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Validation of a Subjective Test for Assessing Cognitive Load in Emergency Coordination Center ProFessionals Under High-Demand Situations

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ABSTRACT

Background: No studies have been developed and validated to assess the perceived cognitive load of healthcare professionals at an emergency coordination center during simulated high-demand situations.

Method: We designed a 22-item questionnaire (19 Likert-scale, 3 open-ended) validated via expert judgment (n=7) and pilot-tested (n=10) in simulated high-demand environments. The objective is to provide a practical tool for real-time identification of cognitive overload and its potential mitigation through training.

Results: Expert validation showed high content agreement (CVI > 0.8). Cronbach's alpha for internal consistency was 0.861. Participants reported perceived cognitive load levels varying with task type and professional profile.

Conclusions: This instrument is reliable and adaptable for identifying perceived cognitive overload in high-stress simulations. It can improve training design and safety procedures, avoiding failures due to overload.

Keywords: Cognitive Load; Expert Review; Validation Study; Simulated Training

Abbreviations: CVI: Content Validity Index; NASA-TLX: Task Load Index; SWAT: Subjective Workload Assessment Technique; WP: Workload Profile

Introduction

The authors of Cognitive Load Theory themselves assert that it was designed to provide guidelines that promote activities optimizing intellectual performance—that is, to be identified as a determining factor in human performance, especially in high-pressure contexts [1,2]. The theory assumes the limited capacity of working memory, so the key is to reduce this "load" and promote the construction of mental schemas. Cognitive overload can lead to errors, decreased performance, and mental fatigue [3]. Therefore, precise, even subjective, evaluation of cognitive load is crucial in preventing adverse events [4]. Besides its role in working memory, cognitive load is crucial in various aspects of learning and instruction. Some key points where cognitive load plays an important role include [5,6].

1. Instructional design: Cognitive load influences how learning materials should be structured to avoid mental overload and facilitate understanding.
2. Schema construction: Essential for forming and automating mental schemas, which enable organ-izing and applying knowledge efficiently.
3. Attention and concentration: An adequate cognitive load helps maintain focus on complex tasks, avoiding distractions and improving performance.
4. Knowledge transfer: Facilitates applying learned material in new contexts by allowing better inte-gration and adaptation of information.
5. Extraneous load reduction: Identifying and minimizing unnecessary elements in information presentation helps reduce extrinsic cognitive load, improving learning efficiency.
6. Development of metacognitive skills: Proper management of cognitive load promotes reflection on the learning process, strengthening metacognitive abilities.
7. Adaptation to expertise level: Cognitive load should be adjusted according to the learner's prior knowledge, as overload can harm novices while insufficient load may not challenge advanced learners.
8. Optimization of multimedia learning: In environments combining text, images, and audio, managing cognitive load is vital to avoid sensory overload and improve information retention.
9. Mental evaluation effort: Subjective cognitive load measures, such as questionnaires and self-assessments, estimate the mental effort perceived by learners during tasks.
10. Design of effective assessments: Considering cognitive load when creating tests ensures they assess real knowledge without adding unnecessary complexity.

Working memory is a set of processes that can be defined as a mental workspace. Humans are only aware of what is in working memory. All other cognitive activity is hidden from view unless brought into working memory. Therefore, the working memory is used to organize, contrast, and compare information. Interaction between elements in working memory consumes its capacity, reducing the number of items that can be managed simultaneously [7,8]. Baddeley's theory [9] defines working memory as an active memory system that allows temporary retention and manipulation of information to perform complex cognitive tasks. It divides working memory into a visuospatial sketchpad for processing visual information and a phonological loop for auditory, mainly spoken, information. These two systems are coordinated by a central executive system. From this division comes the idea of Dual Coding, ie, the effectiveness of presenting information visually and auditorily. Any activity design ignoring working memory limitations is inevitably flawed. Although several dimensions have been proposed, all authors agree that cognitive load—especially subjective load—fits into three broad areas. The first includes time pressure aspects of the task (available time, needed time). The second refers to variables related to processing resource demands of the task (mental, sensory, task type). The third relates to emotional aspects (fatigue, frustration, stress level) [10].

To complement these dimensions, various techniques for predicting and assessing mental load have been identified, and their usefulness depends on how well they meet the following criteria: sensitivity, di-agnostic power, selectivity/validity, intrusiveness, reliability, implementation requirements, and operator acceptance [4,11]. Most methods used to evaluate mental load can be classified into three general cate-gories [12]:

1. Performance-based procedures: any increase in task difficulty raises demands, manifested by re-duced performance. The main advantage of these measures is their high diagnostic power.
2. Physiological measures: mental load can be measured through physiological activation levels. Their drawbacks include high implementation requirements, poor acceptance by participants, and questions about their validity as mental workload indices. Examples include P300 evoked potential, pupil diameter, and heart rate measurements.
3. Subjective procedures: greater capacity expenditure is associated with subjective feelings of effort, which individuals can adequately evaluate. Manyvalidated subjective methods exist for assessing mental load, notably the Cooper-Harper Scale, Bedford Scale, SWAT (Subjective Workload Assessment Technique), NASA-TLX (Task Load Index), and WP (Workload Profile) [13]. The wide variety of sub-jective techniques has led authors to study their characteristics to establish methodology reflecting properties to consider when choosing among techniques, depending on the research objective and con-text. Due to their particular characteristics (minimal implementation requirements, high acceptance, good validity and reliability, etc.), subjective instruments are most frequently used in applied contexts.

General Objective

To develop and validate a specific subjective instrument to assess perceived cognitive load in healthcare professionals at an emergency coordination center during high-demand simulated situations, specifically adapted to the characteristics and demands of their work contexts.

Specific Objectives

1. Design an initial cognitive load assessment questionnaire based on literature review and adapted to the work environments of emergency physicians and nurses in an emergency call center.

2. Subject the questionnaire to expert judgment validation to assess item relevance, clarity, and per-tinence.

3. Analyze the instrument's adequacy to differentiate perceived cognitive load levels according to task type, professional profile, or participant experience.

Justification

Cognitive load is a determining factor in performance and decision-making in mentally demanding contexts, such as coordination of healthcare emergencies at coordination centers. Accurate evaluation of this load allows detection of overload situations, error prevention, and design of strategies to optimize performance and safety. However, most of the validated instruments available for assessing cognitive load have significant limitations when applied to these specific contexts: they include irrelevant items, are not adapted to the language or tasks of the professionals involved or have not been validated in similar populations. Therefore, there is a need to develop and validate a subjective instrument conditions based on individuals' self-perception, specifically tailored to the working conditions of staff that work under of great cognitive pressure such as emergency physicians and nurses participating in high-load emergency call simulations. The development and validation of this instrument through expert judgment and pilot testing in simulated situations will provide a reliable, valid, and useful tool for researching and managing cognitive load in these environments. This will not only provide scientific evidence in a scarcely explored area within these professions but also have practical applications for training, simulation design, and operational safety improvement.

Method

Study Design

A quasi-experimental instrumental study with quantitative and qualitative approaches, aiming to design and validate a subjective questionnaire to evaluate perceived cognitive load in professionals under high cognitive demand during simulated situations. Prediction models are used in various healthcare settings to estimate the value of an outcome or risk. Most models estimate the probability of a specific medical condition or whether a specific outcome will occur in the future. Examples of commonly used prediction models include EuroSCORE II (cardiac surgery) [14], the Gail model (breast cancer) [15], the Framingham Risk Score (cardiovascular disease) [16], IMPACT (head injury) [17], and FRAX (osteoporotic and hip fractures) [18]. Poor information from a model could mask flaws in the design, data collection, or conduct of a study that may cause harm. Better information can build greater trust and influence acceptance of the use of prediction models in healthcare by patients and the public. In this case, we need a subjective scale adapted to emergency coordination work. Other validated scales exist, but they are not adapted to this specific task, as mentioned in the introduction, because this work tends to be increasingly demanding for workers. The economic crisis and technological advances have led to an increase in the number of tasks and in their perceptual-cognitive demands, giving rise to more complex work situations in which task accumulation is frequent.

The direct consequence of these factors is an increase in mental workload. Numerous studies have been conducted using validated subjective tests [19-21], although, as we have mentioned, they are not adapted to these specific jobs. To give more consistency to the study and to be able to objectively see its validity, we have followed the TRIPOD+AI guide [22]. The TRIPOD (Transparent Reporting of a Multivariate Prediction Model for Individual Prognosis or Diagnosis) statement was published in 2015 to provide minimum reporting recommendations for studies developing or evaluating the performance of a prediction model [22]. TRIPOD+AI aims to promote comprehensive, accurate, and transparent reporting of studies by developing a prediction model or evaluating its performance. Comprehensive reporting will facilitate study appraisal, model evaluation, and implementation. TRIPOD 2015 (Appendix A & B) Comprises a 37-item checklist, including 25 items for reporting in both development and validation studies, and six additional items for model development studies and six items for validation studies. TRIPOD 2015 focused primarily on models developed using regression models, which was the predominant approach at the time. Since then, additional guidance has been created, such as for studies developing or validating prediction models using clustered data (TRI-POD-Cluster19 20) (https://www.tripod-statement.org/).

Appendix A: Tripod AI Checklist.

Section/Topic	Item	Development /evaluation	Checklist item	Reported on page
TITLE				
Title	1	D,E	Identify the study as developing or evaluating the performance of a multivariable prediction model, the target population, and the outcome to be predicted	1
ABSTRACT				
Abstract	2	D,E	See TRIPOD+AI for Abstracts checklist	i
INTRODUCTION				
Background	3a	D,E	Explain the healthcare context (including whether diagnostic or prognostic) and rationale for developing or evaluating the prediction model, including references to existing models	2-3
	3b	D,E	Describe the target population and the intended purpose of the prediction model in the context of the care pathway, including its intended users (e.g., healthcare professionals, patients, public)	4
	3c	D,E	Describe any known health inequalities between sociodemographic groups	N/A
Objectives	4	D,E	Specify the study objectives, including whether the study describes the development or validation of a prediction model (or both)	3
METHODS				
Data	5a	D,E	Describe the sources of data separately for the development and evaluation datasets (e.g., randomised trial, cohort, routine care or registry data), the rationale for using these data, and representativeness of the data	4
	5b	D,E	Specify the dates of the collected participant data, including start and end of participant accrual; and, if applicable, end of follow-up	5
Participants	6a	D,E	Specify key elements of the study setting (e.g., primary care, secondary care, general population) including the number and location of centres	5
	6b	D,E	Describe the eligibility criteria for study participants	5
	6c	D,E	Give details of any treatments received, and how they were handled during model development or evaluation, if relevant	N/A
Data preparation	7	D,E	Describe any data pre-processing and quality checking, including whether this was similar across relevant sociodemographic groups	N/A
Outcome	8a	D,E	Clearly define the outcome that is being predicted and the time horizon, including how and when assessed, the rationale for choosing this outcome, and whether the method of outcome assessment is consistent across sociodemographic groups	5
	8b	D,E	If outcome assessment requires subjective interpretation, describe the qualifications and demographic characteristics of the outcome assessors	5
	8c	D,E	Report any actions to blind assessment of the outcome to be predicted	N/A

Predictors	9a	D	Describe the choice of initial predictors (e.g., literature, previous models, all available predictors)	3
			and any pre-selection of predictors before model building	
	9b	D,E	Clearly define all predictors, including how and when they were measured (and any actions to blind assessment of predictors for the outcome and other predictors)	5
	9c	D,E	If predictor measurement requires subjective interpretation, describe the qualifications and demographic characteristics of the predictor assessors	5
Sample size	10	D,E	Explain how the study size was arrived at (separately for development and evaluation), and justify that the study size was sufficient to answer the research question. Include details of any sample size calculation	5
Missing data	11	D,E	Describe how missing data were handled. Provide reasons for omitting any data	N/A
Analytical methods	12a	D	Describe how the data were used (e.g., for development and evaluation of model performance) in the analysis, including whether the data were partitioned, considering any sample size requirements	6-7
	12b	D	Depending on the type of model, describe how predictors were handled in the analyses (functional form, rescaling, transformation, or any standardisation)	13
	12c	D	Specify the type of model, rationale, all model-building steps, including any hyperparameter tuning, and method for internal validation	14
	12d	D,E	Describe if and how any heterogeneity in estimates of model parameter values and model performance was handled and quantified across clusters (e.g., hospitals, countries). See TRIPOD-Cluster for additional considerations	14
	12e	D,E	Specify all measures and plots used (and their rationale) to evaluate model performance (e.g., discrimination, calibration, clinical utility) and, if relevant, to compare multiple models	5-14
	12f	E	Describe any model updating (e.g., recalibration) arising from the model evaluation, either overall or for particular sociodemographic groups or settings	N/A
	12g	E	For model evaluation, describe how the model predictions were calculated (e.g., formula, code, object, application programming interface)	6-8
Class imbalance	13	D,E	If class imbalance methods were used, state why and how this was done, and any subsequent methods to recalibrate the model or the model predictions	N/A
Fairness	14	D,E	Describe any approaches that were used to address model fairness and their rationale	13
Model output	15	D	Specify the output of the prediction model (e.g., probabilities, classification). Provide details and rationale for any classification and how the thresholds were identified	14

Training versus evaluation	16	D,E	Identify any differences | between the development and evaluation data in healthcare setting, eligibility *evaluation* criteria, outcome, and predictors	N/A
Ethical appoval	17	D,E	Name the institutional research board or ethics committee that approved the study and describe the participant-informed consent or the ethics committee waiver of informed consent	16
OPEN SCIENCE				
Funding	18a	D,E	Give the source of funding and the role of the funders for the present study	N/A
Conflicts of interest	18b	D,E	Declare any conflicts of interest and financial disclosures for all authors	16
Protocol	18c	D,E	Indicate where the study protocol can be accessed or state that a protocol was not prepared	16
Registration	18d	D,E	Provide registration information for the study, including register name and registration number, or state that the study was not registered	16
Data sharing	18e	D,E	Provide details of the availability of the study data	16
Code sharing	18f	D,E	Provide details of the availability of the analytical code[l]	16
PATIENT & PU BLIC IN YOLMENT				
Patients & public involvement	19	D,E	Provide details of any patient and public involvement during the design, conduct, reporting, *Involvement* interpretation, or dissemination of the study or state no involvement	5
RESULTS				
Participants	20a	D,E	Describe the flow of participants through the study, including the number of participants with and without the outcome and, if applicable, a summary of the follow-up time. A diagram may be helpful	5, 13
	20b	D,E	Report the characteristics overall and, where applicable, for each data source or setting, including the key dates, key predictors (including demographics), treatments received, sample size, number of outcome events, follow-up time, and amount of missing data. A table may be helpful. Report any differences across key demographic groups	5-14
	20c	E	For model evaluation, show a comparison with the development data of the distribution of important predictors (demographics, predictors, and outcome)	N/A
Model development	21	D,E	Specify the number of participants and outcome events in each analysis (e.g., for model development, hyperparameter tuning, model evaluation)	5, 13
Model specification	22	D	Provide details of the full prediction model (e.g., formula, code, object, application programming *specification* interface) to allow predictions in new individuals and to enable third-party evaluation and implementation, including any restrictions to access or re-use (e.g., freely available, proprietary)	5
Model performance	23a	D,E	Report model performance estimates with confidence intervals, including for any key subgroups (e.g., *performance* sociodemographic). Consider plots to air presentation	14

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CUESTIONARIO POST-TEST

Fecha: **Hora:**

Código:

Actividad realizada:

Indique, si las hay, situaciones estresantes referentes a la actividad que acaba de realizar y mejoras que cree se pueden implementar para mejorar dicho disconfort, marcando el número que mejor se corresponda (**1 totalmente en desacuerdo, 2 en desacuerdo, 3 indiferente, 4 de acuerdo, 5 totalmente de acuerdo**):

Estresores del ambiente físico:	**1**	**2**	**3**	**4**	**5**
1. Tuve la sensación de que la tarea se llevó a cabo con poca iluminación:	☐	☐	☐	☐	☐
2. Encontré dificultades en realizar la intervención por la presencia de ruidos molestos o intensos:	☐	☐	☐	☐	☐

Estresores de la tarea:	**1**	**2**	**3**	**4**	**5**
3. Tuve la sensación de que la tarea se llevó a cabo con poco tiempo para realizarla:	☐	☐	☐	☐	☐
4. No me dio tiempo a finalizar la tarea en el tiempo asignado:	☐	☐	☐	☐	☐
5. La velocidad de la tarea no me ha permitido ver los detalles de esta:	☐	☐	☐	☐	☐
6. La distribución de tareas ha sido irregular y provocó que se me acumulara el trabajo:	☐	☐	☐	☐	☐
7. Considero que la cantidad de trabajo asignado era excesiva:	☐	☐	☐	☐	☐
8. Según avanzaba la tarea me he sentido menos cómodo/a:	☐	☐	☐	☐	☐
9. Según avanzaba la tarea me he sentido más agotado/a:	☐	☐	☐	☐	☐
10. La tarea me ha generado frustración:	☐	☐	☐	☐	☐
11. No he quedado satisfecho/a con mis resultados:	☐	☐	☐	☐	☐
12. No he sido capaz de gestionar el estrés, los cambios, los contratiempos de la tarea con mis herramientas internas:	☐	☐	☐	☐	☐
13. La tarea me ha desgastado mentalmente:	☐	☐	☐	☐	☐
14. La tarea me ha desgastado emocionalmente:	☐	☐	☐	☐	☐
15. La terea me ha desgastado físicamente:	☐	☐	☐	☐	☐

Estresores de la organización:	**1**	**2**	**3**	**4**	**5**
16. Considero que no se me explicó la actividad con detalle, los objetivos y resultados esperados de mi:	☐	☐	☐	☐	☐
17. He necesitado ayuda/apoyo:	☐	☐	☐	☐	☐
18. He necesitado ayuda/apoyo y no la he tenido:	☐	☐	☐	☐	☐
19. No tenía toda la información necesaria para llevar a cabo la tarea:	☐	☐	☐	☐	☐

20. Lo más difícil para mí ha sido:

21. Lo más fácil para mí ha sido:

22. Otros comentarios:

Appendix B: Form.

Depending on the type of study being conducted (development, validation, or both), each checklist item must be addressed somewhere in the report. If a particular checklist item cannot be addressed, the in-formation should be indicated as unknown or irrelevant. Many items follow a natural order and sequence in a report, but others do not.

Participants

The target population includes physicians, nurses, and emergency technicians engaged in divided attention tasks in a lab setting, performing a primary task whose complexity increases by adding progressively difficult secondary tasks. The sample was selected non-probabilistically by convenience, including participants available during the study period, with n=10 for initial validation.

Instruments

The developed questionnaire consists of 22 items (see Table 1, initial question column):

- 19 items with a 5-point Likert scale (from "strongly disagree" to "strongly agree")
- 3 open-ended questions exploring aspects not captured by closed scales.

Table 1: Proposal for change by experts and adaptation of questions.

Initial question	Comments from the expert committee	Final question
1. The task was performed under inadequate lighting	1. The proposed phrase asks about the subject's perception of the lighting while performing the task. This aspect can be subjective for various reasons. A less subjective question would be better for assessing a physical environmental stressor. It could be replaced with: "The lighting during the task was not adequate to perform it" or "The lighting was not adequate to perform the task." 2. Emergency professionals sometimes have to work in low-light conditions. If it is understood that this situation necessarily affects cognitive load, then low lighting would be included as a defining characteristic of the test itself. My recommendation would be to word the question in even more subjective terms: (eg, "I had the feeling that the task was performed under insufficient lighting.") 4. I had the feeling that the lighting under which the task was performed was inadequate. 5. The low lighting clearly made it difficult for me to perform my task. 1. I had the feeling that the task was performed under poor lighting	1. I had the feeling that the task was carried out in poor lighting
2. I had difficulty concentrating and making decisions while performing the proposed task due to annoying or loud noises	1. I would put a clearer sentence... since the test doesn't define what "the intervention" is... is it the same as "the task" or is it different? Therefore, I think I would change the sentence to something clearer... for example, "I had difficulty performing the proposed task due to annoying or loud noises." 5. The ambient noise clearly made it difficult for me to concentrate on the task and make decisions	2. I had difficulty performing the intervention due to the presence of annoying or loud noises
3. The short time to complete the tasks clearly made it difficult for me to concentrate and complete my tasks	1. This could be changed to "The time allotted to complete the task was not enough." 3. I had the feeling that the time given to complete the task was not enough to complete it. 5. The short time to complete the tasks clearly made it difficult for me to concentrate and complete my tasks. 7. I think it would be clearer if it were stated as follows: "I had the feeling that there was little time to complete the task."	3. I had the feeling that the task was completed with little time to complete it

4. I had enough time to concentrate and adequately perform my task	2. This question might be somewhat redundant with the previous one, both relating to the time available for task completion. As for task completion or non-completion, this could be considered an objective parameter of the test, in which case: However, including a subjective consideration of the degree of completion or the degree of satisfaction with task completion is appropriate because it would reflect the influence of differential (stressful) conditions on the subject's performance in relation to their own expectations or in relation to their usual subjective degree of individual performance (which is consistent with the objective of the work), avoiding the need to establish a standardized degree of successful performance for the group of subjects in the study. 5. I had enough time to concentrate and adequately perform my task	4. I did not have time to complete the task in the allotted time
6. My tasks have accumulated due to their distribution	2. I understand that the task will be presented with the typical disorder of uncontrolled situations, to see to what extent it subjectively affects the subject's performance. 5. My tasks have accumulated due to their distribution	6. The distribution of tasks has been irregular and caused my work to accumulate
7. The amount of work assigned was excessive to adequately perform the task	5. You can adequately perform the tasks despite their number/quantity	7. I considered that the amount of work assigned was excessive
8. My comfort increased as the task progressed	5. My concentration/confidence increased throughout the task. 7. As an alternative, without specifying gender, you could ask the following question: "My comfort increased as the task progressed."	8. As the task progressed, I felt less comfortable
9. My exhaustion increased as the task progressed	5. Performing the task caused me psychological stress/loss of concentration. 7. As an alternative, without specifying gender, you could ask the following question: "My exhaustion increased as the race progressed."	9. As the task progressed, I felt more exhausted
10. I have felt unable to perform the task adequately	5. I have felt unable to perform the task adequately	10. The task has caused me frustration
11. I am satisfied with my results	1. I believe that when you perform tasks, you still don't know the outcome of all of them... you can have the feeling of doing something well and then not be so... rather, we should ask if we want to explore the feeling in relation to the results the subject has had in the tasks... "I think I have completed the task successfully or with a good result." 5. I am very satisfied with the results of my tasks and the way they were performed. 7. As an alternative, without marking gender, you could ask the following question: "My results satisfy me."	11. I have not been satisfied with my results
12. My training has allowed me to complete the tasks without any significant incidents such as stress or setbacks	1. I would remove the phrase "with my internal tools" from the sentence... as it can cause confusion and is actually understood... because if someone can manage or overcome something stressful during a task on their own... they could only do so with their internal tools... 5. My training has allowed me to complete the tasks without any significant incidents such as stress, setbacks, etc. 7. I recommend replacing the last comma with "and": I have been able to manage the stress, changes, and setbacks of the task with my internal tools	12. I have not been able to manage the stress, changes, or setbacks of the task with my internal tools

13. The exceptional conditions of the task have exhausted me mentally	1. Here I would give an example of mental exhaustion... A Likert scale could be used for this question. 2. If the intention is to attribute the exhaustion to the differential (stressful) conditions of the test, and not to the task itself, I will specify the wording of the question. Eg: "The exceptional conditions of the task have exhausted me mentally." 5. Performing the task has caused me great stress/mental exhaustion	13. The task has exhausted me mentally
14. The exceptional conditions of the task have exhausted me emotionally (sadness, frustration, etc.)	1. Here I would give some examples of emotional exhaustion... A Likert scale could be used for this question. 3. Add "emotions" to the question that may give clues to the recipient (sadness, frustration, etc.) 5. The emotional burden of the task has been very high	14. The task has exhausted me emotionally
15. The physical effort of the task was very high, causing great fatigue	1. A Likert scale could be used for this question. 5. The physical effort of the task was very high, causing great fatigue	15. The task exhausted me physically
17. I needed external help to perform task	2. It would be necessary to ensure that for the task posed, the subject would not require help or support under "normal" conditions, so that this need could be attributed to the specific differential conditions of the test. 5. The performance of the task requires external help. 7. I would leave only help or support in the statement	17. I needed help/support
18. I have not been able to adequately complete the task due to lack of help	1. I would replace it with "I have not been given help/support" and thus explore the fact that help has not been given... since the question of whether or not it was needed was already addressed in the previous question. 4. Delete. 5. I have not been able to adequately complete the task due to lack of help. 7. I would leave only help or support in the result.	18. I have needed help/support and I have not had it
19. I had all the necessary information to carry out the task	4. "I had all the necessary information to carry out the task." 7. It would be clearer if the question were affirmative: "I had all the necessary information to carry out the task."	19. I did not have all the necessary information to carry out the task

Study Phases

To carry out this study, the following development stages have been carried out:

- Literature review and preliminary questionnaire design: various existing instruments (NASA-TLX, SWAT, WP) were analyzed, and relevant items were selected and adapted to the study context (Appendix B).
- Expert judgment validation: the initial questionnaire was presented to a panel of 7 experts in psy-chology, emergency medicine and nursing, technicians, and air traffic controllers. The Content Validity Index (CVI) proposed by Lawshe [23] and adapted by Tristán [24] was used to assess item relevance, clarity, and representativeness [25,26] (Appendix C). After the first expert evaluation, the questionnaire was revised incorporating feedback. The revised version was sent again to experts to confirm correct integration of comments. The questionnaire was approved after this second review (Appendix D).
- Pilot application in simulated situations: the questionnaire was administered as an exploratory study following controlled simulation sessions in laboratory tests with divided attention loads and physiological constants monitoring, as shown in the Figures 1-4 to 10 participants with profiles similar to the target population, collecting quantitative and qualitative data. The aim was to identify comprehension difficulties and estimate response times. All participants rated the questionnaire positively without identifying irrelevant or incomprehensible items. The final validation will be carried out on a larger sample of professionals from an emergency coordination center (n=30) for its final validation.

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FORMULARIO

Título de la encuesta: Cuestionario post-test

Título de la tesis: Valoración de la carga cognitiva al someter a un trabajador a alta carga mediante la monitorización de constantes fisiológicas

En las siguientes páginas usted evalúa el cuestionario para poder validarlo.

En las respuestas de las escalas tipo Likert, por favor, marque con una X la respuesta escogida de entre las seis opciones que se presentan en los casilleros, siendo:

1= muy en desacuerdo
2= en desacuerdo
3= en desacuerdo más que de acuerdo
4= de acuerdo más que en desacuerdo
5= de acuerdo
6= muy de acuerdo

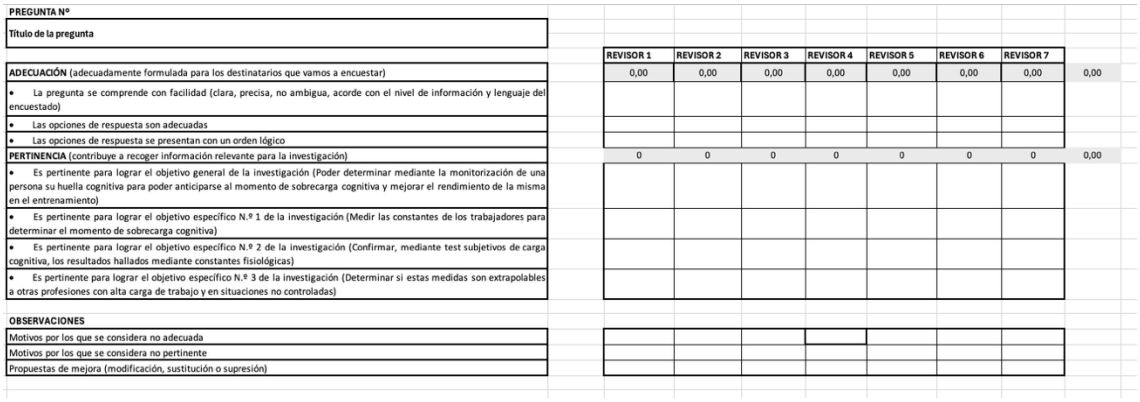
Pregunta N.º

Indique su grado de acuerdo frente a las siguientes afirmaciones: (1= muy en desacuerdo; 2= en desacuerdo; 3= en desacuerdo más que de acuerdo; 4= de acuerdo más que en desacuerdo; 5= de acuerdo; 6= muy de acuerdo	**Grado de acuerdo** 1	2	3	4	5	6
ADECUACIÓN (adecuadamente formulada para los destinatarios que vamos a encuestar)						
• La pregunta se comprende con facilidad (clara, precisa, no ambigua, acorde con el nivel de información y lenguaje del encuestado)						
• Las opciones de respuesta son adecuadas						
• Las opciones de respuesta se presentan con un orden lógico						
PERTINENCIA (contribuye a recoger información relevante para la investigación)						
• Es pertinente para lograr el objetivo general de la investigación (Poder determinar mediante la monitorización de una persona su huella cognitiva para poder anticiparse al momento de sobrecarga cognitiva y mejorar el rendimiento de la misma en el entrenamiento)						
• Es pertinente para lograr el objetivo específico N.º 1 de la investigación (Medir las constantes de los trabajadores para determinar el momento de sobrecarga cognitiva)						
• Es pertinente para lograr el objetivo específico N.º 2 de la investigación (Confirmar, mediante test subjetivos de carga cognitiva, los resultados hallados mediante constantes fisiológicas)						
• Es pertinente para lograr el objetivo específico N.º 3 de la investigación (Determinar si estas medidas son extrapolables a otras profesiones con alta carga de trabajo y en situaciones no controladas)						

Observaciones y recomendaciones en relación a la pregunta N.º	
Motivos por los que se considera no adecuada	
Motivos por los que se considera no pertinente	
Propuestas de mejora (modificación, sustitución o supresión)	

Appendix C: Questionnaire.

Appendix D: Expert validation table.



PREGUNTA Nº									
Título de la pregunta									
	REVISOR 1	REVISOR 2	REVISOR 3	REVISOR 4	REVISOR 5	REVISOR 6	REVISOR 7		
ADECUACIÓN (adecuadamente formulada para los destinatarios que vamos a encuestar)	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	
• La pregunta se comprende con facilidad (clara, precisa, no ambigua, acorde con el nivel de información y lenguaje del encuestado)									
• Las opciones de respuesta son adecuadas									
• Las opciones de respuesta se presentan con un orden lógico									
PERTINENCIA (contribuye a recoger información relevante para la investigación)	0	0	0	0	0	0	0	0,00	
• Es pertinente para lograr el objetivo general de la investigación (Poder determinar mediante la monitorización de una persona su huella cognitiva para poder anticiparse al momento de sobrecarga cognitiva y mejorar el rendimiento de la misma en el entrenamiento)									
• Es pertinente para lograr el objetivo específico N.º 1 de la investigación (Medir las constantes de los trabajadores para determinar el momento de sobrecarga cognitiva)									
• Es pertinente para lograr el objetivo específico N.º 2 de la investigación (Confirmar, mediante test subjetivos de carga cognitiva, los resultados hallados mediante constantes fisiológicas)									
• Es pertinente para lograr el objetivo específico N.º 3 de la investigación (Determinar si estas medidas son extrapolables a otras profesiones con alta carga de trabajo y en situaciones no controladas)									
OBSERVACIONES									
Motivos por los que se considera no adecuada									
Motivos por los que se considera no pertinente									
Propuestas de mejora (modificación, sustitución o supresión)									

	PREGUNTA	PUNTUACIÓN DE EXPERTOS									VALIDACIÓN
N°.	EVALUATION	1	2	3	4	5	6	7	SUMA	PROMEDIO	MARCAR SI >4
1	Adecuación	5,67	6	6	5,33	1	6	6	36	5,14	☑
	Pertinencia	4,25	6	5,75	6	6	6	6	40	5,71	
2	Adecuación	5,33	6	6	6	3	6	6	38,33	5,48	☑
	Pertinencia	5,25	6	5,75	6	6	6	4,75	39,75	5,68	
3	Adecuación	5	6	5,67	6	3	6	5,73	37,4	5,34	☑
	Pertinencia	4	6	5,75	6	6	6	4,75	38,5	5,50	
4	Adecuación	4	5	5	6	4	6	5,67	35,67	5,10	☑
	Pertinencia	4,75	6	5,75	6	6	6	4,75	39,25	5,61	
5	Adecuación	5,67	6	5	6	3	5	5,33	36	5,14	☑
	Pertinencia	5,25	6	5,75	6	6	6	4,75	39,75	5,68	
6	Adecuación	6	6	6	6	2	5	6	37	5,29	☑
	Pertinencia	5,25	6	6	6	6	6	4,75	40	5,71	
7	Adecuación	5,33	6	5,33	6	3	5	6	36,66	5,24	☑
	Pertinencia	5,25	6	4	6	6	6	4,75	38	5,43	
8	Adecuación	6	6	6	6	3	2	6	35	5,00	☑
	Pertinencia	5,25	6	5,75	6	6	6	4,75	39,75	5,68	
9	Adecuación	6	6	6	6	3	2	6	35	5,00	☑
	Pertinencia	6	6	5,75	6	6	6	4,75	40,5	5,79	
10	Adecuación	6	6	6	6	3	6	6	39	5,57	☑
	Pertinencia	6	6	5,75	6	6	6	4,75	40,5	5,79	
11	Adecuación	6	6	6	6	4	2	6	36	5,14	☑
	Pertinencia	6	6	5,75	6	6	6	4,75	40,5	5,79	
12	Adecuación	6	6	6	6	3	4	6	37	5,29	☑
	Pertinencia	5	6	5,75	6	6	6	4,75	39,5	5,64	

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13	Adecuación	5	6	6	6	4	5	6	38	5,43	☑
	Pertinencia	5	6	5,75	6	6	6	4,75	39,5	5,64	
14	Adecuación	5	6	6	6	4	5	5,67	37,67	5,38	☑
	Pertinencia	5,25	6	5,75	6	6	6	3,75	38,75	5,54	
15	Adecuación	6	5,76	6	6	4	4	6	37,76	5,39	☑
	Pertinencia	6	6	5,75	6	6	6	4,75	40,5	5,79	
16	Adecuación	6	5,67	5,33	6	4	3	6	36	5,14	☑
	Pertinencia	6	6	5,75	6	6	6	4,75	40,5	5,79	
17	Adecuación	6	5,67	6	5,33	4	3	6	36	5,14	☑
	Pertinencia	6	6	5,75	6	6	6	4,75	40,5	5,79	
18	Adecuación	5,33	6	6	6	4	6	5,67	39	5,57	☑
	Pertinencia	6	6	5,75	6	6	6	4,75	40,5	5,79	
19	Adecuación	6	6	6	6	4	4	5,67	37,67	5,38	☑
	Pertinencia	6	6	5,75	6	6	6	4,75	40,5	5,79	
20	Adecuación	5,33	6	6	2	4	1	5,67	30	4,29	☑
	Pertinencia	6	6	5,75	6	6	6	4,75	40,5	5,79	
21	Adecuación	6	6	6	3	3	1	5,67	30,67	4,38	☑
	Pertinencia	6	6	5,75	6	6	6	4,75	40,5	5,79	
22	Adecuación	6	6	6	6	1	5	6	36	5,14	☑
	Pertinencia	6	6	5,75	6	6	6	4,75	40,5	5,79	
23	Adecuación	6	6	6	6	1	5	6	36	5,14	☑
	Pertinencia	6	6	5,75	6	6	6	4,75	40,5	5,79	
24	Adecuación	6	6	6	6	1	5	6	36	5,14	☑
	Pertinencia	6	6	5,5	6	6	6	4,75	40,25	5,75	

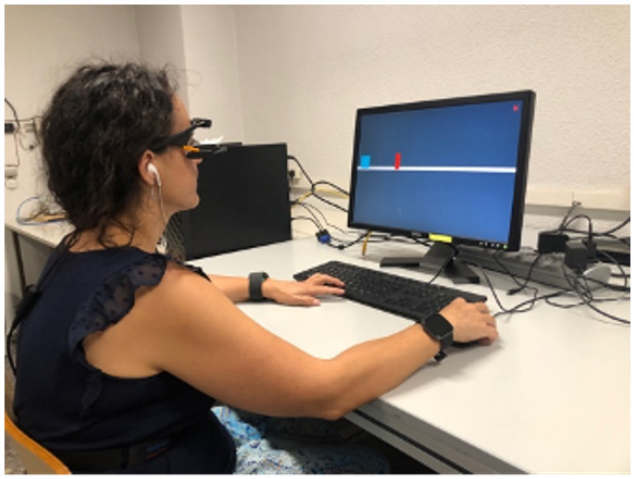

Figure 1: Participant during the lab test.

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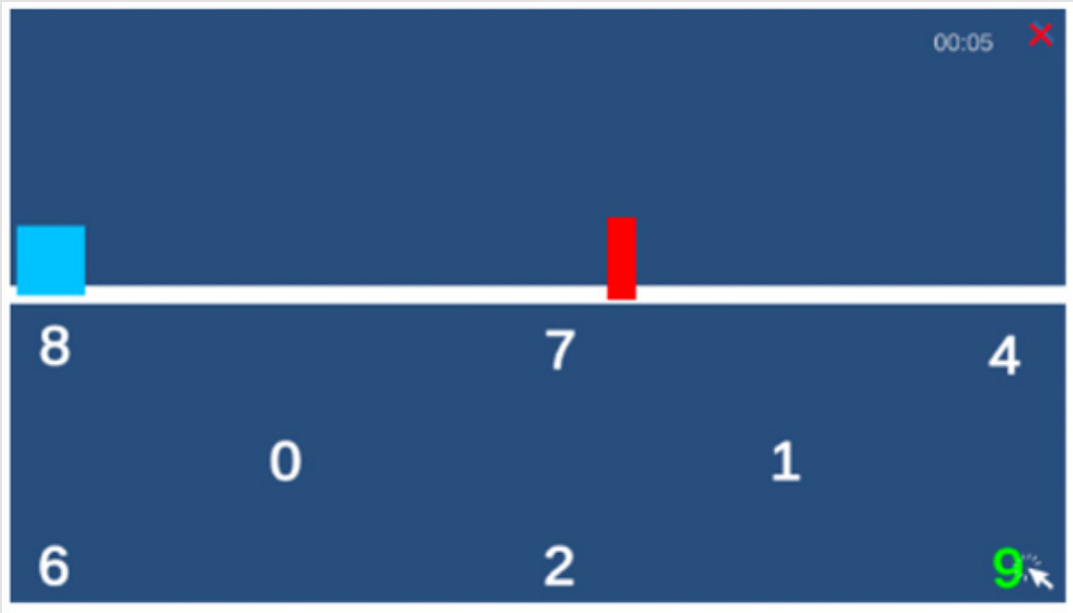


Figure 2: Visualization of a correct answer clicked.

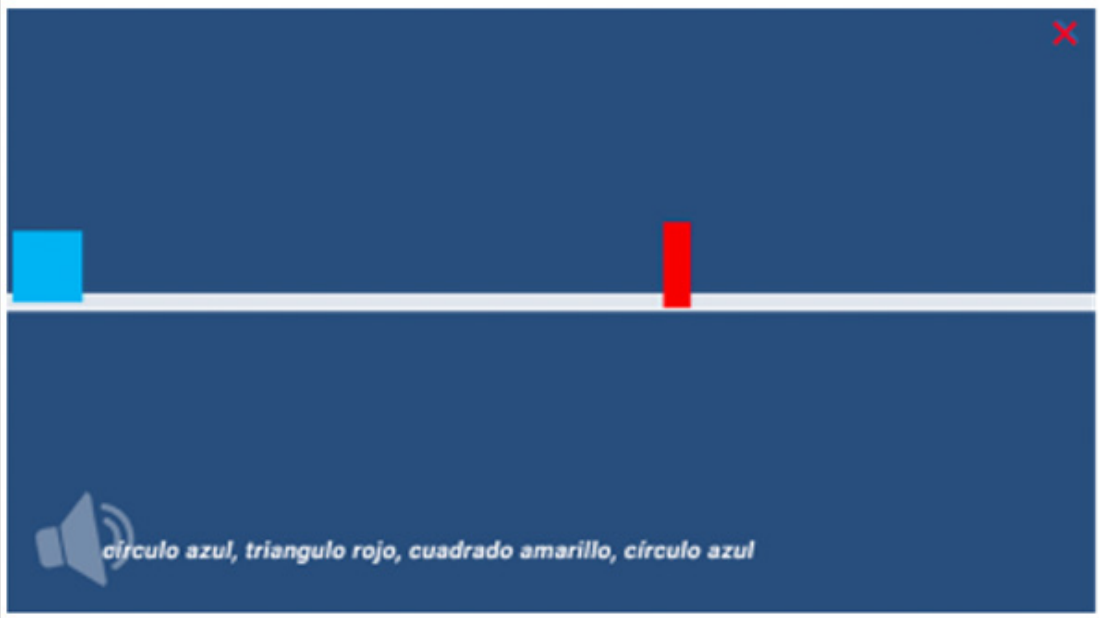


Figure 3: Primary task visualization.

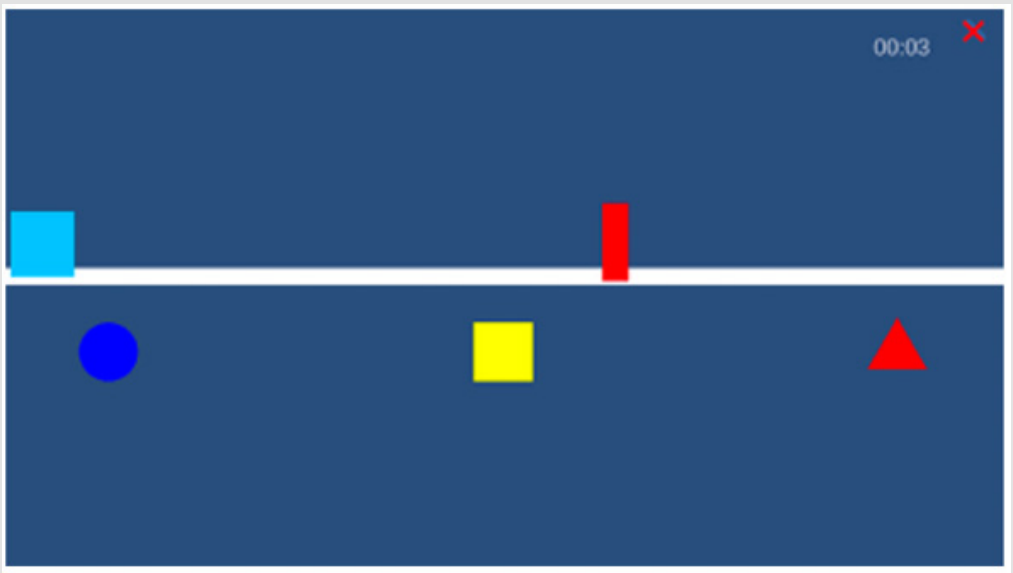


Figure 4: Audio task with pairs of color-figure.

Results

The tool was applied in these mentioned simulation contexts, followed by the subsequent analysis:

- to. Quantitative: reliability analysis (Cronbach's alpha), exploratory factor analysis (in the next phase of the study with a higher n), and descriptive analyses.
- b. Qualitative: thematic analysis of open-ended questions to identify emerging categories related to the cognitive load experience.

Based on the results, items may be adjusted or removed to optimize the validity and usefulness of the instrument. The Content Validity Index (CVI) was used for phase 2, the expert validation. Statistical analyzes were performed using Jamovi:

The questionnaire was administered to 7 experts in emergency healthcare and emergency coordination center. Of the participants, 57% were male and 43% female, achieving a balanced gender distribution. The mean age was 49.71 years, with a standard deviation of 4.33. The participants' professional back-grounds were 57.14% physicians, 28.57% nurses, and 14.49% emergency medical technicians, all working in environments similar to those of the study's target participants (high cognitive load environments). The Content Validity Index (CVI) was calculated for both adequacy and relevance by averaging all evaluators' scores for each question, combining the adequacy and relevance ratings. In all cases, for both categories, the scores were above 4, as shown in Table 2, which validates the question.

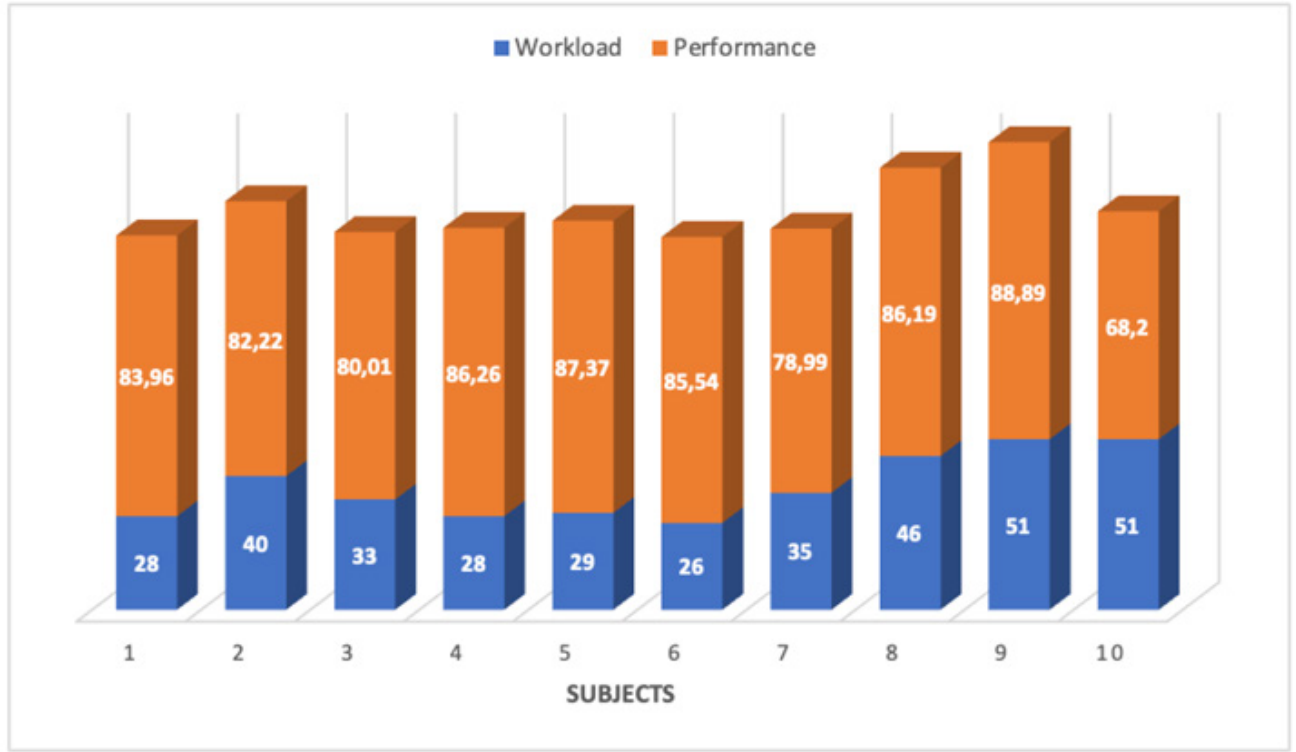
Table 2: CVI Scoreboard.

QUESTION		EXPERT SCORE								
No.	**EVALUATION**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**SUM**	**AVERAGE**
1	Adequacy	5.67	6	6	5.33	1	6	6	36	5.14
	Relevance	4.25	6	5.75	6	6	6	6	40	5.71
2	Adequacy	5.33	6	6	6	3	6	6	38.33	5.48
	Relevance	5.25	6	5.75	6	6	6	4.75	39.75	5.68
3	Adequacy	5	6	5.67	6	3	6	5.73	37.4	5.34
	Relevance	4	6	5.75	6	6	6	4.75	38.5	5.5
4	Adequacy	4	5	5	6	4	6	5.67	35.67	5.1
	Relevance	4.75	6	5.75	6	6	6	4.75	39.25	5.61

5	Adequacy	5.67	6	5	6	3	5	5.33	36	5.14
	Relevance	5.25	6	5.75	6	6	6	4.75	39.75	5.68
6	Adequacy	6	6	6	6	2	5	6	37	5.29
	Relevance	5.25	6	6	6	6	6	4.75	40	5.71
7	Adequacy	5.33	6	5.33	6	3	5	6	36.66	5.24
	Relevance	5.25	6	4	6	6	6	4.75	38	5.43
8	Adequacy	6	6	6	6	3	2	6	35	5
	Relevance	5.25	6	5.75	6	6	6	4.75	39.75	5.68
9	Adequacy	6	6	6	6	3	2	6	35	5
	Relevance	6	6	5.75	6	6	6	4.75	40.5	5.79
10	Adequacy	6	6	6	6	3	6	6	39	5.57
	Relevance	6	6	5.75	6	6	6	4.75	40.5	5.79
11	Adequacy	6	6	6	6	4	2	6	36	5.14
	Relevance	6	6	5.75	6	6	6	4.75	40.5	5.79
12	Adequacy	6	6	6	6	3	4	6	37	5.29
	Relevance	5	6	5.75	6	6	6	4.75	39.5	5.64
13	Adequacy	5	6	6	6	4	5	6	38	5.43
	Relevance	5	6	5.75	6	6	6	4.75	39.5	5.64
14	Adequacy	5	6	6	6	4	5	5.67	37.67	5.38
	Relevance	5.25	6	5.75	6	6	6	3.75	38.75	5.54
15	Adequacy	6	5.76	6	6	4	4	6	37.76	5.39
	Relevance	6	6	5.75	6	6	6	4.75	40.5	5.79
16	Adequacy	6	5.67	5.33	6	4	3	6	36	5.14
	Relevance	6	6	5.75	6	6	6	4.75	40.5	5.79
17	Adequacy	6	5.67	6	5.33	4	3	6	36	5.14
	Relevance	6	6	5.75	6	6	6	4.75	40.5	5.79
18	Adequacy	5.33	6	6	6	4	6	5.67	39	5.57
	Relevance	6	6	5.75	6	6	6	4.75	40.5	5.79
19	Adequacy	6	6	6	6	4	4	5.67	37.67	5.38
	Relevance	6	6	5.75	6	6	6	4.75	40.5	5.79
20	Adequacy	5.33	6	6	2	4	1	5.67	30	4.29
	Relevance	6	6	5.75	6	6	6	4.75	40.5	5.79
21	Adequacy	6	6	6	3	3	1	5.67	30.67	4.38
	Relevance	6	6	5.75	6	6	6	4.75	40.5	5.79
22	Adequacy	6	6	6	6	1	5	6	36	5.14
	Relevance	6	6	5.75	6	6	6	4.75	40.5	5.79

The following results were obtained: Based on these evaluations and the comments from the expert panel, the questionnaire was modified according to the experts' corrections. The questionnaire has been validated in Spanish. In Table 1, the initial and final questions have been translated into English for better understanding. Phase 3, or pre-pilot phase, the test was administered to 10 volunteer participants following expert approval.

Jamovi was again used to conduct descriptive analyses: 40% of the participants were male and 60% female, achieving a balanced gender distribution, with a mean age of 45.4 years and a standard deviation of 9.69. The participants' professional backgrounds were 10% physicians, 50% nurses, and 40% emergency medical technicians. The average time dedicated to emergency work was 21.2 years, with a median of 25 years. At the time of the study, 40% were single, and 60% were in a relationship. Twenty percent reported alcohol consumption, 50% had visual acuity impairments, and 10% had color blindness. Regarding other health conditions, only 10% had hypertension (HTN). All tests were conducted in the morning, between 9:00 AM and 2:15 PM. The test was administered to all participants immediately after completing the task, with 70% receiving a low workload and 30% a medium workload; none reported a high workload. Performance during the test was above 80% in 80% of the participants, between 70-80% in 10%, and below 70% in only 10% as shown in Figure 5.



Note: Values between 19 and 44 indicate low workload; between 45 and 70 indicate medium workload; and between 71 and 95 indicate high workload.

Figure 5: Relationship between perceived workload and test performance.

Internal consistency of the test was evaluated using Cronbach's alpha coefficient, obtaining a value of 0.861. This result indicates a high degree of internal consistency among the questionnaire items, sug-gesting that participant responses were homogeneous and that the items coherently measure the construct of perceived cognitive load. This level of reliability is considered adequate for exploratory and initial validation studies.

Discussion

The development and initial validation of a subjective instrument for evaluating perceived cognitive load in high-demand contexts represents a significant advance both in research and professional practice. The results support the relevance of this proposal in environments where decisions must be made under pressure, with limited resources, and under high mental demand. The findings indicate

a high internal reliability (α = 0.861), consistent with other validated subjective instruments for cognitive load assessment, such as NASA-TLX [27] and WP [4]. This level of internal consistency suggests the items measure a coherent underlying dimension—in this case, perceived cognitive load—and supports the instrument's utility in future applications and research as well as improving the training of these professionals to improve their performance and increase their confidence and reaction speed. The expert validation process ensured clarity, relevance, and appropriateness of the items to the specific study context. This phase was key to guarantee content validity, an essential dimension in constructing measurement tools, particularly in contexts with highly specific professional tasks. The consensus achieved among professionals from diverse disciplines (medicine, nursing, and psychology) strengthens the instrument's applicability in interprofessional high cognitive demand settings. The pre-pilot phase not only confirmed participant comprehension of the questionnaire but also explored the instrument's ability to detect differences in perceived load by professional profiles and individual characteristics.

Although the sample was small (n=10), preliminary results showed a reasonable distribution of responses, predominantly low to medium load perceptions, consistent with the controlled de-sign of the simulations. Additionally, descriptive analyzes provided a detailed characterization of participants, which will be useful in future study phases to evaluate the instrument's sensitivity to demographic, clinical, or con-textual variations. Factors such as professional experience, visual acuity, or alcohol consumption might influence perceived cognitive load and should be considered in subsequent studies with larger samples and multivariate analyses. A noteworthy aspect is the inclusion of open-ended questions, which captured qualitative facets of the cognitive experience not reflected in closed items. This mixed-methods approach contributes to a richer, more contextualized understanding of the phenomenon studied and could be enhanced with more systematic thematic analyzes in future applications. However, some limitations must be acknowledged. The small sample size in the pre-pilot phase limits robust factorial analyzes and generalization of findings. Furthermore, while simulated designs allow some experimental control, they do not fully replicate real working conditions, where contextual and emotional variables may more significantly affect cognitive load. Replication in real environments or with high-er-fidelity simulations will be necessary to confirm the instrument's ecological validity.

Another limitation relates to potential social desirability bias inherent in self-report questionnaires, which could lead to underestimating perceived load, especially in contexts valuing resilience or stress tolerance. Triangulation with objective measures (such as physiological or performance indicators) could help mitigate this bias in future research. This study constitutes a solid initial step toward building a useful, specific, and valid tool for subjective cognitive load assessment in high-demand professional contexts. Its implementation could contribute not only to early diagnosis of overload situations but also to the design of training, organizational, and technological interventions aimed at optimizing human performance and safety in these critical environments.

Conclusion

An initial validation of a subjective instrument was developed and conducted to assess perceived cog-nitive load among healthcare professionals at an emergency coordinating center during simulated high-demand situations. This instrument was specifically adapted and developed to the characteristics and demands of their work environments and demonstrated an adequate level of reliability. The design was based on a literature review and adapted to the work environments of emergency physicians and nurses. The questionnaire was validated through expert judgment, assessing the relevance, clarity, and adequacy of the items. The instrument is suitable for differentiating levels of perceived cognitive load according to the type of task, professional profile, or experience of the participant.

Author Contributions

All authors contributed to the study conception, investigation and design, methodology, PB, BL and MA; software, PB, AG and BL; validation, PB and MA; formal analysis, PB and AV; resources, PB and BL; data curation, PB, AG and BL; writing—original draft preparation, PB and AV; writing—review and editing, PP, MA, AG and AV; visualization, AV, AG and PB.; supervision, PB; project administration, PB All authors have read and agreed to the published version of the manuscript.

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Funding

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Declaration of Interest

The authors declare no conflicts of interest related to this work.

Data Availability Statement

This test needs to be tested by a larger number of participants, so the data will be available for review at the end of the project.

Institutional Review Board Statement

The study was conducted in accordance with the Decla-ration of Helsinki and approved by the Ethics Committee of HOSPITAL UNIVERSITARIO 12 DE OCTUBRE (protocol code 25/092 and date May 13, 2025).

Informed Consent Statement

Informed consent was obtained from all subjects involved in the study.

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