



Development of an Optimal Time for Learning Questionnaire in Chinese University Students

**Lingshan LIU¹, Hongyuan LV², Yifan LU³, Chu WANG⁴, Hao CHAI⁵, Lars M.
RIMOL⁶, Wei WANG^{7*}**

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Abstract

Autonomous learning is crucial for students' academic achievements, however, there lacks a structure-validated questionnaire to measure the optimal time for autonomous learning with different learning contents. Based on the previous investigations, we have designed a matrix of 49 items based on seven learning contents and seven time periods of a day to measure the optimal time for autonomous learning and invited 305 Chinese university students to answer the matrix. Through both exploratory and confirmatory factor analyses, we have developed an Optimal Time for Learning Questionnaire with a satisfactory model structure of five factors (7, 6, 6, 6, 5 items per factor respectively) namely Noon, Late Night, Nightfall, Morning and Afternoon. The internal reliabilities of these factors were acceptable, and their inter-correlations were significant, albeit in low or medium levels. The Optimal time for Learning Questionnaire may help students find their optimal learning efficiency individually.

Key words: Confirmatory factor analysis; Optimum time for learning; Principal component analysis; Structure-validated questionnaire

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¹ Lingshan Liu, Department of Clinical Psychology and Psychiatry, School of Public Health, Zhejiang University College of Medicine, Hangzhou, China, E-mail: 3170104506@zju.edu.cn

² Hongyuan Lv, Department of Clinical Psychology and Psychiatry, School of Public Health, Zhejiang University College of Medicine, Hangzhou, China, E-mail: 3170103973@zju.edu.cn

³ Yifan Lu, Department of Clinical Psychology and Psychiatry, School of Public Health, Zhejiang University College of Medicine, Hangzhou, China, E-mail: 3170104451@zju.edu.cn

⁴ PhD Chu Wang, The Second Clinical Medical College, Zhejiang Chinese Medical University, Hangzhou, China, E-mail: 21718608@zju.edu.cn

⁵ PhD Hao Chai, Department of Psychology, College of Education, Zhejiang University of Technology, Hangzhou, China, E-mail: chaihao2009@aliyun.com

⁶ PhD Lars M. Rimol, Department of Psychology, Norwegian University of Science and Technology, Trondheim, Norway, E-mail: lars.rimol@ntnu.no

⁷ PhD Wei Wang, Department of Psychology, Norwegian University of Science and Technology, Trondheim, Norway, E-mail: wew@ntnu.no or wangmufan@msn.com

* Corresponding author

1. Introduction

Autonomous learning, also named self-managed learning (Lizzio & Wilson, 2005), self-regulated learning (Boekaerts & Niemivirta, 2000; Entwistle & McCune, 2004), or self-directed learning (Garrison, 1997), denotes a process where students possess sufficient opportunity to organize and regulate their own learning. In autonomous learning, students' learning efficiency may vary with the learning contents (or concepts) and time epochs during a day. Previous studies have suggested that there exists a time-of-day effect in one's learning efficiency. For example, young participants showed superior memory accuracy in the afternoon compared to that in the morning (Hourihan & Benjamin, 2014). When identified as morning type or evening type, students reported differences in memory, interest, motivation, and achievement across time of day (Anderson et al., 1991; Itzek-Greulich et al., 2016). In the field of logical reasoning, students' speed and performance improved markedly from morning to noon, and subsequently performance fell off rapidly from afternoon to night (Folkard, 1975).

Several other factors influence cognitive performance and thus contribute to intra-individual variance in learning efficiency. Most importantly, the circadian rhythms in cognitive processes affect school related activities such as attention and memory (Valdez, 2019). Circadian rhythms have been found in three basic cognitive processes which are interconnected with each other: attention, working memory and executive functions. Attention denotes to the act of selectively concentrating on a discrete aspect of information while ignoring other perceivable information, which also interacts effectively with the environment (Nobre & Kastner, 2014); working memory comprises the storage, retrieval, and use of information (Baddeley & Hitch, 1974); and executive functions refer to the ability to program or regulate behavior, which is essential for problem solving, decision making as well as self-control (Lezak et al., 2012). These cognitive processes roughly reach their lowest levels during nighttime and early morning, improve around noon, and are at even higher levels during afternoon and in the evening (Valdez et al., 2005; Ramírez et al., 2006; García et al., 2012; Gallegos et al., 2019), demonstrating their coordination with the physiological rhythms of the human body (Valdez, 2019).

The learning efficiency and time course of cognitive performance are nonetheless also modulated by other conditions. The "chronotype" is a reproducible and stable trait of individuals, which encompasses morning type, evening type and intermediate type according to preferred time of learning or other activities (Kantermann & Eastman, 2018). The morning and evening types show an advance or a delay in cognitive rhythms respectively (Roenneberg et al., 2003). Hunger and sleep deprivation influence the rhythms of cognitive performance as well (Benau et al., 2014; Killgore & Weber, 2014), leading to the impairment of attention, memory and executive functions (Benton & Parker, 1998; Doniger et al., 2006; Krause et al., 2017). The fluctuations of attention interrelate with emotion (Taylor & Fragopanagos, 2005), and certain emotional states appear to facilitate memory control (Engen & Anderson, 2018) and decision making (Woodcock et al., 2020). Finally, exposure to environmental noise deteriorates cognitive performance with regard to comprehension, memory, attention, as well as executive functions (Clark & Paunovic, 2018).

A classical theory of learning skills is the "Building Blocks of Learning" (Goldstein & Mather, 1998). Learning skills are regarded as comprising ten building blocks that reflect foundational skills, symbolic or perceptual processing skills, and conceptual or thinking skills, including attention and self-regulation, emotion, behavior, self-esteem, phonological processing, orthographical processing, motor processing, thinking with language, thinking with images, and thinking with strategies (Abu-Hamour, 2014; Goldstein & Mather, 1998). In the current study, we would separate the learning contents into seven elements, i.e., language learning, problem analyzing, memorizing, comprehension, logic thinking, drawing and writing.

There are several inventories that have been developed to assess learning efficiency and learning style (Horne & Östberg, 1976; Fleming & Mills, 1992; Duff, 2004; Fleming, 2001; Roenneberg et al., 2003). To date however, there is no single study which illustrates a structure-validated questionnaire that investigates the optimal time for autonomous learning of different leaning-contents. There is no standard division of time epoch of a day either. Some scholars preferred to use the exact scales of time epoch (e.g., 04:00-07:00 AM or 8:00-11:00 PM) when measuring the rhythms of cognitive performance (Garcia et al., 2012; Ramirez et al., 2006; Valdez et al., 2005). However, cognitive performance and learning efficiency fluctuate with numerous factors within different individuals (Benau et al., 2014; Roenneberg et al., 2003; Taylor & Fragopanagos, 2005), and the exact time points may not be suitable for all participants when referring to the automatic learning.

In the current study, we adopted both exploratory and confirmatory factor analyses in order to validate the structure of a questionnaire. Furthermore, we roughly divided the day into the early morning, morning, noon, afternoon, nightfall, evening, and the late night. On the other hand, based on previous studies, the optimal time of learning refers to the time epoch when an individual is highly focused, does not easily fatigue, stable in mood, fluent in thinking, and with the highest learning efficiency. Thus, we recruited a group of university students to answer a matrix of statements regarding the optimal time for autonomous learning. Considering that different cognitive performances show similar rhythms in a day (Valdez, 2019), we hypothesized that the efficiency of autonomous learning is primarily affected by the time of day instead of the learning contents.

2. Method

2.1. Participants

Altogether 305 students (116 men, mean age: 21.39 years \pm 1.94 S.D., range: 19-28 years; and 189 women, mean age: 21.31 \pm 1.85, range:18-26) were recruited in the current study. The participants were enrolled in the Zhejiang University (Hangzhou, China), a typical comprehensive Chinese university with a large student population. They were all of Han ethnicity and majored in Modern Medicine, Science, Engineering, Management, Agronomy, History, Sociology, Literature, and Philosophy. There was no significant age difference between the male and female participants ($t = .35$, $p = .728$, 95% Confidence Interval = $-.36 \sim .52$). All participants were free from any somatic or psychiatric illnesses, had not experienced stressful life-events recently, and were medication or alcohol free at least 72h prior to testing. The study protocol was approved by the Ethic Committee of the School of Public Health, Zhejiang University and all participants had given their written informed consents.

2.2. Measures

Participants were asked to respond to a matrix of 49 items regarding the optimal time for autonomous learning in a quiet room. They were asked to use a five-point Likert rating scale: 1-very unlike me, 2-moderately unlike me, 3-somewhat like and unlike me, 4-moderately like me, and 5-very like me. The matrix concerned following aspects (seven items each based on time periods below): 1) the optimal time for language learning, 2) the optimal time for analyzing a problem, 3) the optimal time for memorizing, 4) the optimal time for comprehension, 5) the optimal time for logical thinking, 6) the optimal time for drawing, and 7) the optimal time for writing. The participants were asked to choose between the following time periods: 1) early morning (between getting up and breakfast), 2) morning, 3) noon (between lunch and midday rest), 4) afternoon, 5) nightfall (around dinner), 6) evening, and 7) late night. The presentation of the items was randomized in the matrix.

2.3. Statistical Analyses

Responses to the 49 items were subjected to principal component analysis using the Predictive Analytics Software Statistics, Release Version 18.0 (SPSS Inc., 2009, Chicago, IL). The factor loadings were rotated orthogonally through the varimax normalized methods. Items which loaded less heavily (below .50) on a target factor, or cross-loaded heavily (above .25) on more than one factors were removed from subsequent analyses one-by-one. The procedure continued until no further item was needed to be removed. Then, the fit of the remaining data (i.e., components extracted as latent factors) were assessed by confirmatory factor analysis via the structural equation modeling software Analysis of Moment Structures (AMOS), version 17.0 (Arbuckle, AMOS Development Corp. 2008, Crawfordville, FL). The following indices were used to identify the model fit: the χ^2/df , the goodness of fit index, the adjusted goodness of fit index, the comparative fit index, the Tucker-Lewis Index, and the root mean square error of approximation (Bentler & Bonett, 1980; Bentler, 1990; Browne & Cudeck, 1993).

When factors and their related items had been identified, the factor scores of each gender group and the internal reliabilities (the Coefficient H) were then calculated in all participants. The gender difference of each factor scores was evaluated by two-way ANOVA (i.e., gender \times factor score) plus the post-hoc Student *t* test. A *p* value below .05 was considered significant. Moreover, the Pearson correlation test was used to search for possible relationships within the factors, with a *p* value below .01 was considered significant.

3. Results

Responses to the 49 items measuring the optimal time for autonomous learning were first submitted to a principal component analysis. Results of the pre-analysis check were acceptable (KMO = .84; the Bartlett test of sphericity = 7099.99; *p* < .001). The analysis disclosed 11 factors with eigenvalues greater than 1.0, and the scree plot indicated a level-off from the sixth factor on. The eigenvalues of the first five factors were 7.50, 7.27, 3.25, 2.85 and 2.42 respectively, which altogether accounted for 47.50% of the total variance (the first four factors altogether accounted for 42.57%). After the varimax normalized rotation, in the six-factor model, there were no validly consistent items in the sixth factor. Therefore, a five-factor model was chosen for the confirmatory factor analysis.

Three AMOS fit-models of five-factors with different items were constructed (Table 1) and the 30-item model (7, 6, 6, 6, 5 items respectively for the five factors) was the best among the models.

Table 1. Five-factor fitting models of the Optimum Time for Learning Questionnaire in 305 participants

Total item number	Item numbers each factor	X ² /df	Goodness of fit index	Adjusted goodness of fit index	Tucker-Lewis index	Comparative fit index	Root mean square error of approximation	Standardized Root Mean Square Residual
38	12, 8, 7, 6, 5	2.56	.75	.72	.77	.78	.07	.072
34	8, 8, 7, 6, 5	2.51	.78	.75	.79	.81	.07	.070
30	7, 6, 6, 6, 5	2.11	.84	.81	.85	.87	.06	.064

The standardized factor correlations for the 30-item model structure were also acceptable (Figure 1). Based on these 30 items, we developed an Optimal Time for Learning Questionnaire (OTL, Table 2), and used it in the subsequent analyses.

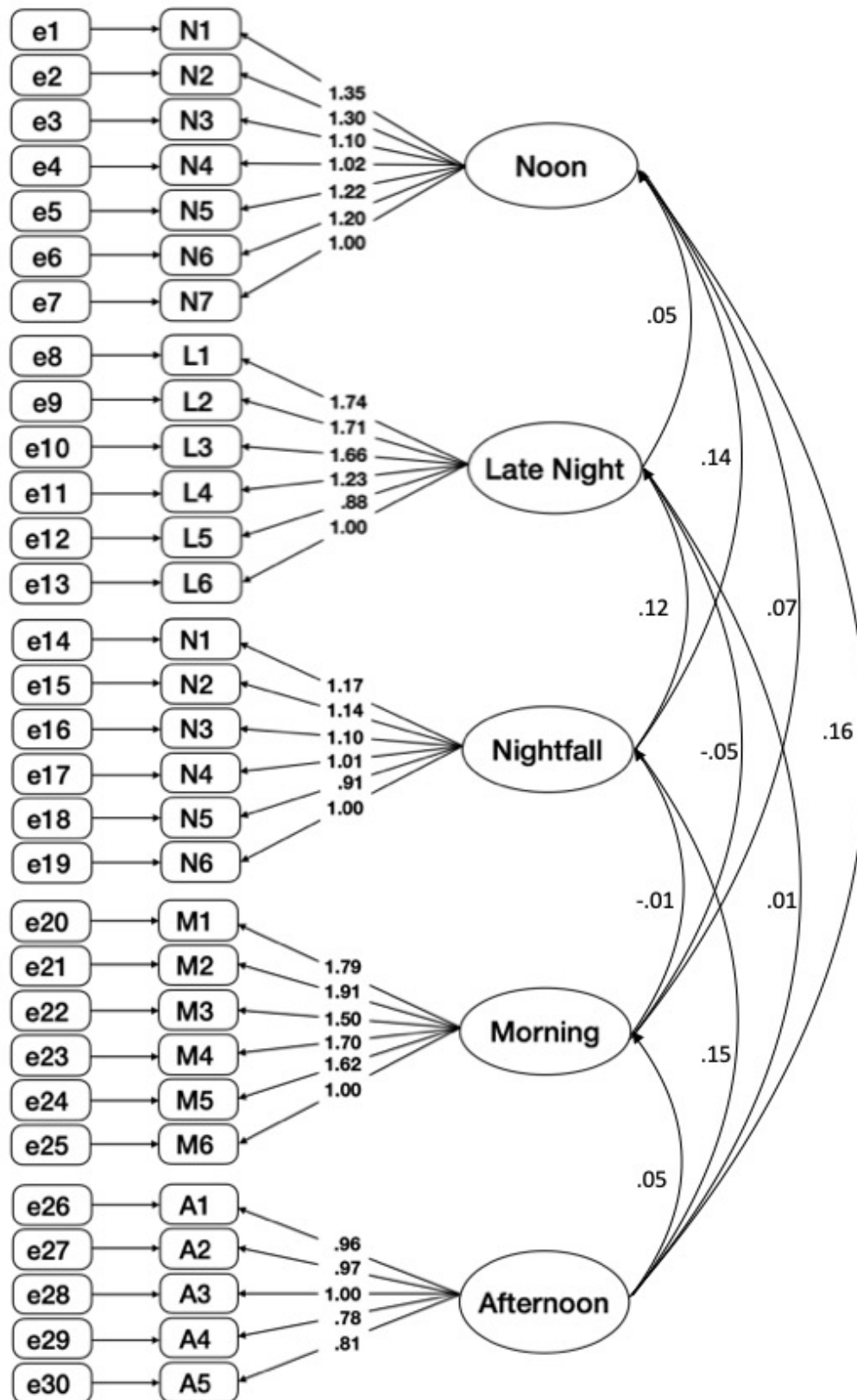


Figure 1. Standardized factor structures for a confirmatory factor analysis of a five-factor model

Table 2. Item-factor loadings in 305 participants

Item (My optimal time of...)	Factor 1	2	3	4	5
Comprehension is noon.	.77	.02	.17	.11	.08
Problem analyzing is noon.	.74	-.03	.10	.12	.18
Language learning is noon.	.70	.01	.10	.08	.08
Memorizing is noon.	.70	.03	.06	-.04	.07
Logic thinking is noon.	.69	.06	.04	.04	.12
Drawing is noon.	.67	.05	.09	.24	.14
Writing is noon.	.62	.06	.18	.07	.01
Comprehension is late night.	.17	.82	.08	-.07	-.10
Problem analyzing is late night.	.13	.82	.01	-.11	-.06
Logic thinking is late night.	.10	.81	.10	-.02	-.07
Memorizing is late night.	.12	.70	.04	-.14	.09
Problem analyzing is evening.	-.23	.66	.21	-.08	.07
Writing is late night.	-.11	.61	.16	.10	.11
Comprehension is nightfall.	.11	.07	.77	.03	.06
Problem analyzing is nightfall	.03	.14	.75	-.03	.16
Logic thinking is nightfall.	.13	.16	.71	-.01	.11
Drawing is nightfall.	.11	.08	.71	-.03	.18
Writing is nightfall.	.10	-.01	.68	.06	-.09
Memorizing is nightfall.	.24	.14	.62	-.14	.04
Language learning is morning.	-.04	-.04	-.05	.80	.10
Language learning is early morning.	.14	-.06	.11	.73	-.09
Logic thinking is morning.	.08	-.01	-.09	.69	.16
Memorizing is morning.	.02	-.22	-.08	.68	.02
Memorizing is early morning.	.16	-.06	.09	.68	-.15
Drawing is morning.	.20	.11	-.08	.51	.23
Problem analyzing is afternoon.	.02	.03	.11	.12	.76
Logic thinking is afternoon.	.08	-.02	.08	.11	.75
Memorizing is afternoon.	.25	.02	.04	-.11	.75
Language learning is afternoon.	.25	.09	-.01	-.11	.63
Comprehension is afternoon.	.06	-.08	.18	.15	.61

Note: Loadings $\geq .50$ are in bold for clarify.

Factor 1 was called “Noon”, which described the time between lunch and midday rest and was applicable to all the seven learning contents. Factor 2 was called “Late Night”, which represented the dead of night and was applicable to all learning contents except for language learning and drawing. Factor 3 was called “Nightfall”, which reflected the time around dinner. This factor was applicable to the other six learning contents excluding language learning. Factor 4 was called “Morning”, which comprised the time between getting up and lunch. The learning contents in Factor 4 consisted of language learning, logical thinking, memorizing, and drawing. Factor 5 was called “Afternoon”, which referred to the time between lunch and dinner and includes five learning contents, other than drawing and writing.

There was no significant difference in the OTL factor scores between two gender groups ($F[1, 303] = .47, p = .495$, mean squared effect = 17.44). The internal reliabilities of OTL five factors were all above .80, and their inter-correlations were significant but remained on a low or medium level (Table 3).

Table 3. Scale scores (means \pm S.D.) of the Optimum Time for Learning Questionnaire in men ($n = 116$) and women ($n = 189$), and their internal reliabilities (Coefficient H) and inter-correlations

Factor	Factor scores			Coefficient H	Inter-correlation			
	Male	Female	95% Confidence Interval		Factor 1	2	3	4
Factor 1 (Noon)	14.78 \pm 5.37	14.71 \pm 4.77	-1.09 ~ 1.24	.88				
Factor 2 (Late Night)	20.47 \pm 5.52	19.77 \pm 5.67	-.60 ~ 2.00	.89	.10			
Factor 3 (Nightfall)	17.63 \pm 5.13	17.94 \pm 4.93	-1.48 ~ .85	.86	.30*	.26*		
Factor 4 (Morning)	17.69 \pm 5.19	18.80 \pm 5.20	-2.32 ~ .09	.86	.23*	-.14	-.02	
Factor 5 (Afternoon)	14.85 \pm 3.80	15.30 \pm 3.65	-1.31 ~ .41	.84	.32*	.04	.23*	.11

Note: * $p < .01$ (for intercorrelations)

4. Discussion

Using both exploratory and confirmatory factor analysis on 49 items regarding optimal time for autonomous learning, we have constructed a satisfactory model structure of 30 items with five scales, namely Noon, Late Night, Nightfall, Morning and Afternoon. These scales had acceptable internal reliabilities and low or medium inter-correlations, which confirmed our hypothesis that the efficiency of autonomous learning was mainly affected by time epoch of day. Although we have included various learning contents, the distribution of OTL items was primarily based on time of day, indicating that the time effect was most prominent in one’s learning efficiency. Our results are consistent with the idea of circadian rhythms of cognitive performance, in that the different aspects such as memory, comprehension, logical thinking and language learning followed similar patterns of cognitive rhythm, i.e., with higher level during daytime hours and lower during nighttime and early in the morning. This maintains a phasic relationship to body temperature (Valdez et al., 2019).

Factor 1 (Noon) and Factor 3 (Nightfall) are linked with the times of eating, and thus are closely related with food and diet. Some people prefer to study around eating time since a healthy dietary pattern and adequate nutrition are necessary to optimize brain function and prevent cognitive decline (Marie-Noël et al., 2009). Meanwhile, cognitive capacity could be influenced by components of diet, such as fish, fruits, vegetables, nuts, and seeds help to prevent cognitive deterioration, while those rich in added sugars and saturated fat are associated with the impairment of cognitive function (Martinez Garcia et al., 2018; Tucker, 2016). Particularly, the

Mediterranean diet, characterized by using olive oil as the main culinary fat, being high in plant-based foods, moderate in fish, seafood and red wine, and low in meat, butter or other dairy products, has been suggested to improve cognition and protect against decline (Martínez-Lapiscina et al., 2013; Petersson & Philippou, 2016). Moreover, food intake also regulates the release of neurotransmitters (Briguglio et al., 2018). For instance, sufficient dopamine contributes to the improvement of cognitive capacity, and promotes attention, insight and problem solving (Nieoullon, 2002; Volkow et al., 2011; Zhang & Zhang, 2016) and low levels of serotonin has been linked with deterioration in learning, reasoning and memory (Martinez Garcia et al., 2018).

Factor 4 (Morning) and Factor 5 (Afternoon) are correlated with diet as well, but the effect of sleep or rest also appears in these factors, as these periods take place immediately after a period of sleep. Previous studies have suggested that sleep plays a crucial role in memory stabilization and integration, and functions as a brain state optimizing memory consolidation (Cousins & Fernández, 2019; Rasch & Born, 2013). Sleep deprivation impairs brain functions and the cognitive performance in the field of attention and work memory especially in the capacity to encode new information (Killgore & Weber, 2014; Krause et al., 2017). Indeed, Wild et al. (2018) reported that sleeping more than usual the night before testing was associated with better performance, suggesting even a single night's sleep can benefit in learning. Actually, the habit of siesta is prevalent in the Chinese population (Kang et al., 2017). The Factor 5 (Afternoon) of our study might also be explained by the effect of sleep or rest owing to the noon break in study schedule when students could take a nap or get some rest.

Factor 2 (Late Night) refers to the silence of night with a peaceful atmosphere, which is often connected with the calmful of the surrounding physical-environment. The optimal learning efficiency of different task types have been identified under environmental interactions. One study has shown that although the comfortable ambient-temperatures were varied, participants involved in perception, memory, problem-solving and attention tasks performed best under relatively/ fairly quiet and bright or moderately light surroundings (Xiong et al., 2018), suggesting that quiet environment helps to enhance the cognitive performance. Moreover, healthy environment might be related with emotional stability, which benefits the ability of memory control (Engen & Anderson, 2018) and decision making (Woodcock et al, 2020). On the contrary, exposure to noise has a terrible impact on the ability of perception, comprehension, memory as well as writing (Klatte et al., 2013).

Our study also suffered from several design limitations. Firstly, although we recruited students from different academic majors, the participants were mainly undergraduates of clinical medicine, so whether the results can be generalized to other majors or grades needs further research. Secondly, we did not record the chronotypes of the participants. Chronotypes have a nonnegligible impact on the circadian rhythms in cognitive performance (Goldstein et al., 2007). Thirdly, recall bias may have influenced our measurements of optimal learning time for different contents. Fourthly, our study was exclusively conducted in China, where noon-time nap is common, which may negatively affect the generalizability of the present findings. Fifthly, we did not record the nutritional habits of the participants, which may have influenced their responses to the questionnaire, since comfortable diets are fuels for optimal level of cognition. Nevertheless, using both exploratory and confirmatory factor analyses in Chinese university students, we have developed a structure-validated scale of optimal learning time, which might help students of different specialties to optimize their everyday training efficiency.

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Author Contributions

WW conceived the study, LL and HL contributed to the study design, LL, HL, YL, CW, HC, and LR collected, analyzed and interpreted the data, and LL, HL, and WW drafted the paper. LL and HL contributed equally to the work described in the present paper. All authors read and approved the final manuscript.

Declarations

Ethics approval and consent to participate: The current study design was approved by the Ethic Committee of the School of Public Health, Zhejiang University. Participants gave their written informed consent to participate in the current study.

Consent for publication: All authors have read and approved the final version of the manuscript.

Availability of data and materials: The datasets generated and/or analysed during the current study are available in the repository of the Department of Psychiatry and Clinical Psychology/School of Public Health, Zhejiang University.

Competing interests: None to declare.

Others: Regarding research work described in the paper, each one of our co-authors, LL, HL, YL, CW, HC, LR, and WW, declares that there is no conflict of interest, and conforms to the Helsinki Declaration concerning human rights and informed consent, and follows correct procedures concerning treatment of humans in research.

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