Verbal Fluency Difficulties in Chinese Insomnia Patients: Insights from Semantic and Phonemic Tasks

Yumeng Lyu[1,3], Shane Lindsay[1], Shufang Wang[2], Yongliang Zheng[3*]

[1] *School of Psychology and Social Work, University of Hull*
[2] *Yancheng Third People's Hospital*
[3] *Jiangsu Medical College*

[*] *Corresponding author:* Yongliang Zheng, *12131@jsmc.edu.cn*

Abstract

Insomnia is a prevalent sleep disorder associated with cognitive difficulties, including reduced performance in executive control and semantic memory. This study explores the impact of insomnia on language retrieval processes using the Chinese Verbal Fluency Test (VFT), addressing the need for cognitive research beyond English-speaking populations. We hypothesized that insomnia-related difficulties in semantic memory and executive control would result in reduced VFT performance. Participants with insomnia (N = 20) and matched healthy controls (N = 20) were recruited from a community outpatient clinic in China to complete an online Chinese VFT, generating words for semantic categories (e.g., animals) and phonemic conditions (e.g., words beginning with "bai" [白, "white"]). The insomnia group showed significantly lower performance across both task types compared to controls, with particularly pronounced differences in semantic fluency. Analysis of clustering and switching patterns revealed that participants with insomnia generated fewer switches specifically during semantic tasks, suggesting difficulties in executive control processes. These findings suggest that insomnia is associated with reduced efficiency in both semantic memory retrieval and executive control components of verbal fluency, contributing to our understanding of how sleep disturbances influence language processing across different linguistic contexts.

Keywords: Insomnia, Verbal Fluency Test (VFT), Chinese language, Cognitive performance, Executive function, Semantic memory, Clustering and Switching analysis, Phonemic fluency

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Insomnia is a pervasive sleep disorder characterised by persistent difficulties in initiating and maintaining sleep, resulting in non-restorative sleep (Riemann et al., 2023). Insomnia affects approximately 30% of the global population. According to clinical criteria (e.g., DSM-5), insomnia disorder affects about 10% of the population, while insomnia symptoms, such as difficulty falling asleep or staying asleep, are more common, affecting approximately 20% (Morin & Jarrin, 2022). Insomnia is not only a significant health concern, but is also associated with a range of cognitive difficulties, including reduced performance in episodic memory, working memory, attention, and executive control (Fortier-Brochu et al., 2012; Fortier-Brochu et al., 2014; Wardle -Pinkston et al., 2019; Brownlow et al., 2020; Chen et al., 2020; Kong et al., 2023). These cognitive difficulties contribute to reduced daily functioning, poor performance in professional and academic settings, difficulty concentrating, and reduced memory capacity (Fortier-Brochu et al., 2012; Spencer et al., 2017; Hirshkowitz et al., 2015; Yassin et al., 2020).

Language performance, a critical aspect of daily communication and cognitive function, has been shown to be adversely affected by insomnia (McGregor et al., 2015; Jacobs et al., 2021). Insomnia patients may experience a range of language-related difficulties, including challenges in word retrieval, a monotonous speech pattern, stuttering, and reduced verbal memory performance (Harrison & Horne, 1997; McGregor et al., 2015; Chen et al., 2020; Jacobs et al., 2021). These difficulties are observed across different age groups and are exacerbated in populations with comorbid conditions such as depression and schizophrenia (Linlin et al., 2023; Naismith et al., 2011; Naismith et al., 2009).

The process of speech and language production involves the activation of semantic memory and the retrieval of phonological codes, which are intrinsically linked to executive control mechanisms (Delis, Kaplan, & Kramer, 2001; Luo et al., 2010). Insomnia-related disruptions in memory consolidation and executive function, domains critically supported by the frontal cortex, can therefore lead to significant difficulties in language production and retrieval (Fortier -Brochu et al., 2012; Ballesio et al., 2019; Fortier-Brochu & Morin, 2014; Shao et al., 2014).

Research suggests that insomnia may affect language processing by impacting both semantic memory and executive control (McGregor et al., 2015). Sleep plays a crucial role in memory consolidation, including the integration of new information into existing semantic networks (Lindsay & Gaskell, 2010; Rasch & Born, 2013). Insomnia may disrupt this process, potentially affecting the efficiency of semantic memory (Fortier-Brochu et al., 2012). Additionally, chronic sleep disturbance has been associated with alterations in executive functions, including a reduced ability to inhibit irrelevant information (Ballesio et al., 2019; Fortier-Brochu & Morin, 2014). These cognitive changes may contribute to

difficulties in language processing, such as reduced working memory capacity and slower information retrieval (Shao et al., 2014).

The Verbal Fluency Test (VFT) is a widely used tool for assessing language proficiency and executive control (Lezak, 2012; Troyer et al., 1997). It consists of two tests: a semantic fluency test that requires participants to generate words within a given category, and a phonemic fluency test that requires them to generate words starting with a specific letter (Lezak, 2012). Both tasks are typically administered within a one-minute timeframe (Aita et al., 2018; Shao et al., 2014). The VFT engages cognitive processes likely impacted by insomnia, such as retrieving information from semantic memory, employing effective retrieval strategies, and using executive control to filter responses, inhibit irrelevant information, and adhere to task constraints (Aita et al., 2018; Shao et al., 2014). Therefore, the VFT could be a valuable tool for investigating specific language-related performance differences associated with insomnia.

Previous research on VFT performance in individuals with insomnia presents conflicting results. A number of studies report no significant differences between insomnia and control groups. For instance, Altena et al. (2008), Rezende et al. (2024), Zhou et al. (2024), and Wu et al. (2023) found no differences in either semantic or phonemic fluency. Other studies observed no differences specifically in semantic fluency (Sun et al., 2017; Ling et al., 2016) or phonemic fluency (Orff et al., 2007; Fortier-Brochu et al., 2014). Fernandez‐Mendoza et al. (2010) also reported no differences, although they did not specify the VFT condition used. However, some studies have reported reduced VFT performance among insomnia patients. Koo et al. (2017) found that insomniacs generated fewer responses in both semantic and phonemic tests compared to the normal population. Other studies reported worse performance specifically in semantic fluency tests for insomnia patients (Chen et al., 2017; Noh et al., 2012; Mendelson et al., 1984; Fortier-Brochu et al., 2014).

The conflicting findings in VFT performance among individuals with insomnia may stem from limitations in the test's sensitivity to cognitive changes. While behavioural measures often show no significant differences, neuroimaging studies have revealed alterations in brain areas related to verbal fluency in insomnia patients, such as reduced hippocampal volume and changes in frontal and temporal cortical regions (Altena et al., 2008). This discrepancy between behavioural and neurological findings suggests that the VFT, in its conventional scoring form, may not capture the full extent of cognitive changes associated with insomnia.

The VFT involves multiple cognitive processes, including retrieving words from semantic memory, inhibiting irrelevant responses, and activating the correct ones. The phonemic fluency test relies more heavily on executive control for letter-based retrieval, while the semantic fluency test depends on both executive control and efficient access to semantic knowledge (Delis et al., 2001; Luo et al., 2010; Paap et al., 2017; Sandoval et al., 2010; Shao et al., 2014). Fortier-Brochu et al. (2010) noted the difficulty of attributing complex cognitive tasks to single processes, suggesting

that the VFT's reliance on correct response scores alone might mask subtle cognitive differences in individuals with insomnia.

To address these limitations and better understand the cognitive processes underlying VFT performance in insomnia, more informative analytical approaches may be necessary. One such method is cluster and switch analysis, which provides more detailed information about dynamic semantic retrieval and executive control processing during the VFT. Clustering refers to the number of responses generated within a given semantic subcategory or with similar phonemic characteristics, while switching measures how often participants shift between subcategories or clusters (Troyer et al., 1997; Carpenter et al., 2021). Clustering is seen to relate to semantic retrieval efficiency, while switching reflects executive control particularly cognitive flexibility and shifting (Troyer et al., 1997; Carpenter et al., 2021). Currently, no studies on insomnia have used cluster and switch analyses. This approach could help determine whether individuals with insomnia show differences in specific aspects of verbal fluency, potentially revealing subtle cognitive changes that are not apparent in overall VFT scores.

The variability in VFT performance across insomnia studies suggests that insomnia patients may employ cognitive compensation strategies, relying on alternative cognitive resources to maintain performance in some domains required by the VFT. Cluster and switch analysis could potentially reveal these compensatory mechanisms by providing a more detailed picture of how individuals with insomnia navigate the task. For instance, if insomnia primarily affects executive function, one might expect to see reduced switching frequency but preserved cluster sizes. Conversely, if semantic retrieval is more impacted, one might observe smaller cluster sizes but normal switching patterns.

Another approach might be using language with more cognitive demand. Studying VFT performance in Chinese-speaking populations offers a unique opportunity to uncover these mechanisms and resolve some of the inconsistencies observed in previous insomnia research. The Chinese language adds complexity to the VFT due to its tonal and logographic nature, which may impose greater cognitive load and demands on executive control (Quan et al., 2015; Chan & Chen, 2004; Liu et al., 2022). Furthermore, the Chinese VFT differs from versions in other languages primarily in its phonemic fluency component. While the semantic fluency test remains largely similar across languages, the phonemic test in Chinese typically requires generating words based on a given character rather than a letter. These unique features of the Chinese language and VFT may introduce additional cognitive demands, particularly in executive function and language processing. Therefore, studying the impact of insomnia on VFT performance within a Chinese context may reveal specific cognitive difficulties that are not apparent in other linguistic settings.

Studies conducted in Chinese populations have similarly shown mixed results regarding insomnia and VFT performance. Chen et al. (2017) found poorer semantic fluency performance among Chinese insomnia patients compared to the healthy population, while the phonemic fluency test was not included in their study. However, other studies have not observed significant differences in overall VFT performance

between insomnia patients and controls. Neuroimaging studies (Sun et al., 2017; Zhou et al., 2024; Gong et al., 2022; Wu et al., 2023) have revealed alterations in brain regions associated with language processing and executive function during VFT performance in insomnia patients, despite finding no behavioural differences in verbal fluency. Other studies have examined VFT performance in Chinese-speaking individuals with comorbid insomnia and other conditions (e.g., Liu et al., 2020; Li et al., 2024; Xu et al., 2023). Crucially, the absence of clustering and switching analyses in previous studies leaves an important gap in understanding how insomnia affects domain-specific verbal fluency patterns in Chinese speakers. These analytical approaches could help explain the cognitive mechanisms underlying differences in semantic and phonemic retrieval associated with sleep disturbances.

To advance understanding in this area, our study will compare the performance of Chinese individuals with insomnia to those with normal sleep on both phonemic and semantic fluency tests, incorporating clustering and switching analyses. This approach aligns with growing calls to expand psycholinguistic and cognitive research beyond English-speaking populations (Bak, 2016; Marian & Hayakawa, 2021). By examining these specific components of verbal fluency, we can potentially identify cognitive changes that are particularly relevant to the Chinese language context, addressing the need for language-specific investigations in cognitive science (Byers-Heinlein et al., 2021). This research may contribute to a broader understanding of how sleep disturbances affect language processing and cognitive function across different linguistic and cultural contexts, responding to the demand for more diverse and representative samples in psychological research (Henrich et al., 2010).

Thus, this study examined VFT performance in Chinese-speaking adults with insomnia and healthy controls in both semantic and phonemic tests. Beyond the traditional measure of correct responses, we also used clustering and switching measures to further explore the processes related to semantic retrieval and executive control. We hypothesized two main effects. At the group level, the insomnia group would generate fewer correct responses overall than the control group. At the task level, participants would produce more correct responses in the semantic fluency test compared to the phonemic fluency test. Given the unique features of the Chinese language and its heightened engagement of executive control processes, we expected the Chinese VFT to be particularly sensitive to insomnia-related cognitive differences. For the clustering and switching measures, we predicted a similar pattern of main effects across both measures: the insomnia group would perform worse than the control group, and performance would be better in the semantic fluency test compared to the phonemic fluency test. Beyond the main effects, we were interested in potential interactions. For cluster number, we may observe an interaction between group and test type, with the insomnia group showing a more pronounced reduction in performance in the phonemic fluency test compared to the semantic fluency test. This interaction was expected to reflect the greater executive control demands of the phonemic fluency test, which could be particularly challenging for insomnia patients. While for the number of switches, we might not see an interaction, suggesting that insomnia's impact on switching ability would be consistent across both test types.

Additionally, recruitment and data collection among populations with chronic diseases have been reported to face several challenges, particularly in community- or home-based settings (Holden et al., 2015). These challenges include a lack of initial trust and mutual understanding between researchers and participants, participants' busy personal schedules, and logistical barriers related to study procedures (Holden et al., 2015). To address these issues, we employed an online follow-up system that is routinely used by local hospitals and community clinics. This approach helped mitigate trust-related concerns, as participants engaged through a familiar and trusted platform rather than interacting directly with unfamiliar researchers. It also minimised scheduling conflicts and logistical burdens for participants. Although no studies have specifically examined the reliability of an online VFT in insomnia populations, previous work has found no significant differences in performance between traditional and online versions of the VFT and has demonstrated acceptable reliability in healthy young adults (Pesau et al., 2021).

Methods and Materials

Participants

Forty native Mandarin-speaking participants aged over 18 years were recruited from the Jiangsu Medical Vocational College Xindu Community Outpatient Clinic and the surrounding Xindu community in Yancheng Province. The sample included twenty healthy controls (7 males, 13 females; mean age = 36.6 years, SD = 16.9 years) and twenty individuals diagnosed with insomnia (7 males, 13 females; mean age = 44.9 years, SD = 17.7 years). Sample size was determined primarily by practical constraints, including limited access to participants meeting diagnostic criteria for chronic insomnia, available funding, and the timeframe available for data collection at the clinic.

All participants underwent medical history interviews and diagnosis by professional doctors and were assessed using the Pittsburgh Sleep Quality Index (PSQI; Buysse et al., 1989) to evaluate recent sleep quality. The insomnia group completed sleep diaries to record sleep status the night before testing for the past week. These diaries were used to confirm the persistence of sleep disturbances and helped to support insomnia diagnostic criteria. Control participants were not required to complete sleep diaries, as they had no history of sleep complaints, PSQI scores $\leqslant$ 5, and had reported no insomnia-related symptoms during clinical interview.

Participants in the insomnia group were diagnosed with chronic insomnia disorder by a healthcare professional using both DSM-5 criteria (American Psychiatric Association, 2013) and the Criteria for Disease Diagnosis in TCM (China Association of Chinese Medicine, 2012). Inclusion criteria required participants to be over 18 years of age, have a PSQI score above 9, and to have been abstinent from antidepressants, psychotropic medications potentially affecting cognitive function, and sleep-inducing medications (e.g., benzodiazepines or non-benzodiazepines) for at least one month prior to enrolment. Exclusion criteria included: individuals with severe mental illness or suicidal tendencies; those with

substance use disorders; individuals with cognitive, visual, or auditory impairments; a history of epilepsy, mania, bipolar disorder, or parasomnia; current use of medications known to cause insomnia (e.g., steroids); and those suspected of having severe sleep apnoea (defined by ≥ 5 positive responses on items assessing snoring, tiredness, observed apnoea, high blood pressure, body mass index, age, neck circumference, restless legs syndrome, circadian rhythm sleep disorders, or personal or family (first-degree relatives) history of parasomnia).

The control group comprised healthy individuals with no history of sleep disorders (confirmed through clinical interview by healthcare professionals); PSQI global score ≤ 5 and no self-reported insomnia symptoms (e.g., difficulty initiating/maintaining sleep) in the past 6 months; who had not taken any medication within the past month, and who had obtained sufficient sleep (at least 7 hours) the night before the testing session. In addition, control participants were screened for psychiatric, neurological, and sleep related conditions using the same structured interview approach as the insomnia group and were excluded if they met any of the exclusion criteria applied to the patient group.

Participation was entirely voluntary, and all participants provided written informed consent prior to enrolment. The study protocol was approved by the Ethics Committee of Yancheng Third People's Hospital (Approval No: 2021-022-01).

No formal estimate of general cognitive ability was administered. The recruited participants in the insomnia and control groups were compared in age and years of education.

Materials

Pittsburgh Sleep Quality Index (PSQI).

The PSQI (Buysse et al., 1989) is a 19-item self-report questionnaire that assesses sleep quality over the past month. It includes seven component scores: subjective sleep quality, sleep latency, sleep duration, habitual sleep efficiency, sleep disturbances, use of sleeping medication, and daytime dysfunction, each ranging from 0 to 3. The global score ranges from 0 to 21, with higher scores indicating poorer sleep quality.

The Chinese version of the PSQI has demonstrated good psychometric properties, with a Cronbach's alpha above .80 and satisfactory test-retest reliability (Tsai et al., 2005). A cut-off score of > 5 is generally used to identify poor sleepers across all versions of the PSQI (Buysse et al., 1989). However, in this study, a stricter threshold of ≥ 9 was adopted for the inclusion of participants with insomnia to meet the clinical practice (Cheuk et al., 2012). Similar criteria have also been used in Chinese-language studies (Hu et al., 2003; Liu et al., 2021).

Verbal Fluency Test (VFT).

In this study, we adopted a version of a Chinese VFT developed by Quan et al. (2015). Their phonemic fluency test items were chosen based on frequency, educational familiarity, and ease of use, making them accessible across different educational backgrounds. Although formal reports on the psychometric properties of this version are not available, it has been widely adopted in subsequent Chinese VFT

studies (Wang et al., 2017; Ji et al., 2020; Luo et al., 2022), indicating its acceptability and feasibility in Chinese populations.

This led to three phonemic cues ("bai", "tian", "da") in the phonemic fluency task and three semantic categories (vegetables, fruits, and animals) in the semantic fluency task. Participants were asked to generate as many appropriate responses as possible within one minute. Responses were scored for correct responses, clustering, and switching. The clustering and switching analyses followed the procedures described by Troyer et al. (1997) and Ledoux et al. (2014).

Procedure

Prior to the experiment, all participants underwent medical history interviews conducted by professional physicians, with clinical diagnoses confirmed for the insomnia group. Participants recorded their sleep status using sleep diaries the night before testing, and their recent sleep quality was assessed using the Pittsburgh Sleep Quality Index (PSQI; Buysse et al., 1989).

The experiment was conducted remotely via the Jiangsu Medical Vocational College Chronic Disease Follow-up Platform, a telecommunications system routinely used for clinical communication. Researchers initiated recorded voice calls to participants through this familiar platform, maintaining consistency with their typical clinical interactions. Participants provided consent for call recording before the session.

The online system included a basic noise detection feature. The researcher also monitored audio quality and reminded participants to complete the VFT independently, without assistance. If voices from other individuals were detected, the data were excluded. Before the test began, researchers explained the experimental procedure and task instructions. The test began only after participants confirmed their understanding. If participants expressed uncertainty, the researcher provided further explanation until they fully understood.

During the call, participants completed two assessments: first the PSQI, followed by the VFT. For the VFT, participants completed both the phonemic fluency test and the semantic fluency test. The VFT was administered in Mandarin Chinese. Standardised instructions with examples were provided: "For semantic fluency, if the category is flowers, you might say 'peony, rose, lotus.' For phonemic fluency, if asked to generate words beginning with the character 'fang' (方 - 'square'), you might say 'fang bian' (方便 - 'convenient') or 'fang xing' (方形 - 'square')."

The phonemic fluency assessment utilised three foundation characters selected according to Quan et al.'s (2015) criteria for common usage and educational accessibility: "bai" (白 - "white"), "tian" (天 - "sky"), and "da" (大 - "big"). Participants were instructed to generate two- to four-syllable words beginning with these characters. The semantic fluency component required participants to generate words within three categories: vegetables, fruits, and animals. Each one-minute trial was digitally recorded and subsequently transcribed by a native Mandarin speaker.

Response validity criteria were standardised across tasks. For semantic fluency, responses were deemed invalid if they were: repetitions, category violations, mythical/fictional entities, non-existent words, or alternative names for the same item (e.g., both "tu dou" [土豆] and "ma ling shu" [马铃薯] for potato). For phonemic fluency, invalid responses included: words not beginning with the specified character, repetitions, phonemic violations, non-Mandarin words, or compound words exceeding permitted complexity (e.g., "bai da mao" [白大猫], combining three characters to mean "white big cat").

Clustering and switching analyses employed modified versions of Troyer et al.'s (1997) and Ledoux et al.'s (2014) protocols, adapted for Mandarin Chinese (see Appendix A for detailed scoring guidelines). Switches were defined as transitions between semantic subcategories (e.g., "whale, dolphin, octopus, jellyfish, monkey, elephant" contains one switch between marine and non-marine animals). Cluster sizes were calculated starting from the second word in each group, with single-word clusters scored as zero and two-word clusters as one.

In this study, "word" refers to a full lexical item rather than individual syllables. Due to the structure of the Chinese language, responses were treated as multi-character words, and cluster size was calculated based on similarity between complete words, not syllables.

Although no formal measures of motivation or effort were used, participants were clearly informed of the importance of performing to the best of their ability during the verbal fluency tasks. Each participant received a 100 Yuan incentive upon study completion, which can help promote task engagement (see Bonner & Sprinkle, 2002; Camerer & Hogarth, 1999). Meanwhile, assessments were conducted using a familiar clinical follow-up system, which we assume would help minimise test-related anxiety and support a comfortable testing environment. No participants showed signs of disengagement, and all completed the tasks without interruption.

Statistics

Statistical analyses were conducted using Jamovi (Version 2.3.24; The Jamovi Project, 2023). Group comparisons were performed using two-way mixed-design ANOVA, with group (insomnia vs. control) as a between-subjects factor and test type (phonemic vs. semantic) as a within-subjects factor. Dependent variables included the number of correct responses, mean cluster size, and number of switches.

Before the analysis, the normality of each dependent variable was assessed within each group using the Shapiro–Wilk test. Where violations of normality or homogeneity of variance were detected, appropriate adjustments were made, including the use of Welch's *t*-tests.

Planned post hoc comparisons using independent t-tests were conducted where appropriate, with Bonferroni correction applied to control multiple comparisons. The alpha level was set at .05, and effect sizes were reported as partial eta squared (η^2_p) for ANOVA and Cohen's d for *t*-tests.

Results

The dataset for this study is publicly available in the Open Science Framework repository at https://osf.io/uqzfb/?view_only=e66414eec6e14b688e72a568fe151147.

Groups were comparable on key demographic variables, with post hoc independent *t*-tests showing no significant differences in age and years of education (both $p > .05$), and a significant difference in Pittsburgh Sleep Quality Index (PSQI) scores ($p < .001$). Details are presented in Table 1. No formal cognitive screening measure was administered; groups were comparable in age and years of education (Table 1).

Table 1

Demographic Characteristics for the Groups

	Insomnia	Control	Group comparison
Total *N*	20	20	
Age (*M* years ±_SD)	44.9 ± 17.7	36.6 ± 16.9	$t(38) = 1.459$, $p = .153$, $d = .23$
Male/Female	7/13	7/13	
Years of education (*M* ± SD)	12.9 ± 4	12.4_±_2.5	$t(31.9) = .474$*, $p = .639$, $d = .08$
Mean PSQI ± SD	12.1 ± 2.2	3.0_±_1.78	$t(38) = 13.993$, $p < .001$, $d = 2.21$

Note. * Indicates Welch's t-tests were used in cases where Levene's test indicated a violation of the assumption of equal variances.

The Shapiro–Wilk test showed that correct responses were approximately normally distributed in the insomnia group [$W = .980$, $p = .116$], but deviated slightly from normality in the control group [$W = .963$, $p = .002$]. Switch number was normally distributed in both the insomnia group [$W = .983$, $p = .123$] and control group [$W = .984$, $p = .153$]. Cluster size showed significant deviations from normality in both groups [insomnia: $W = .924$, $p < .001$; control: $W = .881$, $p < .001$]. Given these results, parametric tests were retained due to their robustness to moderate violations of normality with balanced sample sizes ($N = 20$ per group; Blanca et al., 2017; Glass et al., 1972). In addition, Welch's t-tests were used when the assumption of equal variances was violated.

A two-way mixed ANOVA was used to analyse the number of correct responses on the VFT. Results indicated that the insomnia group performed significantly worse than the control group [$F(1, 40) = 17.7$, $p < .001$, $\eta^2_p = .317$], with the insomnia group generating, on average, 3.5 fewer responses ($MD = 3.5$, $SD = 5.13$). There were also significantly more responses for the semantic fluency task compared to the phonemic fluency task [$F(1, 40) = 145.481$, $p < .001$, $\eta^2_p = .793$], with participants generating 7.2 more responses ($SD = 3.7$) in the semantic fluency test. However, as

illustrated in Figure 1, the interaction between group and task was not significant [$F(1, 40) = .174$, $p = .679$, $\eta^2_p = .005$]. Descriptive statistics are presented in Table 2 and Figure 1.

Table 2

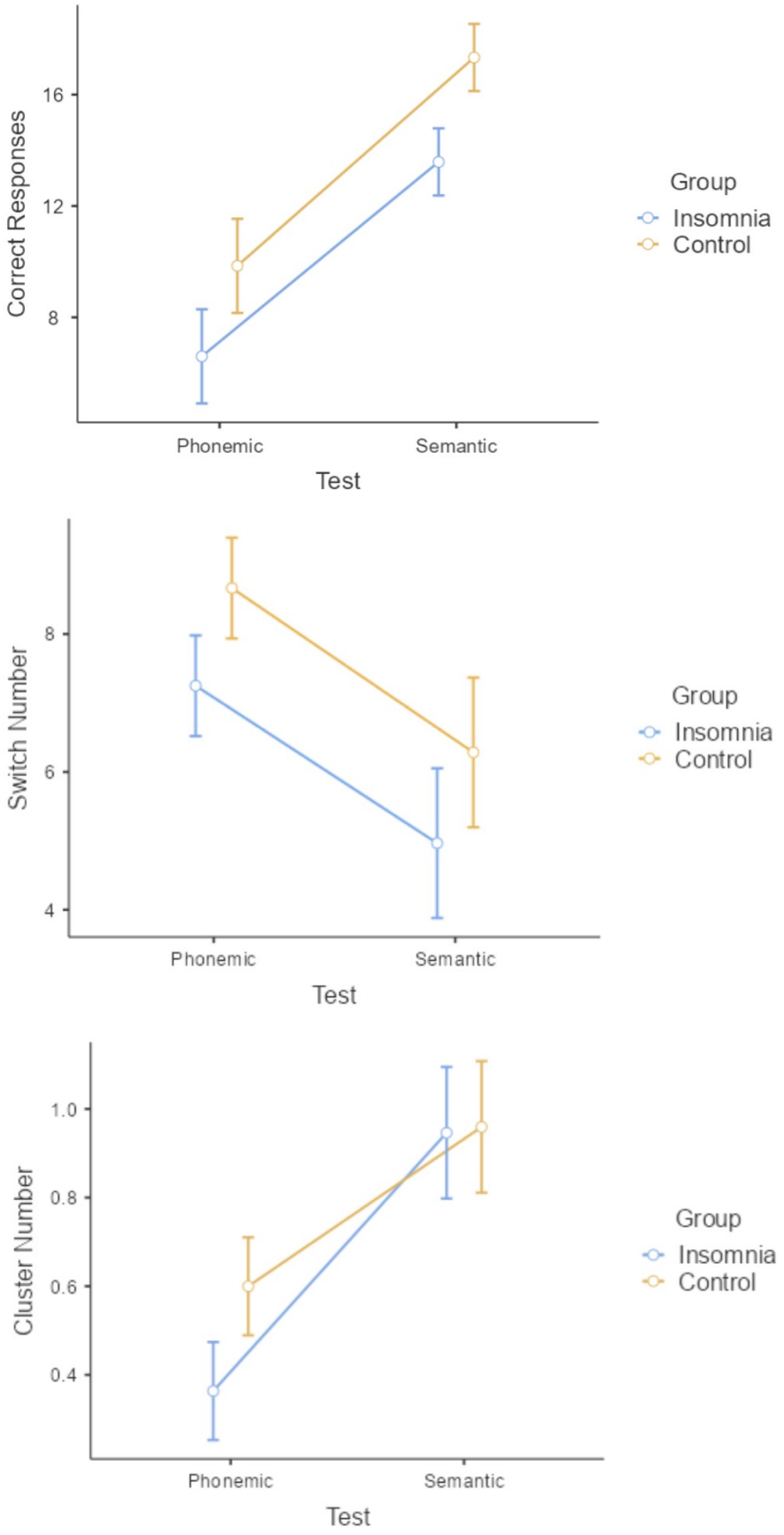
Descriptive Statistics for Verbal Fluency Performance Measures in Insomnia and Control Groups

Measures	Task	Group	*M*	*Median*	*SD*	Statistical Test Results
Correct Responses	Semantic	Insomnia	13.6	13.3	2.5	$p < .001$*, $d = 1.41$
		Control	17.3	17.2	2.8	
	Phonemic	Insomnia	6.6	6.3	2.6	$p = .01$*, $d = .87$
		Control	9.9	7.3	4.6	
Switch Number	Semantic	Insomnia	7.3	7.2	1.6	$p = .01$*, $d = .88$
		Control	8.7	8.5	1.6	
	Phonemic	Insomnia	5.0	4.8	2.1	$p = .09$*, $d = .55$
		Control	6.3	5.7	2.7	
Cluster Number	Semantic	Insomnia	0.9	0.9	0.3	$p = .90$, $d = .04$
		Control	1.0	0.9	0.3	
	Phonemic	Insomnia	0.4	0.4	0.2	$p < .001$, $d = .97$
		Control	0.6	0.5	0.3	

Note. * Indicates Welch's t-tests were used in cases where Levene's test indicated a violation of the assumption of equal variances.

Figure 1

Comparison of Verbal Fluency Measures Between Insomnia and Control Groups for Correct Responses (top), Switch Number (middle) and Cluster Number (bottom).



Note. Error bars indicate the 95% confidence intervals for each mean.

Planned comparisons showed that the insomnia group performed significantly worse than the control group in both tests [semantic: $t(38) = 4.45$, $p < .001$, $d = 1.37$]; phonemic: $t(30.1) = 2.75$, $p = .01$, $d = .81$] (with Welch correction when Levene's test for homogeneity was significant).

For the cluster and switch analyses (see Figure 1) a repeated mixed ANOVA found that in terms of switch number, the insomnia group performed significantly worse than the control group [$F(1, 38) = 7.17$, $p = .011$, $\eta^2_p = .105$], and the switch number was significantly lower in the phonemic fluency test compared with the semantic fluency test [$F(1, 38) = 34.721$, $p < .001$, $\eta^2_p = .256$]. There was no significant interaction [$F(1, 38) = .0159$, $p = .900$, $\eta^2_p = .000$]. Planned comparisons showed there were significantly fewer switches for the insomnia group in the semantic fluency test [$t(38) = 2.78$, $p = .008$, $d = .88$], but no significant difference in performance in the switch number of the phonemic fluency test [$t(38) = 1.74$, $p = .09$, $d = .55$].

For the number of clusters, the phonemic fluency score was significantly lower [$F(1, 38) = 100.61$, $p < .001$, $\eta^2_p = .411$], but there was no main effect of group [$F(1, 38) = 2.53$, $p = .120$, $\eta^2_p = .047$]. However, as shown in Figure 1, there was a significant interaction [$F(1, 38) = 5.64$, $p = .023$, $\eta^2_p = .038$]. Planned comparisons revealed that compared with the control group, the insomnia group showed no significant difference in the semantic fluency test [$t(38) = .127$, $p = .900$, $d = .04$], but were significantly worse in the phonemic fluency test [$t(38) = 3.060$, $p = .004$, $d = .97$].

Discussion

This study examined the impact of insomnia on language production by comparing individuals with insomnia to healthy controls using the Chinese version of the VFT. Our results indicate that insomnia was associated with reduced performance on both semantic and phonemic fluency tests, with the insomnia group generating fewer correct responses across both tests. The insomnia group produced fewer words, made fewer switches, and formed smaller clusters than the control group, with the most pronounced differences observed in the phonemic fluency tests. These findings suggest that insomnia disrupts components of language production, with a stronger impact on tasks requiring flexible retrieval and mental switching.

Consistent with prior findings (Chen et al., 2017; Koo et al., 2017), these results support the view that insomnia has a detrimental effect on cognitive processes involved in language generation. The observed patterns in switching and clustering analyses further support theoretical models distinguishing automatic semantic processes from executive control mechanisms during the VFT (Troyer et al., 1997). The insomnia group's reduced switching frequency and smaller cluster sizes suggest that executive control difficulties may contribute to their lower performance. However, as cluster sizes remained comparable in the semantic fluency test, automated semantic memory retrieval processes may be less impacted by insomnia, while tests requiring more deliberate retrieval processes, like the phonemic fluency

test, revealed greater performance differences between groups. Additionally, the Chinese language's unique demands, such as tonal processing and character-based retrieval, may intensify the executive control requirements in the phonemic fluency test, potentially magnifying these observed performance differences in insomnia.

This study extends the current research by focusing on Chinese-speaking individuals, a population for whom empirical data on VFT performance in the context of insomnia are scarce. In contrast to prior studies that have produced mixed results, often failing to find significant differences in overall VFT performance among individuals with insomnia (Altena et al., 2008; Rezende et al., 2024; Zhou et al., 2024; Wu et al., 2023), our study provides behavioural evidence supporting the detrimental impact of insomnia on the VFT in Chinese speakers. This finding is particularly important given the unique linguistic characteristics of Chinese, including its tonal nature and logographic writing system. These features may increase the complexity of the VFT and the demand for executive control (Chan & Chen, 2004; Liu et al., 2022; Wang et al., 2017), potentially amplifying the executive control load and further revealing the widespread impact of insomnia on executive control functions in Chinese speakers.

Contrary to our expectations, no significant interaction was found between group (insomnia vs. control) and task type (semantic vs. phonemic) in VFT performance. This finding suggests that the cognitive impact of insomnia is primarily reflected in executive control difficulties, which are evident in both semantically-driven and phonemically-driven word retrieval tasks. These results are consistent with the "global cognitive deficit" hypothesis proposed by Fortier-Brochu et al. (2012), suggesting that insomnia broadly impacts multiple cognitive domains rather than selectively impairing specific processes. Our findings support this hypothesis, indicating that difficulties in executive control influence both semantic and phonemic fluency, even when the function of semantic memory remains relatively intact. The absence of a significant interaction further suggests that the cognitive difficulties observed in the insomnia group are not selectively associated with a particular task type but rather reflect a more generalised difficulty in executive control.

Our behavioural findings align with and extend previous neuroimaging research on insomnia and verbal fluency. For instance, Sun et al. (2017) reported altered activation in frontal and temporal regions during VFT performance in people with insomnia, despite observing no significant behavioural differences. Our study, by demonstrating behavioural differences, suggests that these neural alterations indeed have functional consequences. The poor performance we observed in both semantic and phonemic fluency is consistent with neuroimaging evidence of disrupted connectivity in frontotemporal network in insomnia (Khazaie et al., 2017). Furthermore, our finding of greater difficulty in the phonemic fluency test aligns with neuroimaging studies reporting more pronounced prefrontal cortex dysfunction in individuals with insomnia (Altena et al., 2008), a region crucial for the executive demands of this task.

Our study also provides evidence supporting the validity of the Chinese version of the VFT, while simultaneously demonstrating its sensitivity to insomnia-related

cognitive difficulties. We observed a pattern common in VFT research across languages: participants generated fewer responses in the phonemic fluency test compared to the semantic fluency test. This difference is typically attributed to the phonemic fluency test being more cognitively demanding, as it requires a less natural search strategy (Luo et al., 2010). These results align with the theoretical framework proposed by Troyer et al. (1997), demonstrating that while both tests engage semantic-memory-retrieval–related processes and executive control, the greater cognitive demands of phonemic fluency reveal more pronounced difficulties in individuals with insomnia. The semantic fluency test relies more heavily on semantic memory retrieval related process, while the phonemic fluency test places greater emphasis on executive control. Despite the unique characteristics of Chinese characters, which often combine phonemic and semantic information (Wang et al., 2017; Chan et al., 2004), our results indicate that the Chinese VFT maintains its focus on assessing these distinct cognitive functions. This finding is particularly important as it demonstrates the cross-linguistic applicability of the VFT, addressing concerns raised by Henry et al. (2004) about potential language-specific effects on VFT performance.

Several methodological limitations warrant consideration when interpreting these findings, including sample-size constraints, the absence of a general cognitive estimate, remote test administration, and broader design- related issues. Modest sample size limits statistical power, particularly for detecting interaction effects in the clustering analysis. While the insomnia and control groups were not formally matched, post hoc analyses confirmed no significant differences in these key demographic variables. We did not use the formal estimate of general cognitive ability; although age and education were comparable, these are coarse proxies. Future studies should include a validated, untimed, reading-based measure of crystallised ability to enable matching or statistical adjustment. The use of remote, telephone-based online assessment for administering the VFT may be a further limitation, due to potential variability in testing conditions. While prior research has found no significant differences between online and traditional versions of the VFT in healthy young populations (Pesau et al., 2021), there may still have been variables we could not control, such as mild background noise containing information related to the test items, or other variations in participant environments.

The study design also presents important limitations. The lack of insomnia subtype classification (e.g., sleep onset vs. maintenance) prevents analysis of how specific sleep disruption patterns might differentially affect cognitive performance. The absence of objective sleep measures (e.g., polysomnography) limits our understanding of the relationship between specific sleep parameters and cognitive difficulties. While the VFT effectively assesses language production and executive control, it cannot capture the full range of cognitive domains potentially affected by insomnia, such as attention and working memory. Additionally, the observational case-control design cannot fully account for potential confounding factors such

as socioeconomic status or comorbid mood disorders. Future research should address these limitations through larger, multi-site studies incorporating comprehensive sleep assessment, detailed insomnia phenotyping, and multiple cognitive measures.

These findings highlight several promising avenues for future research. Investigating the relationship between objective sleep measures (e.g., polysomnography) and VFT performance could reveal which aspects of sleep disturbance, including sleep fragmentation, reduced slow-wave sleep, or REM sleep alterations, most strongly predict cognitive difficulties (Fernandez-Mendoza et al., 2016). Comparing VFT performance across insomnia subtypes (e.g., sleep onset vs. maintenance insomnia) might identify distinct patterns of cognitive performance differences, informing targeted interventions (Bjorøy et al., 2020). Additionally, controlled sleep deprivation studies could help disentangle acute versus chronic sleep loss effects on verbal fluency. While one night of sleep deprivation has been shown to reduce verbal fluency performance (Harrison & Horne, 1997; Horne, 1988), its relationship to chronic sleep disruption in insomnia remains unclear. Examining whether patterns of reduced performance in sleep deprivation mirror those observed in chronic insomnia could help illuminate shared underlying mechanisms (Drummond et al., 2001). Additionally, for the VFT, there is still a need to further explore the reliability and validity of using an online VFT in clinical populations such as insomnia patients.

In terms of the Chinese VFT, its sensitivity to insomnia-related cognitive difficulties suggests its potential as a valuable clinical tool, offering an efficient screening measure for cognitive challenges due to its brevity and ease of administration. The distinct patterns in clustering and switching analyses could guide targeted interventions, particularly for improving cognitive flexibility. However, understanding how the Chinese language's tonal nature and logographic writing system interact with insomnia-related cognitive difficulties remains crucial, as these linguistic features may affect fluency tasks differently than in non-tonal, alphabetic languages (Tan et al., 2005; Perfetti et al., 2013). This exploration could reveal language-specific aspects of cognitive functioning while contributing to culturally sensitive assessment tools. Establishing normative data and cut-off scores for Chinese populations (Lezak et al., 2012) and examining correlations between sleep quality improvements and VFT performance would enhance the test's clinical utility in assessing and treating insomnia-related cognitive difficulties.

In conclusion, this study substantiates the adverse effects of insomnia on verbal fluency in Chinese-speaking individuals, highlighting reduced performance in both semantic retrieval and executive control. The application of clustering and switching analyses provides a deeper understanding of the specific cognitive processes disrupted by insomnia, affirming the Chinese VFT as a valuable tool for assessing language-related cognitive performance. The analyses reveal specific cognitive difficulties while providing a framework for tailored clinical assessments, suggesting that incorporating the Chinese VFT into routine cognitive evaluations could help identify subtle differences in executive control performance that standard assessments might miss. By demonstrating the Chinese VFT's sensitivity to insomnia-related cognitive

difficulties, this study advances our understanding of how sleep disturbances affect language processing across linguistic contexts. Future research should establish normative data and clinical cut-off scores to enhance the test's diagnostic utility, while exploring targeted interventions to mitigate cognitive difficulties in insomnia patients.

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Contributions

Conceptualisation: Yumeng Lyu, Yongliang Zheng
Data curation: Yumeng Lyu, Yongliang Zheng
Formal analysis: Yumeng Lyu
Funding acquisition: Yongliang Zheng, Yumeng Lyu
Investigation: Yumeng Lyu
Methodology: Yumeng Lyu
Project administration: Yumeng Lyu
Resources: Yongliang Zheng, Shufang Wang
Software: Yumeng Lyu
Supervision: Shane Lindsay, Yongliang Zheng
Validation: Yumeng Lyu, Shane Lindsay
Visualisation: Yumeng Lyu, Shane Lindsay
Writing: Yumeng Lyu, Shane Lindsay

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Appendix A

Table A1

Detailed Scoring Rules with Examples for Cluster Identification in Phonemic and Semantic Fluency Tests

		Scoring Rule	Example Text
Phonemic Fluency Test	1	Words with the same first two characters	*Tian tian xiang shang* (天天向上,"to make progress every day"), *Tian tian kai xin* (天天开心,"happy every day")
	2	Words with the same number of characters	*Bai hua hua* (白花花, "looks like all in white"), *Bai yan se* (白颜色, "white colour")
	3	Homophones	*Da yi* (大一, "freshman") and *Da yi* (大衣, "coat")
	4	Words that rhyme (the second character has the same initials or finals, or have the same character)	*Da ya* (大牙, "molar tooth"), *Da ma* (大妈,"old aunt") *Da bai cai* (大白菜, "Chinese Cabbage "), *Da qing cai* (大芹菜, "large celery")
	5	Real-world semantic associations	
	5.a	Members of a superordinate category	*Da suan* (大蒜, "garlic"), *Da cong* (大葱, "green onions")
	5.b	Words that obviously hold strong associations in the real world	*Bai xie* (白鞋, "white shoes"), *Bai wai zi* (白袜子, "white sock")
	5.c	Antonyms or synonyms	*Bai zhou (白昼*, "daytime"), *Bai tian* (白天, "daytime")
Semantic Fluency Test	1	Words in the same subcategory	*Gou* (狗, "dog"), *Mao* (猫, "cat"), *Cang shu* (仓鼠, "hamster")
	2	Strong real-world associations	*Mian bao* (面包, "bread"), *Niu Nai* (牛奶, "milk")
	3	Words with the same initial character	*Jin qian bao* (金钱豹, "leopard"), *Jin si hou* (金丝猴, "golden monkey")
	4	Items with shared characters	*Xi hu lu* (西葫芦, "zucchini"), *Hu lu gua* (葫芦瓜, "bottle gourd")
	5	Words that rhyme (the second character has the same initials or finals, or have the same character)	*Bai cai* (白菜, "Chinese cabbage"), *Qing cai* (青菜, "green vegetable")

Cluster size was calculated starting from the second word in each cluster. Switches were defined as the number of transitions between clusters, including

single words, for both phonemic and semantic tests. Errors and repetitions were included in the calculations of cluster size and switching.

For overlapping categories, items belonging to multiple categories were assigned to each relevant category. For example, in the sequence “dog, cat, tiger, lion”, “cat” would be included in both the “pets” and “feline animals” categories.

When smaller clusters were fully contained within larger clusters, only the larger cluster was scored.