Validation of a Cognitive State Fatigue Induction Protocol Using the N-Back Task

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Introduction

Measuring state cognitive fatigue is a challenge

- State cognitive fatigue (CF) refers to a temporary decline in **cognitive performance** and **motivation** following a sustained mental effort [1].
  - It is associated with increased risk of accidents in the workplace and on the road [2].
  - It is a common and often pervasive symptom in various disorders, contributing to reduced quality of life [3].
- However, accurately measuring state CF remains surprisingly **challenging** [4].

This study aims to validate an **N-Back-based protocol** [5,6] for both **subjective** (perceived) and **objective** (performance) **fatigue measurement**.

Materials and Method

Participants

100 healthy young adults (M_{age} = 19 y/o, SD_{age} = 1.37; 89 females) were recruited from a participant pool.

Protocol

VAS → Block 1 | Block 2 | Block 3 | Block 4 → VAS

1 block (10 min) = 9 N-Back sequences
(three 1-back, 2-Back and 3-Back)

Measures

Subjective Measures

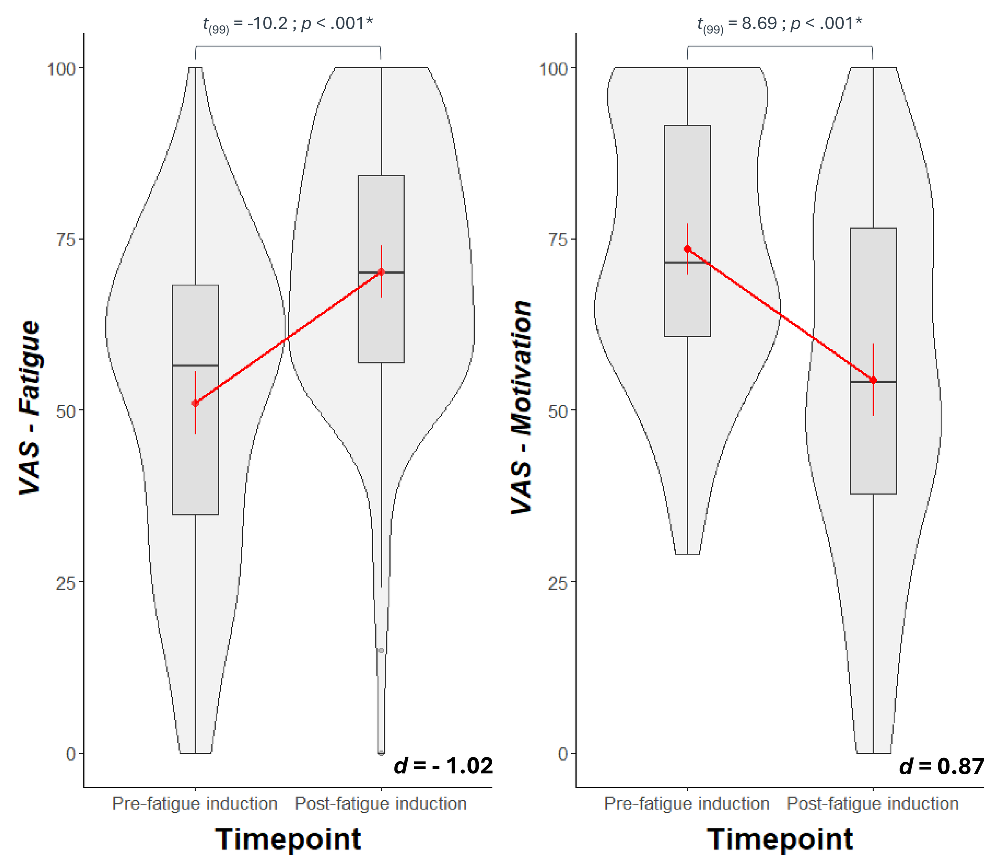
- Visual Analog Scales of:
  - Fatigue (VAS-F)
  - Motivation (VAS-M)
  - Effort (VAS-E)
- KSS (Karolinska Sleepiness Scale) [7]

Objective Measures

- Sensitivity (d')
- Response Times (*RT*)
- Hit and False Alarm Rates
- Criterion (*C*)

Results

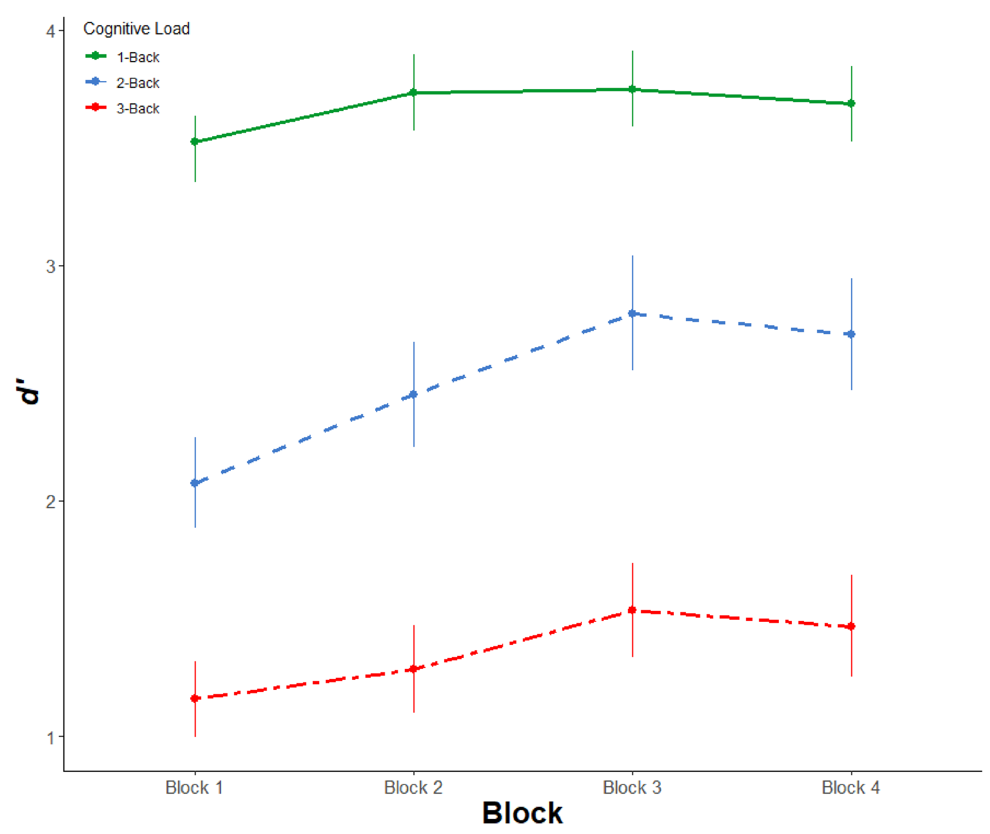
VAS indicate a build-up of subjective fatigue following induction



- *Effort (VAS-E)*
  W = 212 ; p < .001 ; r_β ***= - 0.91***
- *Sleepiness (KSS)*
  W = 364 ; p < .001 ; r_β ***= - 0.79***

Performances improved with time-on-task

- Sensitivity *d'* increased over time
  $F_{(2.54, 251.02)}$ = 23.97 ; p < .001 ; η^2_p = 0.195

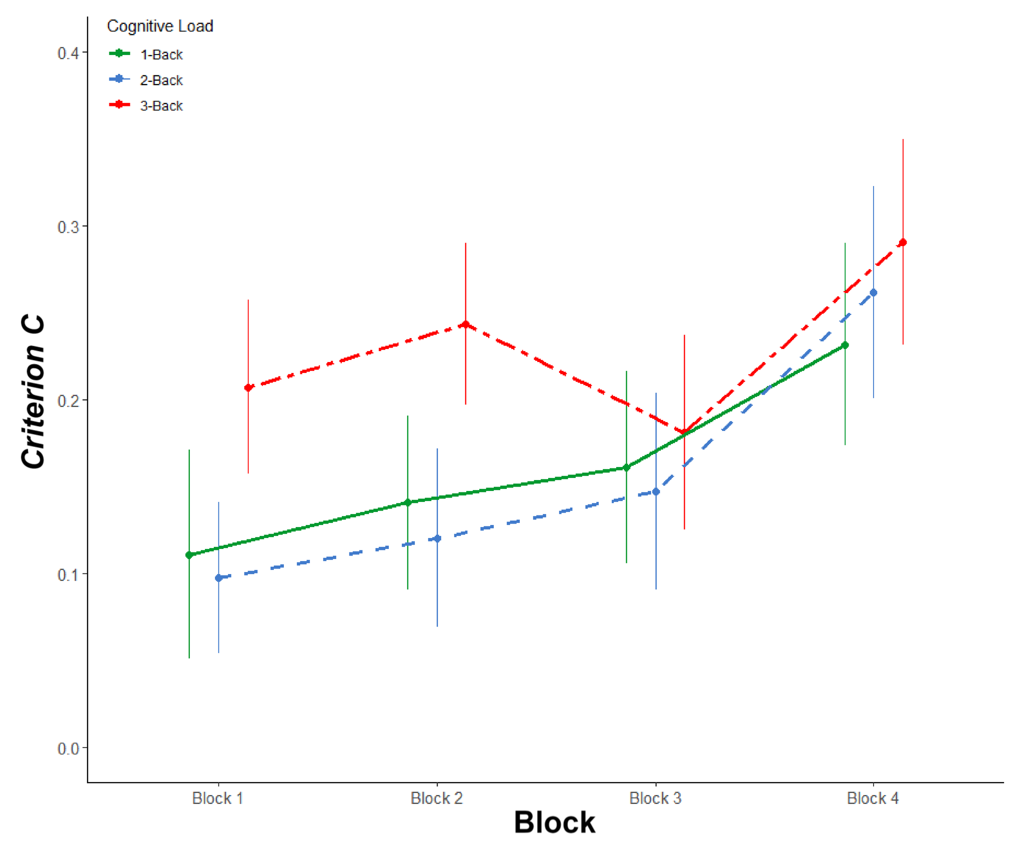


- Hit rates improved over time
  $F_{(2.54, 251.16)}$ = 9.56, p < .001, η^2_p = 0.088
- False alarm rates decreased over time
  $F_{(2.72, 269.41)}$ = 48.55, p < .001, η^2_p = 0.329
- *RTs* decreased over time
  $F_{(2.37, 234.78)}$ = 251.3, p < .001, η^2_p = 0.717

Criterion fluctuated with time-on-task

$F_{(3,252)}$ = 10.77 ; p < .001 ; η^2_p = 0.114

- Criterion *C* was significantly higher in Block 4
  $t_{(84)}$ = 4.394 ; p < .001 ; $d_{B4\ vs\ B3}$ = 0.329



- Harder trials were answered more conservatively
  $F_{(2,168)}$ = 6.4 ; p = 0.002 ; η^2_p = 0.013

Discussion

Fatigue was induced subjectively but not objectively

- **Subjective measures** proved sensitive to fatigue, showing a significant increase post-task.
- **Objective performance metrics** improved, suggesting that a **learning effect** may have masked the expected fatigue effect.
  - However, **response patterns** became more conservative over time, potentially reflecting a **strategic adaptation** or **disengagement** associated with cognitive fatigue [8].

Follow-up

To assess **objective cognitive fatigue**, future protocols could:

- Extend **the task duration**, allowing fatigue effects to manifest beyond learning.
- Incorporate **a probe task**, to specifically assess fatigue without interference from learning [9].

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