the total cognitive-load score: ($r = 0.61$, $p < 0.01$). This result indicates that individuals reporting higher levels of brain fog also concurrently experience higher levels of cognitive load.

Correlations between the BFS subscales (for example, mental fatigue, confusion, and reduced concentration) and the cognitive-load components (such as perceptual load, processing load, and working-memory load) were also significant and in the theoretically expected directions (see Table 5). These correlation patterns align with existing theories about the brain-fog construct and support both the concurrent and criterion validity of the Persian BFS.

Therefore, the instrument used in this study not only demonstrates a satisfactory factor structure but also effectively discriminates between different degrees of cognitive load in individuals.

**Table 5**

*Correlations between BFS components and Cognitive Load components*

| BFS components | Intrinsic load | Mental processing load | Working memory load | Overall cognitive load |
|---|---|---|---|---|
| Mental fatigue | 0.51** | 0.57** | 0.48** | 0.61** |
| Mental confusion | 0.46** | 0.49** | 0.52** | 0.58** |
| Reduced attention and concentration | 0.43** | 0.50** | 0.55** | 0.59** |
| Total BFS score | 0.53** | 0.60** | 0.58** | 0.66** |

## 4. Discussion and Conclusion

The present study examined the psychometric properties of the Persian version of the Brain Fog Scale (BFS) among Iranian university students, and the findings collectively demonstrate that the adapted instrument possesses strong factorial validity, internal consistency, structural stability, and meaningful convergent and discriminant validity. The confirmatory factor analysis supported the theorized three-factor structure—mental fatigue, reduced cognitive



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sharpness, and confusion—with robust loadings across items, indicating that the Persian BFS accurately captures the multidimensional nature of brain fog as theorized in prior literature (Atik & Manav, 2023; Debowska et al., 2023). The acceptable fit indices further affirm the suitability of this structure for the Iranian student population. These results align with long-standing conceptual descriptions of brain fog as a multi-layered cognitive disturbance involving attentional deficits, reduced processing capacity, and episodic cognitive disorganization (Lucius, 2021; McWhirter et al., 2023). In this sense, the Persian BFS succeeds in translating and operationalizing neurocognitive constructs that have been well-documented across diverse global contexts.

The strong psychometric performance of the scale is consistent with emerging scientific evidence linking brain fog to complex biological and psychological processes. In particular, studies have emphasized the potential role of inflammation and neurovascular dysregulation in generating persistent cognitive symptoms, especially among individuals with post-COVID conditions (Greene et al., 2024; Nouraeinejad, 2023). Such mechanisms may provide the physiological basis for the experiences of cognitive slowing and confusion captured by the BFS factors, thereby reinforcing the validity of measuring brain-fog symptoms through a structured psychometric tool. Furthermore, the strong internal consistency coefficients observed in this study echo earlier research demonstrating that brain fog is expressed in patterned, predictable ways across clinical populations such as chronic fatigue syndrome, autoimmune disorders, and neurological conditions (Mackay, 2015; Makhlouf et al., 2017; Ocon, 2013). These converging findings suggest that although the causes of brain fog may differ, the subjective symptom profiles measured by the BFS remain stable and interpretable across different populations.

The results also highlighted meaningful associations between BFS scores and cognitive load, where higher levels of brain-fog symptoms were strongly correlated with higher perceived mental load. This finding mirrors theoretical and empirical links identified in global research, wherein cognitive overload, decreased attentional bandwidth, and emotional fatigue act as reinforcing contributors to the subjective experience of mental clouding (Callan et al., 2022; Ceban et al., 2021). Moreover, the significant associations with general health status reinforce prior studies suggesting that brain fog often emerges at the intersection of mental, physical, and emotional health disturbances. Research across diverse groups—including individuals with viral infections, hormonal dysfunction, chronic inflammation, and prolonged stress—demonstrates that compromised health predicts disruptions in working memory, processing speed, and mental clarity (Anderson et al., 2022; Ettleson et al., 2022). These patterns align with the present study's findings and further support the convergent validity of the Persian BFS.

Additionally, discriminant validity was established through weak associations between BFS scores and lifestyle variables such as physical activity and nutrition. This is in line with the broader literature emphasizing that while healthy behaviors may influence energy levels and generalized well-being, the deeper neurocognitive processes underlying brain fog operate through more specific neurological, inflammatory, or psychological pathways rather than general lifestyle variables alone (Mitchell & Woods, 2001; Ross et al., 2013). The instrument's ability to differentiate between symptom-relevant and symptom-irrelevant constructs contributes to its usefulness for both clinical and academic contexts in Iran.

The results of multigroup structural invariance analysis indicated that the BFS operates equivalently among male and female students, with no meaningful differences in factor loadings, error variances, or covariance structures. This gender invariance is significant, as it allows for reliable comparison of brain-fog experiences across male and female populations, a finding consistent with emerging cross-population studies showing that subjective cognitive symptoms do not differ significantly by gender when measurement tools retain conceptual and factorial stability (Bernstein et al., 2017; Kverno, 2021). The structural equivalence also suggests that gender-based patterns of reporting cognitive difficulties—often influenced by cultural or social factors—do not interfere with the scale's psychometric integrity, further validating its utility in diverse demographic applications.

Broader international findings reinforce the significance of having a reliable instrument for evaluating brain fog, especially given the growing recognition of the phenomenon in post-viral, metabolic, autoimmune, and psychological conditions. Recent research has demonstrated that subjective complaints of cognitive dysfunction reliably predict real-world impairments in academic, professional, and interpersonal functioning, even when objective neuropsychological testing yields mixed results (Alim-Marvasti et al., 2024; Gu et al., 2024). This pattern supports the argument that subjective experience itself is a critical clinical indicator, particularly in populations experiencing


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chronic cognitive strain or high academic workload. The BFS, therefore, holds unique value by capturing symptom dimensions that are strongly linked to functional outcomes but may not always be fully represented through performance-based testing alone.

The findings of this study are also consistent with literature pointing to the importance of understanding brain fog as a subjective cognitive disturbance embedded within emotional, physiological, and social contexts. Qualitative investigations have shown that individuals struggling with brain fog often report frustration, reduced confidence, diminished sense of identity, and challenges sustaining social participation (Atik & Manav, 2023; Callan et al., 2022). These experiences parallel the cognitive and emotional domains assessed in the BFS, suggesting conceptual harmony between the instrument and the lived realities it intends to quantify. The context of Iranian university students further underscores the relevance of the BFS, as high academic pressure, increased digital engagement, and post-pandemic learning environments may intensify vulnerability to cognitive disruptions.

This study's findings also resonate with neurological and neuroimmunological models that have emerged in recent years. Research has repeatedly shown that brain fog can be driven by immune activation, altered neurotransmission, and blood-brain-barrier permeability—mechanisms that have been reported in individuals recovering from COVID-19, autoimmune disorders, and other inflammatory conditions (Aghajani Mir, 2024; Delgado-Alonso et al., 2025). These biological insights support the conceptualization of brain fog as more than a psychological phenomenon and validate the importance of instruments that capture both subjective cognitive fatigue and transient confusion. The Persian BFS demonstrated sensitivity to these multidimensional aspects, reinforcing its construct validity within a neurobiological and cognitive-psychological framework.

Furthermore, the present study supports existing evidence that brain fog is not a uniform condition but rather a heterogeneous syndrome that varies depending on disease context, stress exposure, metabolic factors, and environmental demands. Studies in chronic autoimmune disease (Mackay, 2015), gluten sensitivity (Makhlouf et al., 2017), and post-viral syndromes (Asadi-Pooya et al., 2022) all reveal diverse symptom patterns that nonetheless converge around the core constructs measured by the BFS. This reinforces the scale's theoretical robustness and its adaptability across populations.

Overall, the study's findings highlight the importance of having a psychometrically sound Persian instrument to assess brain-fog symptoms, enhancing clinical screening, epidemiological research, and academic intervention strategies within Iran. Considering the rising prevalence of cognitive complaints among students, healthcare workers, and individuals recovering from viral infections, the BFS offers a valuable linguistic and cultural tool for monitoring cognitive health in diverse Iranian contexts. This work aligns with international efforts to refine cognitive-symptom measurement tools and contributes meaningfully to the global literature on subjective cognitive impairment.

This study's limitations should be acknowledged. First, the sample consisted exclusively of university students from a single institution, limiting the generalizability of findings to broader age groups and clinical populations. Second, the cross-sectional design inhibits causal inferences regarding the relationships between brain fog, cognitive load, and general health indicators. Third, although self-report measures are essential for capturing subjective cognitive experiences, they may be influenced by situational factors such as mood, stress, or response bias. Finally, the test–retest subsample was relatively small, suggesting that future studies should evaluate temporal consistency across larger and more diverse groups.

Future research should examine the Persian BFS across clinical populations, such as individuals with autoimmune disorders, chronic fatigue, long COVID, and neurological conditions, to establish broader clinical validity and diagnostic utility. Longitudinal studies are recommended to assess the sensitivity of the BFS to changes over time and to identify predictors of cognitive recovery or decline. Researchers should also consider integrating neuroimaging, neurophysiological markers, and objective cognitive assessments to explore the relationship between subjective symptoms and underlying neural mechanisms. Finally, establishing normative data across different age groups, socioeconomic backgrounds, and educational levels would enhance the instrument's applicability for population-level research.

Practitioners may use the Persian BFS as a screening tool for detecting emerging cognitive disturbances among students and other high-demand groups, enabling earlier intervention and targeted cognitive support. Educational institutions can incorporate BFS-based assessments into academic counseling and mental-health programs to monitor student well-being. Clinicians may also integrate BFS scores into broader diagnostic evaluations to track cognitive


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changes over time and tailor treatment plans accordingly. The scale's multidimensional structure allows practitioners to identify specific areas of cognitive vulnerability—mental fatigue, reduced clarity, or confusion—and design interventions that address the most affected domains.

## Authors' Contributions

All authors significantly contributed to this study.

## Declaration

In order to correct and improve the academic writing of our paper, we have used the language model ChatGPT.

## Transparency Statement

Data are available for research purposes upon reasonable request to the corresponding author.

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## Declaration of Interest

The authors report no conflict of interest.

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## Ethical Considerations

In this study, to observe ethical considerations, participants were informed about the goals and importance of the research before the start of the interview and participated in the research with informed consent.

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