Fatigue Instantaneous Self-Assessment (F-ISA)

Development of a Short Mental Fatigue Rating

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1. Abstract

In this document we present a new fatigue self-assessment questionnaire. The rationale for the development of this fatigue questionnaire is based on the fact that the currently available instruments are either developed for medical purposes, focussing more on sleepiness than on fatigue or interfere with the main experimental task. A brief review of existing instruments is given and the newly developed Fatigue Instantaneous Self-Assessment (F-ISA) is presented. The F-ISA is an easy to administer one item self-report questionnaire, which is non-intrusive and has high face validity. We recommend using this questionnaire in studies conducted in the Institute of Flight Guidance to gain more insight into the interaction of fatigue with other cognitive states such as mental workload or situation awareness.

2. Introduction

Fatigue is a commonly used term to describe a feeling of weariness following long periods of activity. When talking about fatigue, one should distinguish between physical and mental fatigue.

Physical fatigue may be a consequence of physical activity and is usually characterized by overstressed, aching muscles, decreased power and speed of movement (Grandjean, 1979). Mental fatigue is a state of weariness caused by prolonged execution of or sustained attention towards a task (Charbonnier et al., 2016). It is considered a state of arousal between relaxed wakefulness and sleepiness, usually accompanied by a tendency to avoid physical or mental effort, i.e. decreased motivation (Grandjean, 1979). It is therefore a transition point between awake and sleepy and may tend to one or the other, depending on the individual's ability to take breaks (Okogbaa et al., 1994). Empirical evidence shows a correlation between mental fatigue and a decrease in performance (Charbonnier et al., 2016; Dasari et al., 2013; Laurent et al., 2013).

Mental fatigue is of high interest for research in the field of air traffic management research because research activities often focus on air traffic controllers or pilots whose tasks are prolonged and repetitive, yet cognitively demanding. They require sustained attention, vigilance and readiness to react to unexpected and time-critical situations. These tasks therefore have a high potential for inducing mental fatigue. Simultaneously, the effects of mental fatigue can lead to slips in the air traffic controller's or pilot's attention, to errors and in consequence to an increased risk of incidents or accidents.

It is thus necessary to assess and monitor mental fatigue during prolonged demanding tasks. This can be done using physiological methods such as electroencephalography (EEG), electrocardiography ECG) or respiration (for a review see Borghini et al., 2014). These methods, however, are intrusive and complex as they require preparation (sensor placement on the subjects) and a careful data pre-processing and analysis. An easier yet more subjective alternative for mental fatigue assessment is self-report by means of questionnaires.

This document gives a brief overview of existing mental fatigue questionnaires, their shortcomings, and introduces a new and simple instrument for mental fatigue assessment.

3. Overview of Fatigue Questionnaires

The majority of fatigue questionnaires and inventories was developed for medical purposes (e.g. CFQ, FSS, MAF, FAS; for a review see Neuberger, 2003; acronyms explained in Table 1) and comprises items concerning both mental and physical fatigue. In addition, many items target general fatigue in everyday situations. Other questionnaires focus on sleepiness (KSS, ESS) and assess mental fatigue only implicitly as part of the continuum between alertness and sleep. Table 1 gives an overview of common fatigue questionnaires. To the authors' knowledge, there is no questionnaire specifically targeting mental fatigue induced by task demands such as prolonged attention.

Table 1: *Overview of common fatigue and sleepiness questionnaires*

Name	Author(s)	Purpose	Content	No. Items	Rating	Additional
Chalder Fatigue Scale (CFQ)	Chalder et al. (1993)	Medical	Physical and mental fatigue	10 (7 physical, 4 mental)	4-point Likert scale	Two independent sub-scores for physical and mental fatigue
Fatigue Assessment Scale (FAS)	Vries et al. (2004)	Medical	General fatigue symptoms in everyday life	10 (5 physical, 5 mental)	5-point Likert scale	
Fatigue Severity Scale (FSS)	Krupp et al. (1989)	Medical	Impact of fatigue on different aspects of life	9	7-point Likert scale	Motivation, physical exercise, work and social interaction
Multidimensional Assessment of Fatigue Scale (MAF)	Belza et al. (1993)	Medical	Fatigue severity, timing and impact on life	16	1-10 (1-4 for timing)	
Epworth Sleepiness Scale (ESS)	Johns (1991, 1992)	Sleep research	General level of daytime sleepiness	8	0-3 (never – high chance)	Likelihood of falling asleep during specific everyday situations
Karolinska Sleepiness Scale (KSS)	Akerstedt and Gillberg (1990)	Sleep research	Situational sleepiness	1	verbally anchored 1-9 scale (alert to sleepy)	German version by DLR-ME: Niederl (2007)

For the assessment of mental fatigue in an applied research setting, not all subscales and items included in medical questionnaires are of relevance. It is, however, often unclear if parts of the questionnaires can be

left out without compromising internal consistency. The length of the questionnaires poses another problem for research settings: some may take the participant several minutes to fill in. For example, in air traffic control research the participants may not able to divide their attention between the task at hand and a time-consuming questionnaire. Air traffic controllers are expected to deal with a variety of situations and unforeseeable events in a safe, orderly and expeditious manner. Their tasks therefore require continuous focused attention and timely responses. In order to avoid loss of situation awareness, the mental fatigue assessment should be kept as short and easy as possible. Furthermore, lengthy questionnaires pose the risk of losing the participants' acceptance. Disruptions of the workflow due to time-consuming questionnaires may induce artificial situations in otherwise highly realistic simulations. Thereby, the external validity of the experiment might be compromised, especially when working with operational experts.

There are a few attempts to measure mental fatigue with a bespoke one-item approach. Myrden and Chau (2017) assessed task-related mental fatigue with a single 5-point Likert item. Lim et al. (2010) used a 9-point Likert item to assess mental fatigue induced by the experimental task. They report a positive correlation between time on task and subjective ratings of mental fatigue. These publications, however, do not provide information about the construction of the assessment methods used, of their instructions and verbal anchors along the rating scale. Even though such bespoke mental fatigue assessments seem useful compared with the established yet unfitting fatigue scales, the lack of documentation poses a problem for replication.

In conclusion, there is no well-established instrument available to measure task-related mental fatigue in a simple, non-intrusive fashion. The authors of this document propose a new single-item mental fatigue assessment for applied research settings along with its construction, rating scale and guidelines on how to use it.

4. F-ISA and Its Construction

4.1. Fatigue Instantaneous Self-Assessment: F-ISA

The newly developed instrument for mental fatigue assessment consists of a single item, i.e. one question about the participant's mental fatigue. This item is answered on a 5-point Likert rating from low to high. The assessment can be made for the current situation, the last experimental task, block, or a defined timeframe (e.g. the last 5 minutes). The English and German version of the item can be found below. It is highly recommended to explain the concept of mental fatigue to the participant prior to the assessment.

English version:

Instruction

Mental fatigue is considered a state of arousal between alertness and sleepiness. It is caused by the prolonged execution of tasks that demand attention and are either monotonous or challenging. Mental fatigue is characterized by weakened concentration and motivation up to performance decrement.

In the following we will ask for your self-assessment on the continuum between alertness and fatigue.

Please rate your level of mental fatigue *(at the moment/during the last task/block/XX minutes)* from 1-5:

1 – very low (alert)
2 – low
3 – medium (relaxed wakeful)
4 – high
5 – very high (fatigued)

German version:

Instruktion

Kognitive Erschöpfung beschreibt einen Zustand zwischen aufmerksamer Wachheit und Müdigkeit. Sie wird durch länger andauernde, aufmerksamkeitsfordernde Tätigkeiten hervorgerufen, die entweder monoton oder anspruchsvoll sind. Kognitive Erschöpfung äußert sich beispielsweise durch verringerte Konzentrationsfähigkeit und Motivation bis hin zu Leistungseinbußen.

Mit der folgenden Abfrage möchten wir erfassen, wo Sie sich auf der Spanne zwischen aufmerksam und erschöpft befinden.

Bitte schätzen Sie Ihre *(momentane)* kognitive Erschöpfung *(während der letzten Aufgabe/des letzten Blocks/der letzten XX Minuten)* von 1-5 ein:

1 – sehr gering (aufmerksam)
2 – gering
3 – mittel (entspannt wach)
4 – hoch
5 – sehr hoch (erschöpft)

4.2. On the Origin of F-ISA

4.2.1. Content and verbal anchors of the scale

The F-ISA is developed especially for the assessment of task-related mental fatigue because no existing questionnaire fulfils the requirements outlined in 3. The only validated questionnaire with only one item and not designed for a medical setting is the Karolinska Sleepiness Scale (KSS; Akerstedt & Gillberg, 1990). Participants are asked to rate their current state of alertness on a scale from 1 (extremely alert) to 9 (very sleepy). Even though the KSS provides a parsimonious and generic rating, it is designed to cover both extremes of the continuum between alertness and sleepiness. The scale does not include a verbal anchor for mental fatigue, the transition between the two extremes. Nevertheless the KSS is widely used in studies concerning task-related fatigue. Research shows a correlation between KSS scores and an increase of reaction time, a common indicator for growing mental fatigue (Charbonnier et al., 2016).

In order to assess different levels of mental fatigue, the F-ISA is designed to cover the range between alert and fatigued without covering sleepiness as well (Figure 1). The verbal anchors of the scale are adapted accordingly.

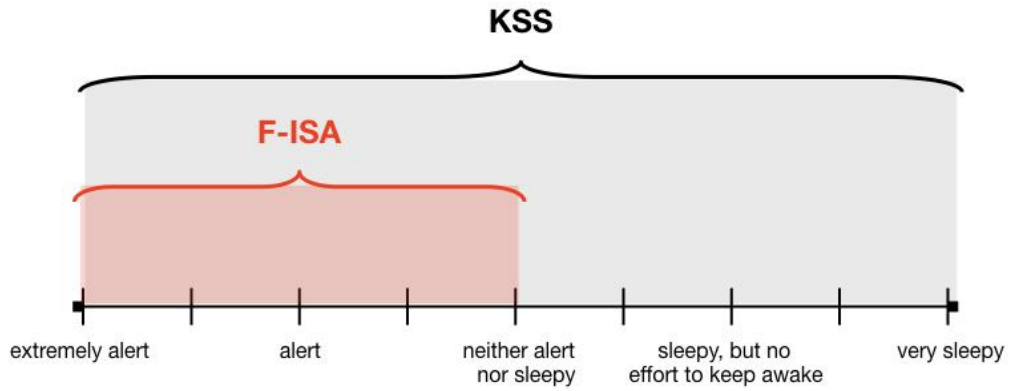

Figure 1: The KSS scale with the original labels. The F-ISA covers the range highlighted in red.

4.2.2. Formal construction of the scale

The construction of the F-ISA follows that of the Instantaneous Self-Assessment (ISA) for mental workload assessment (Tattersall, 1994; Tattersall & Foord, 1996). The ISA makes use of a 5-point Likert rating from 1 (under-utilized) to 5 (excessive) to rate the experienced mental workload within a defined period of time. It was developed for research purposes in the aviation context and is widely used in human-in-the-loop simulations and live trials. Because of its non-intrusiveness, high face validity and easy applicability the ISA has become the standard assessment method for mental workload within the Institute of Flight Guidance. It is technically implemented in all simulation environments of the Air Traffic Validation Center (Validierungszentrum Luftverkehr).

The ISA and the newly developed F-ISA share all features and benefits. Because of their matching scale and low intrusiveness the ISA and F-ISA can be used in the same fashion and even be combined. Because of their easy applicability they can also be used without prior technical integration or in case of technical problems: a verbal or even a non-verbal and silent rating procedure by holding up fingers is possible. Usually the number of fingers on one normally developed human hand matches the range of the rating scale. It is not recommended to adjust the range of the scale to the number of available fingers, however. Hook-handed mute subjects should be encouraged to use toes.

4.2.3. Psychometric Properties

The following two tables give an overview of common psychometric criteria and their degree of fulfilment regarding the F-ISA. The need for empirical evidence is highlighted where deemed indispensable.

Table 2: *Primary Criteria*

Criterion	Degree of Fulfilment	Explanation
Objectivity	High	Data collection: Low risk of social desirability and experimenter bias because of minimal interaction between participant and experimenter (depending on the implementation) Analysis and interpretation: defined scale and verbal anchors reduce risk of biased interpretation
Reliability	Tbd	Need for empirical evidence regarding: Test-retest reliability Due to F-ISA design other types of reliability are not applicable
Validity	Tbd	Content validity is given due to high face validity Need for empirical evidence regarding: Construct validity (convergent/discriminant) Criterion validity (concurrent/predictive)

Table 3: *Secondary Criteria*

Criterion	Degree of Fulfilment	Explanation
Acceptance	High	Short, low intrusiveness, easy to understand
Fairness	High	Item is uncorrelated with personal characteristics
Efficiency	High	One item, fast, easy to administer
Utility	High	Concept of mental fatigue has high relevance in research and practice; no other suitable instrument available
Transparency	High	Instructions are short and easy to understand
Non-fakeability	Low	Subjective character of the item includes possibility to fake the rating Combination with objective measures is recommended
Reasonableness	High	Short, low intrusiveness, easy to understand

4.3. Advantages of F-ISA

The newly developed F-ISA fills the gap of mental fatigue assessment in applied research settings by providing an easy and fast rating of task-related mental fatigue, without unnecessary and unfitting items for physical fatigue, fatigue symptoms in everyday life or ratings of sleepiness.

It is a generic, single-item assessment that can be used in various experimental settings and tasks. It has no technical requirements and can be administered in different ways ranging from simple verbal answers or gestures (holding up fingers), and pen and paper to electronic implementation of the scale. The mode of presentation can be chosen depending on the experiment. The rating itself is easy and intuitive and requires no experience or training in fatigue ratings. It is highly face valid and less intrusive than established fatigue scales and may therefore be more accepted by participants.

When used continuously and with short intervals, the F-ISA ratings can also provide an indication of the course of mental fatigue throughout the experiment without impacting performance measures and the main task. It is therefore well suited for an online assessment of mental fatigue.

The F-ISA can be used together with the well-established ISA because of the shared 5-point rating and the same verbal anchors from *very low* to *very high*. The ISA is already integrated into the technical infrastructure of the Institute of Flight Guidance. The integration of the F-ISA into the existing structures is therefore easy and the same workflow for data analyses can be used. Both ratings can even be combined in studies to gain more insight into the interaction of mental workload and mental fatigue.

5. Conclusion and Outlook

In this document the newly developed mental fatigue assessment F-ISA is introduced. It bridges the gap between medical fatigue assessment and applied research settings.

The F-ISA's new single-item approach to measuring mental fatigue is fast, simple and has high face validity. The assessment is task-related rather than made for everyday fatigue, but at the same time generic and does not require prior training. The F-ISA is less intrusive than most existing questionnaires because the rating procedure takes only a few seconds and does not interfere with the task at hand. It can thus be used for various research settings and tasks.

There is, however, need for a thorough investigation and validation of this newly developed mental fatigue assessment. Especially the criteria enumerated in Table 2 need to be addressed in future empirical studies. As an example, discriminant validity can be assessed by comparing the F-ISA against well-established sleepiness questionnaires like the KSS. Convergent validity on the other hand can be approximated by means of physiological measurements like EEG. Moreover, the benefits of a simultaneous ISA/F-ISA assessment should be investigated by integrating the F-ISA into studies at the Institute of Flight Guidance.

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