Athletes' mental fatigue: development and validation of a scale and application for assessing mental fatigue in athletes

Fatiga mental de los atletas: desarrollo y validación de una escala y aplicación para evaluar la fatiga mental en atletas

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Abstract

Introduction: Mental fatigue can impair athletes' cognitive performance, emotional regulation, decision-making, and physical performance during training and competition. Therefore, reliable tools are needed to assess it effectively. Although the Visual Analog Scale (VAS) is widely used for subjective assessment, a multi-item VAS specifically designed for athletes and integrated with a digital application remains limited.
Objective: This study aimed to develop and validate a multi-item Visual Analog Scale (VAS) for assessing mental fatigue in athletes and to develop and evaluate a mental fatigue assessment application.
Methodology: This research consisted of three phases. Phase 1 developed a 20-item VAS covering four components: cognitive and mental function, emotional function, behavioral function, and physical and physiological responses, with reliability tested using Cronbach's alpha. Phase 2 developed a mental fatigue assessment application including login, assessment, results with management guidelines, history records, and logout, and evaluated reliability and user satisfaction. Phase 3 assessed application suitability by three information technology experts.
Results: Cronbach's alpha coefficients ranged from .76 to .83 across components, with an overall reliability of .90. The application showed reliability of .862 and the highest level of user satisfaction. Experts rated the application's overall suitability at a high level.
Discussion: The findings indicate that the developed VAS and application provide a reliable and practical tool for assessing athletes' mental fatigue and supporting monitoring during training and competition.
Conclusions: The developed scale and application demonstrated acceptable reliability and usability. Future studies should conduct confirmatory factor analysis with larger samples.

Keywords

Athletes visual analog scale; application; athletes' mental fatigue; psychometric validation.

Resumen

Introducción: La fatiga mental puede afectar el rendimiento cognitivo, la regulación emocional, la toma de decisiones y el rendimiento físico de los atletas durante entrenamiento y competición. Aunque la Escala Analógica Visual (VAS) se utiliza ampliamente, el desarrollo de una VAS de múltiples ítems para atletas integrada con una aplicación digital aún es limitado.
Objetivo: Desarrollar y validar una VAS de múltiples ítems para evaluar la fatiga mental en atletas y desarrollar una aplicación para su evaluación.
Metodología: La investigación se realizó en tres fases. En la Fase 1 se desarrolló una VAS de 20 ítems que abarca cuatro componentes: función cognitiva y mental, función emocional, función conductual y respuestas físicas y fisiológicas; su fiabilidad se evaluó mediante el coeficiente alfa de Cronbach. En la Fase 2 se desarrolló una aplicación para evaluar la fatiga mental y se analizaron la fiabilidad de las puntuaciones y la satisfacción de los usuarios. En la Fase 3, expertos en tecnología evaluaron su idoneidad.
Resultados: Los coeficientes alfa de Cronbach oscilaron entre .76 y .83, con una fiabilidad global de .90. La aplicación mostró una fiabilidad de .862 y el nivel más alto de satisfacción de los usuarios. Los expertos calificaron la idoneidad general en un nivel alto.
Discusión: Los resultados sugieren que la escala y la aplicación son herramientas confiables y prácticas para evaluar la fatiga mental en atletas.
Conclusiones: La escala y la aplicación demostraron una fiabilidad y utilidad aceptables. Se recomiendan estudios futuros con análisis factorial confirmatorio y muestras más grandes.

Palabras clave

Escala visual analógica para atletas; aplicación; fatiga mental en atletas; validación psicométrica.

Introduction

Mental fatigue has become a very popular research topic when it comes to athletes and exercise-induced and performance-related fatigue (Russell et al., 2019). Many studies have shown how mental fatigue has detrimental effects on athletes when playing sports such as football (Smith et al., 2016; Smith et al., 2017; Sun et al., 2022), swimming (Penna et al., 2018; Penna et al., 2021), volleyball (Coimbra et al., 2021), table tennis (Le Mansec et al., 2018), and cricket (Veness et al., 2017). Smith et al. (2016) showed mental fatigue decreased football-specific running, passing, and shooting performance. Sun et al. (2022) conducted a systematic review with meta-analysis and showed that mental fatigue can influence sport-specific technical skills (positive effects on offensive and defensive skills, negative effects on tackle frequency and tackling success rate). Smith et al. (2017) also demonstrated mental fatigue decreases passing accuracy on short passes. Penna et al. (2018) found mental fatigue led to impaired swimming performance in youth athletes. Recently, Retos has published articles looking at mental fatigue and sport-specific performance as well. Sinkovic et al. (2025) used an experimental method to induce mental fatigue and impair soccer passing accuracy and speed in university-aged athletes. Zouer Habeb et al. (2025) induced mental fatigue and used portable EEG to show fatigue significantly increased frontal theta power and theta/alpha ratios following the fatigue protocol; these neurophysiological changes were associated with worse tactical decision-making performance in professional soccer players. These recent studies underscore both the applied relevance of mental fatigue in sport and scientific interest in objectively and subjectively assessing mental fatigue in athletes.

The majority of research studies use subjective measures to assess mental fatigue using different scales or visual analog scales (VAS) (Pageaux & Lepers, 2018). Visual analog scales have been implemented frequently (Coimbra et al., 2021; Le Mansec et al., 2018; Penna et al., 2018, 2021; Smith et al., 2017, 2019; Van Cutsem et al., 2017; Veness et al., 2017) and appear to be a feasible, evidence-based tool (Coyne et al., 2021). Visual analog scales typically consist of a straight line that is 10 mm or 10 cm long with different words describing the opposite ends of the continuum (DeVellis, 2012). Examples of descriptors used were “not at all mentally fatigued” and “extremely mentally fatigued” (Le Mansec et al., 2018; Penna et al., 2018; Van Cutsem et al., 2017; Veness et al., 2017). Participants would check off a point on the line that corresponds with how they feel (Le Mansec et al., 2018; Penna et al., 2018; Van Cutsem et al., 2017; Veness et al., 2017). Sometimes the VAS is in response to a question such as “How do you feel at this moment?” (Smith et al., 2019) or “Indicate your current level of mental fatigue” (Coimbra et al., 2021).

After reviewing the literature, it was found that nearly all VAS inquiries consisted of only one question. Mental fatigue is a psychological construct that cannot be seen or directly measured. Measuring a construction that cannot be seen with only one question may not be comprehensive enough to assess the full spectrum of that construction (DeVellis, 2012; Nunnally & Bernstein, 1994). A single question is unlikely to contain enough content to fully represent the construct and may not be indicative of a person’s actual level of mental fatigue. Mental fatigue can theoretically be perceived/subjectively, behaviorally, and physiologically (Russell et al., 2019; Van Cutsem et al., 2017). Therefore, a scale with multiple questions that could assess all of these areas would best assess the construction of mental fatigue. As such, the current study aimed to create a multi-item VAS.

Traditional paper-and-pencil VAS measures are tedious and inconvenient, requiring manual measurement of each response along the continuum. This becomes especially cumbersome when collecting data from large samples and may partly explain the widespread reliance on single-item measures. For these reasons, the authors also aimed to develop a digital mental fatigue assessment application incorporating VAS technology. Such an application enables multi-item assessment, provides immediate score feedback, includes preliminary mental fatigue management guidelines, stores assessment history, and can be accessed via smartphones, tablets, and computers. The objectives of this study were to: (1) develop and validate the quality of a multi-item VAS for assessing athletes' mental fatigue; (2) develop and validate the quality of a mental fatigue assessment application; (3) evaluate user satisfaction with the application; and (4) examine the overall suitability of the application.

Method

The study consisted of three phases: Phase 1, Creating Visual Analog Scale (VAS) for measuring athlete's mental fatigue; Phase 2, Developing application to assess mental fatigue; Phase 3 Assessing suitability of the application.

Phase 1: Creating Visual Analog Scale for measuring athlete's mental fatigue.

Phase 1 included two stages: (1) item generation; (2) Assessing item's quality and measurement reliability.

Stage 1: Item generation

The literature and previous studies on mental fatigue were reviewed. Semi-structured interviews were conducted with coaches and athletes to identify concepts, components, and behavioral exhibition of mental fatigue in athletes. Based on the interviews, researchers defined mental fatigue and created VAS-based items scored on a scale from 0 to 10.

Sample included 6 athletes and 3 coaches, which were recruited from the faculty of sport science. Interview questions: (1) What is your opinion on mental fatigue in athletes? ; (2) Could you describe your experience of mental fatigue in athletes? ; (3) What are the characteristics of mental fatigue symptoms? ; (4) Does these symptoms impact on your sport performance? ; (5) What do you think are reasons of those symptoms?

Content analysis was used in examination of relevant documents, previous research, and interviews.

Stage 2: Assessing item's quality and measurement reliability

Created items were examined by experts for content validity and were edited for pilot testing.

Sample included two groups of participants: (1) content validity was assessed by 3 experts (two sport science experts, and one health psychology expert); (2) examined item's quality and reliability with a sample of 50 athletes.

Inclusion criteria for pilot sample: (a) currently participating in competitive sport at university level or higher; (b) been involved in organized sport for at least one year; and (c) no current injury preventing regular training. Participants were excluded if: (a) had clinically diagnosed psychological disorders; and (b) submitted incomplete questionnaires (less than 80% answered).

Sample size n = 50 was determined to be sufficient for the selection analyses that were conducted in this study. Corrected item-total correlation (CITC) analysis and internal consistency estimation (via Cronbach's alpha) both require a minimum sample size of 5–10 participants per item to be calculated (Nunnally & Bernstein, 1994). As this study included 40 items, our current sample size meets the guidelines for conducting the primary selection analyses (content validity was assessed by content experts and is not generally considered to have sample size minimums or maximums). It should be noted that our sample size of n = 50 is not adequate for exploratory factor analysis (EFA; minimum sample size of 200 participants or 10: 1 ratio of participants to items; DeVellis, 2012). Factor analysis was not conducted at this phase of development and is noted as a priority for future validation efforts.

Data collection. Research instruments included content validity evaluation form and pilot version of athlete's mental fatigue scale. Data analysis

Content Validity was calculated using IOC index, item's quality was examined by corrected item-total correlations (CITC) and reliability was assessed by calculating Cronbach's alpha coefficients.

Phase 2: Development of the Mental Fatigue Assessment Application

Stage 1: Application Design and Pilot Test

The researchers developed a web-based mental fatigue assessment application consisting of login, mental fatigue assessment, result display and management guidelines pages, history records, and logout. They utilize web application development languages and tools such as HTML5, CSS3, JavaScript, and database applications. Procedures included iterative design steps: (1) analysis of needs from Phase 1, (2) creation of prototypes and interfaces, (3) internal verification and debugging of technical elements,

and (4) athlete testing of application functions. After developing the web-based application, researchers recruited 50 participants who possessed attributes similar to their target population for pilot test participation.

Stage 2: Quality of Application and Satisfaction Determination

Measurement instruments used were the mental fatigue assessment application and user satisfaction questionnaire (7 items; 5-point Likert scale). The researchers used Cronbach's alpha to determine reliability of the assessment scores and calculated means and standard deviations to understand participant satisfaction.

Phase 3: Mental Fatigue Assessment Application Suitability Determination

The mental fatigue assessment application's suitability was determined by three IT experts using the application suitability evaluation form (13 items). Descriptive statistics were used to analyze quantitative data and summary of expert recommendations was generated.

Results

Part 1: Development of the Visual Analog Scale for Assessing Athletes' Mental Fatigue

Content analysis of relevant literature and interview data yielded four components of athletes' mental fatigue: (1) Cognitive Function and Mental Activities—manifestations related to cognitive processes such as planning, decision-making, concentration, and memory; (2) Emotional States—manifestations related to emotions such as unhappiness, irritability, boredom, and anxiety; (3) Behavioral Component—manifestations in external behaviors such as motivation, agility, response speed, and accuracy; and (4) Physical and Physiological Responses—manifestations related to physical capabilities such as strength, fatigue, and energy levels.

Forty items (10 items per component) were drafted and sent to experts for content validity review. All items achieved the criteria for item selection (IOC ≥ .50). Items needing revision were revised based on experts' suggestions before pilot testing.

There were 50 athletes in the pilot sample. The sample was predominantly male (62%). Mean age of the athletes was 21 years. Mean years of sport participation was 8 years 8 months. Mean number of hours training per week was 20 hours. Mean number of hours slept per day was 7 hours. Descriptive statistics indicated cognitive and mental activity had the highest mean score among the four components (M = 7.36; SD = 1.28) and physical and physiological responses had the lowest mean score (M = 5.95; SD = 1.78). Correlation analysis demonstrated all components were significantly and positively correlated at the .01 level (Table 1).

Table 1. Means, Standard Deviations, and Correlation Coefficients among Components of Mental Fatigue

Component	M	SD	1. Cognitive	2. Emotional	3. Behavioral	4. Physical
1. Cognitive Function and Mental Activities	7.36	1.28	1.00			
2. Emotional States	6.78	1.60	.66**	1.00		
3. Behavioral	7.02	1.52	.65**	.65**	1.00	
4. Physical and Physiological Responses	5.95	1.78	.48**	.39**	.45**	1.00

**p < .01.

CITCs for the 40-item scale ranged from .412 to .658 for the cognitive component, .310 to .668 for the emotional component, .312 to .640 for the behavioral component, and .486 to .676 for the physical component. Thus, all items met the selection criterion (CITC ≥ .30). Internal consistency reliability was high: Cronbach's alpha for the cognitive, emotional, behavioral, and physical components were .830, .843, .812, and .857, respectively; Cronbach's alpha for the 40-item scale was .928. The scale was then reduced to 20-items. The selection criterion was to retain the five items with the highest CITC value from each component. Retaining the items with the highest CITCs is consistent with psychometric theory and guidance on scale development, which recommends retaining items with the highest discrimination parameters (DeVellis, 2012). Also, all retained items were cross-checked to ensure they fully represented the

conceptual definition of their component. Cronbach's alpha for the reduced 20-item scale was .90, which is high enough to show that reliability was not compromised by removing items. The final 20-item scale can be found in Table 2.

Table 2. The Mental Fatigue Assessment Tool for Athletes (20-Item Version)

	Cognitive Function and Mental Activities Component (Alpha = .76)
1	During training, how well can you focus on your training goals? (Not focused on all to too highly focused)
2	How quickly can you decide during the competition? (Very slow too quick)
3	Is your concentration disturbed by thoughts unrelated to the competition? (Always disturbed to not disturbed at all)
4	Is your strategic thinking efficient in pressure situations? (Not efficient at all to Very efficient)
5	During the competition, how quickly can you decide at crucial moments? (Very slow decision-making to immediate decision-making)
	Emotional States Component (Alpha = .83)
6	Do you feel bored with repetitive training programs? (Very bored to Not bored at all)
7	Do you feel irritable or easily angered during training or competition? (Very irritable to not at all)
8	In monotonous training situations, how is your happiness during training? (Not happy at all to Very happy)
9	Does daily routine training affect your feeling of freshness? (No freshness at all to Very fresh)
10	Do you feel bored during training that lacks novelty or involves repetitive tasks? (Always bored to Not bored at all)
	Behavioral Component (Alpha = .80)
11	Has your accuracy in passing/hitting/shooting decreased? (Decreased significantly to not decreased at all)
12	Do you take breaks more frequently during training or competition? (Persistent breaks to No tendency to take breaks)
13	Is your movement slower than before during the competition? (Much slower than before to Not slower than before)
14	Do you need to rely more on teammates to correct mistakes on the field? (Rely heavily to Do not rely at all)
15	How much has your personality, including your smile and eyes, changed recently? (Changed completely to remain the same)
	Physical and Physiological Responses Component (Alpha = .80)
16	Does your body take longer than usual to recover after training? (Recovery takes much longer to recover quickly)
17	Are you so fatigued that training the next day becomes difficult? (Very difficult to Not at all)
18	Is your physical recovery, such as rest or sleep, less effective than it used to be? (Not as effective as before to Same as before)
19	After the same daily training routines, has your strength declined? (Strength declined unprecedentedly to good strength)
20	When you have to train continuously in the same manner, does your physical power decrease? (Power decreases to Power increases)
	Overall alpha coefficient (20 items) = .90

Note. VAS = Visual Analog Scale (0–10). Alpha coefficients reported per component and for the full scale.

Part 2: Development of the Mental Fatigue Assessment Application

Application Design and Pilot Testing

The Mental Fatigue Assessment Application had 5 sections. Section1 (Login): Access the application through the web browser by entering https://amf.buu.ac.th/work1/index.html. Login with Gmail or Facebook account. Section 2 (Mental Fatigue Assessment): Respond to the 20-item VAS scale that has been embedded into the application. There are 4 components in the application. Participants would input demographic information and move the slider to mark their points that represent the levels of mental fatigue for each item. Section 3 (Result and Management Guidelines): View the results along with the interpretation of mental fatigue level and personalized management guidelines. Section 4 (History): View all previous results with date and time. Section 5 (Logout): Click logout button and you will be directed to the login page.

Quality of Application and Satisfaction

Our pilot sample size consisted of 50 athletes. The participants were majority male (92%). Female athletes made up 6% of the sample and LGBTQ+ athletes made up 2%. The average age of the participants was 21 years old. The sport that most athletes participated in was football (27%). Badminton and golf were also common sports that athletes participated in (8% each). The average amount of years playing sport was 9. The average amount of time spent training per week was 12 hours and 58 minutes. The average amount of sleep the athletes got per day was 7 hours and 37 minutes.

Reliability analysis of the application's assessment scores indicated good internal consistency (Cronbach's alpha = .862). Overall user satisfaction was rated at the highest level (M = 4.44, SD = .70). Ratings for all items except interface design and aesthetics were at the highest level. Detailed results are presented in Table 3.

Table 3. User Satisfaction with the Athletes' Mental Fatigue Assessment Application

Evaluation Items	Mean	SD	Interpretation
1. Convenience of using the application	4.68	0.55	Highest
2. Clarity of instructions and guidance in the application	4.62	0.57	Highest
3. Design and aesthetics of the application interface	4.44	0.70	High
4. Accuracy and credibility of the mental fatigue assessment results	4.60	0.57	Highest
5. Usefulness of feedback information for mental health development	4.54	0.61	Highest
6. Ease of understanding the assessment results presented in graphical or data formats	4.78	0.46	Highest
7. Overall satisfaction with the use of the application	4.72	0.54	Highest

Note. Mean score interpretation: 4.51–5.00 = Highest; 3.51–4.50 = High; 2.51–3.50 = Moderate; 1.51–2.50 = Low; 1.00–1.50 = Lowest.

Part 3: Evaluation of the Suitability of the Application

Three information technology experts evaluated overall application suitability as high (M = 4.41, SD = .42). The highest mean score was for the login method (M = 5.00, SD = .00). Text input fields, typography, background design, ease of use, and overall design all received high ratings (M = 4.67, SD = .58 each). Detailed results are presented in Table 4.

Table 4. Suitability of the Athletes' Mental Fatigue Assessment Application

Evaluation Items	Mean	SD	Interpretation
1. Suitability of the scale format/characteristics used in the application	4.00	0.00	High
2. Suitability of the scoring method and score interpretation	4.00	1.00	High
3. Suitability of recommendations for managing athletes' mental fatigue	4.33	0.58	High
4. Suitability of the login method	5.00	0.00	Highest
5. Suitability of text input fields used in the application	4.67	0.58	Highest
6. Suitability of language used in the application	4.00	1.00	High
7. Suitability of typography used in the application (e.g., font size and color)	4.67	0.58	Highest
8. Suitability of background design used in the application	4.67	0.58	Highest
9. Suitability of the layout and positioning of components in the application	4.33	0.58	High
10. Suitability regarding ease of use of the application	4.67	0.58	Highest
11. Suitability regarding complexity of using the application	4.33	0.58	High
12. Suitability of the overall application design	4.67	0.58	Highest
13. Suitability regarding data security	4.00	0.00	High
Overall	4.41	0.42	High

Note. Mean score interpretation: 4.51–5.00 = Highest; 3.51–4.50 = High; 2.51–3.50 = Moderate; 1.51–2.50 = Low; 1.00–1.50 = Lowest.

Conclusions

This study resulted in a 20-item VAS for assessing athletes' mental fatigue across four components: cognitive and mental activities, emotional states, behavioral manifestations, and physical and physiological responses. The identification of these four components is theoretically grounded. The emotional and behavioral components are consistent with classifications proposed by many researchers, who categorize mental fatigue into behavioral manifestations and subjective feelings (Smith et al., 2019). Russell et al. (2019) and Van Cutsem et al. (2017) have suggested that mental fatigue can be operationalized as perceptual/subjective, behavioral and physiological phenomena. Given that the scale developed here included items pertaining to all three of these elements, it could be argued that this scale adequately samples the domain of mental fatigue. This notion maps onto tenets of construct validity that propose that good measures should demonstrate evidence of domain sampling (DeVellis, 2012; Nunnally & Bernstein, 1994).

Additionally, the development of a multi-item scale represents a step forward from most of the research bases because previous studies have tended to use single-item VAS measures of mental fatigue. Single-item scales may not sufficiently encapsulate latent psychological constructs such as mental fatigue (DeVellis, 2012). The developed scale demonstrated high reliability at both the overall (alpha = .90) and component levels (.76 to .83), indicating acceptable psychometric properties for a newly developed instrument.

The mental fatigue assessment application incorporates the validated VAS scale across all four components and provides immediate assessment results, score interpretation, historical tracking, and preliminary management guidelines. Reliability of scores from the application was Cronbach's alpha = .862, reflecting the high quality of the embedded items. Maximum ratings were found in relation to user satisfaction. This could be due to the user-friendly interface of the application, instant feedback provided,

cross-platform capability and question stems being based on evidence. Notably, user satisfaction was rated highly on almost all items. This finding is in line with emerging research demonstrating athlete acceptance of technology-based assessment tools (Zouer Habeb et al., 2025). Content validity was rated as high after assessment by experts.

From a practical standpoint, the developed scale and accompanying application can be used to benefit sport science practitioners. For example, coaches and sport scientists can easily track athletes' mental fatigue levels during training camps or throughout a season using the application. Additionally, athletes' mental fatigue can be tracked overtime using the history recording feature. Monitoring mental fatigue over time can help coaches spot warning signs of accruing mental fatigue before it begins to negatively impact performance. Mental fatigue has been demonstrated to debilitate technical and tactical sport performance in a variety of sports. These sports include football via decreased passing accuracy (Smith et al., 2017; Sinkovic et al., 2025) and decision-making speed (Zouer Habeb et al., 2025)—timely identification through accessible assessment tools could enable early intervention and protect athlete performance.

Limitation and Directions for Future Research

There are limitations that should be considered when interpreting these results. Initially, the pilot sample used convenience sampling from one university, limiting the ability to generalize results to athletes. Future studies should employ probability sampling strategies and recruit participants from multiple institutions and competitive levels. Second, as noted earlier, the sample size (n = 50) did not allow us to conduct an EFA or CFA to determine structural validity (scale development typically includes both; DeVellis, 2012). Thus, future research with larger samples (EFA = MINIMUM n = 200, CFA = n = 300+) should explore the factor structure of the scale. Third, we only determined internal consistency reliability. Future investigations should include test-retest reliability, convergent validity, and discriminant validity. Fourth, mental fatigue management guidelines released within the application were only general recommendations. Athletes registering high mental fatigue scores should be given more prescriptive advice from professionals in the field. Correcting for these limitations can help ensure that we have a psychometrically-sound scale and a trustworthy application as a monitoring tool.

Recommendation

1. User satisfaction with the interface design and visual aesthetics was the lowest rated aspect; therefore, future improvements should incorporate UI design principles to enhance visual appeal, usability, and efficiency.
2. Validity assessment of the VAS only used Cronbach's α, and exploratory factor analysis and confirmatory factor analysis should be conducted in future research.
3. Future development should explore athletes' and coaches' needs regarding additional application features to enhance functionality and better meet user demands.
4. The psychological recommendations offered by the application are only based on psychological tiredness; further concrete recommendations and support should be offered to highly mentally fatigued athletes by professionals.

Conclusion

The developed 20-item Visual Analog Scale demonstrated good to excellent reliability at both the subscale and overall levels, indicating satisfactory psychometric properties for assessing athletes' mental fatigue across cognitive and mental activities, emotional states, behavioral aspects, and physical and physiological responses. The mental fatigue app offered instant evaluation, score explanation, history tracking and basic management suggestions. Findings from pilot testing indicated high internal consistency, reliability of application scores and highest-level overall user satisfaction. Information technology

experts evaluated the application as highly appropriate. Overall, the developed scale and application constitute effective tools for monitoring and supporting the management of mental fatigue in athletes, with future validation studies using factor analysis and larger samples recommended to establish structural validity.

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