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Original Research

An Exploratory Comparison of Subjective Mental Fatigue Following a Task Designed to Replicate the Observation of Game Film

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ABSTRACT

International Journal of Exercise Science 15(6): 25-35, 2022. Laboratory-induced subjective mental fatigue (MF) has been shown to decrease sport-related performance (23, 38), yet there is a lack of research identifying tasks in real-world sport environments that induce MF (37). Since the identification of real-world tasks that induce MF may inform activities undertaken in the daily training and competition environments, the purpose of the current study was to compare changes in MF following a task designed to replicate the observation of game film to changes in MF following completion of a laboratory-based task (e.g., Stroop test). On separate counterbalanced visits, participants (N = 6) completed either (1) 35 min of replicated game film observation or (2) 35 min of the Stroop test. Visual analogue scales were used to measure MF, and a repeated measures analysis of variance [2 (time) x 2 (task)] was used to compare changes in MF following each task. No significant difference in changes in MF were found between conditions, $F(1, 5) = 1.226$, $p = 0.319$, and no main effect differences were found in MF pre-to-post for either task, $F(1, 5) = 2.211$, $p = 0.197$. Further efforts to identify real-world mentally fatiguing tasks are warranted.

KEY WORDS: Soccer; football; cognitive fatigue; Stroop test

INTRODUCTION

Subjective mental fatigue (MF), a psychobiological state represented by perceived tiredness or lack of energy brought about through prolonged cognitive activity (18), is typically induced by completion of cognitively demanding tasks and can have a deleterious impact on human performance. While early investigations focused on the influence of MF on cognitive performance (3, 15, 25), more recent investigations have turned to its influence on physical performance (23, 38). Stemming from an initial exploration into the topic (18) and grounded in the psychobiological model (17, 22), there has been a notable surge in research surrounding the impact MF has on physical performance within a sport context.

Researchers investigating the impact of MF on physical performance initially focused on endurance activities, reporting that MF increases one's perception of effort thereby negatively impacting performance on endurance tasks such as cycling (4), running (16), and swimming (26). Researchers have since expanded the study of MF influences to include the execution of sport-related technical skills (12, 23). Indeed, MF impairs soccer-specific technical skills such as shooting, passing, and ball control (2, 31, 32) as well as table tennis-specific technical skills such as ball speed and accuracy (14). The MF-related deterioration of technical skills in sport is thought to result from decreased ability to direct attention to relevant stimuli, accurately monitor errors and adjust performance, and/or anticipate and prepare for coming stimuli (2, 12, 31, 33).

As researchers realized the detrimental impact of MF on sport-related performance, the need to identify tasks commonly completed in real-world sport environments that induce MF became apparent (5, 33). While activities that involve screen exposure (e.g., use of social media, watching videos) commonly occur prior to sporting competition (36), mixed results have been observed in studies using activities with screen exposure to induce MF (1, 7, 8, 9). For example, 30-min use of a smartphone puzzle application (9) and use of smartphone-based social media applications (7, 8) induced MF, while video game participation did not induce MF (1). Additionally, tasks that involve problem solving (e.g., excessive instructions during drills) (29), increases in contextual interference (e.g., variability in the consecutive execution of skills) (37), or the intake of complex novel information (e.g., in-depth team meetings) (36), may invoke over-analysis (28), increases in mental workload (13, 37), and sustained auditory processing (20), respectively, all of which contribute the development of MF. It is important to note that the measurement of MF has varied from subjective (e.g., visual analogue scales) to objective (e.g., EEG) to behavioral (e.g., performance on Stroop tests) assessments, which may explain the mixed findings reported above. Therefore, identifying and testing the mentally fatiguing nature of real-world tasks that include the aforementioned characteristics (e.g., screen exposure, problem solving) is a necessary step to further address the calls of previous researchers (5, 33).

A task that includes screen exposure and additional characteristics with the potential to induce MF (e.g., over-analysis, contextual interference) that commonly occurs in a variety of real-world sport environments is the observation of game film. However, at this time it is not known if this real-world task induces MF. Knowledge of the mentally fatiguing nature of the observation of game film may be used by athletes, coaches, and performance services staff alike to inform: (a) pre-training and/or pre-competition schedules so as to avoid MF (29), (b) interventions to mitigate the impact of MF on performance (34, 36), and (c) a need to facilitate recovery from MF (27).

To determine if the observation of game film induces MF, the purpose of the current study was to compare changes in MF following a task designed to replicate the observation of game film in soccer to changes in MF following completion of a laboratory-based task commonly used to induce MF (e.g., Stroop test) (23, 38). It was hypothesized that changes in MF following the game film task would not significantly differ from changes in MF following the Stroop test.

METHODS

Participants

A necessary sample size of six participants was calculated using the G*Power 3.1.9.4 computer software (6), with power set at 0.80, α = .05, and based on previous research, an effect size of 1.50 (2). As such, a total of six participants, three males and three females, were included in data collection. To increase the generalizability of potential findings to soccer performance, participants were recruited from a comprehensive university setting, with participation delimited to currently active soccer players with a minimum level of experience playing at the high school varsity level. All participants exceeded this requirement and possessed participation at the collegiate level. All participants were current college students; age ranged from 19 to 25 years (M = 22.2, SD = 2.1) with an average 13.8 years of total soccer experience (SD = 3.9). Of these, five participants were active soccer players at the collegiate club level, while one was an active soccer player at the National Collegiate Athletic Association level.

Protocol

All procedures were approved by the University Institutional Review Board for human subjects at California State University, Fullerton and further complied with required ethical guidelines (21). Participation consisted of three visits each lasting approximately 45-55 min. The initial familiarization visit (i.e., Visit 1) and Visit 2 were separated by 48 hr (2 days), while Visit 2 and Visit 3 were separated by 120 hr (5 days).

Familiarization: Visit 1 consisted of obtaining informed consent, collecting participant demographics, and in accordance with past research (10, 25, 26), directing participants to maintain their average caffeine consumption and sleep pattern prior to subsequent visits. A modified version of the Caffeine Consumption Questionnaire-Revised (CCQ-R; 11) and a single question related to sleep was used to monitor adherence to the provided directions prior to Visit 2 and Visit 3. Further familiarization included introductions to the game film task, Stroop test, and the visual analogue scale (VAS) (31, 32) used to measure subjective mental fatigue (MF). Familiarization with both the Stroop test and the game film task included the completion of one round of each task.

Experimental Protocol: Visit 2 and Visit 3 began with the confirmation that participants followed the provided directions to maintain their average level of caffeine consumption and quantity of sleep obtained the night before. Participants then completed a VAS to provide an initial measurement of MF and subsequently completed either the game film task or the Stroop test in a counterbalanced, randomized order. After the completion of the appropriate task, participants provided a second measurement of MF.

Game Film Task Protocol: The game film task lasted approximately 35 min and consisted of six 5 min rounds of participants observing a collegiate soccer game with 1 min of rest between each round. Participants were seated at the center of the laboratory and observed the film on the laboratory's screen. Each participant was directed to count aloud the number of passes completed by an assigned team during each 5 min segment of play; the team the participant was assigned to observe switched after round three. Male participants viewed segments of a men's collegiate soccer game and female participants observed segments of a women's collegiate soccer game. Passes were operationally defined for participants as any successful transfer in possession of the ball between players on the observed team.

While observing game film and counting aloud the number of passes, participants were required to respond to visual cues external to the film that denoted specific actions; cues were provided by one of three randomly blinking LED lights from the FitLight Trainer™ system (FitLight Sports Corp., Aurora, Ontario, Canada). The first of the three LED lights was set at the center of the table, approximately 2 ft in front of the participant. Two additional lights were set approximately 1 ft left and right of the center light (see Figure 1). Throughout each round, any of the three LED lights randomly activated and presented as either a red or green light. In rounds one through three, participants were directed to continue counting the number of passes observed when a red LED light was displayed. However, when a green LED light was displayed, participants were directed to deactivate the light as quickly as possible by waving a hand within 40 cm over the surface of the light. Once participants deactivated the light, they continued watching the film and verbally counting the number of passes observed, beginning from the number they previously ended on. During rounds four through six, the appropriate action for each color the LED lights was reversed. Participants were directed to continue observing the game film and counting the number of passes when a green LED light is displayed and to deactivate the LED light when a red LED light is displayed.

The design of the game film task was developed to replicate the observation of game film as it occurs in the real world, including presence of the MF-contributing factors of screen-exposure, over-analysis, high contextual interference, and sustained auditory processing. Specifically, it was intended that the response to the LED lights would stimulate over-analysis, the intermittent breaks between bouts of sustained attention where directions changed would increase contextual interference, and the need to focus through crowd noise or commentary included in the game film would require sustained auditory processing. In addition, the observation of game film within real-world settings includes naturally occurring distractors such as individuals entering or exiting the room, smart-phone or smart-watch notifications, and side conversations or comments. Thus, the inclusion of the LED lights was further intended to replicate these distractors in a controllable manner.

Figure 1. FitLight Trainer™ Arrangement.
Note: Participants were seated at the lab table and cued to act by one of three LED lights that randomly activated as either red or green.

Stroop Test Protocol: The Stroop test is the most common laboratory-based task used to successfully induce MF in past research (23, 38), as it demands the aspects of cognition theorized to induce MF such as sustained attention, response inhibition, and working memory, and it replicates the cognitive demands present in sport (12, 33). As researchers have suggested comparing real-world tasks to other tasks known to consistently induce MF (30), the Stroop test served as the standard for comparison in the current protocol.

The Stroop test protocol employed in the current study consisted of approximately 35 min of completing an app-based Stroop test, separated into six rounds of 5 min each, with 1 min of rest between each round. Each of the six rounds was comprised of five consecutive 60 s individual Stroop tests. Following the completion of each individual Stroop test within a round, the researcher recorded the final score; participants were directed to begin the next test immediately following completion of the previous test. The Stroop testing was completed on a 6th generation Apple iPad (Apple Inc., Cupertino, California, U.S.A) through use of the Brain Test - Stroop Effect© application.

Measuring Instruments: MF was measured through participants' completion of a VAS prior to and immediately following each task, a common method of measurement used in past research (2, 31, 32, 40). However, within this research, MF has yet to be the primary dependent variable under investigation. Rather, the measurement of MF is completed as a manipulation check to ensure that the development of MF has occurred when investigating the effects on subsequent performance tasks. It was theorized that, as a primary dependent variable, the traditionally used

100 mm VAS would lack the sensitivity to detect smaller changes in MF, and thus, use of a wider and more detailed scale would be warranted. As such, initial pilot testing was conducted, from which results were used to determine that a 240 mm VAS with additional markings every 2 mm to use for reference (see Figure 2) was best fit.

Similar to past research, each VAS was anchored by the phrases “not at all” on the left end and “maximal” on the right end. Participants were provided with a definition of MF and directed to place a mark anywhere on the horizontal line to represent their current level of MF with respect to the two anchor statements. Objective assessment of each VAS consisted of the use of a ruler to measure the distance in mm the provided mark is from the left end of the scale.

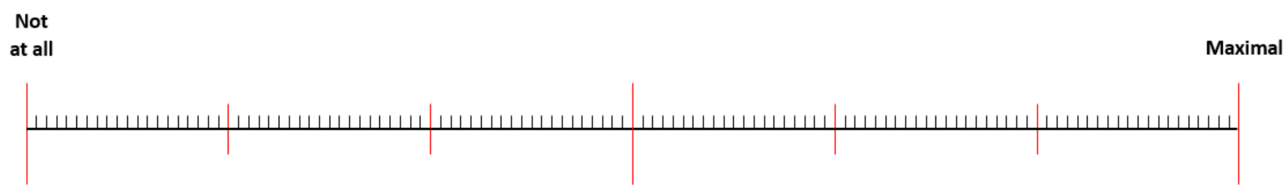

Figure 2. Visual Analogue Scale Modified from 100 mm to 240 mm Based on Pilot Testing
Note: Participants placed an X on the horizontal line indicating how mentally fatigued they felt in the moment. The example pictured is not to scale.

Statistical Analysis
Statistical analysis was conducted using SPSS (Version 26) and consisted of the use of a two-way repeated measures analysis of variance [ANOVA; 2 (time: pre vs. post) x 2 (task: game film task vs. Stroop test)] to test for potential differences in changes of subjective MF. This analysis was completed with an α of 0.05 and Bonferroni post-hoc tests planned, if necessary.

RESULTS

Descriptive statistics for participants' subjective mental fatigue (MF) scores prior to and following each task, as well as statistical results from the repeated measures ANOVA, can be seen in Table 1. In summary, no significant time x task interaction was found, $F(1, 5) = 1.226$, $p = 0.319$ (see Figure 3). Additionally, no significant time, $F(1, 5) = 2.211$, $p = 0.197$, or task main effects were found, $F(1, 5) = 1.504$, $p = 0.275$. However, it should be noted that although moderate effect sizes were indicated, observed power for the time x task interaction and both main effects were below 0.80 for each, respectively.

Finally, to provide a comparable value to past research, two dependent *t*-tests comparing pre-task MF to post-task MF were used to calculate an effect size for each task. Results indicated a moderate Cohen's *d* of 0.557 for the Stroop test and a moderate Cohen's *d* of 0.516 for the film task. In comparison, research has demonstrated large to very large Cohen's *d* ranging from 0.80-2.30 for past Stroop test protocols (26, 32).

Table 1. *Descriptive Statistics of MF and Repeated Measures ANOVA Results*

Descriptive Statistics[a]	Min	Max	Mean	*SD*
Mental Fatigue prior to Stroop test	00	182	56.60	63.66
Mental Fatigue post Stroop test	20	168	87.50	69.82
Mental Fatigue prior to Film task	00	170	52.50	63.53
Mental Fatigue post Film task	00	183	61.00	68.63
Repeated Measures ANOVA Results	F	Sig.	η_p^2	Observed Power
Time	2.211	0.197	0.307	0.228
Task	1.504	0.275	0.231	0.171
Time*Task	1.226	0.319	0.197	0.148

[a] Represents the distance in mm provided marks were from the left end of the visual analogue scales used to measure subjective mental fatigue.

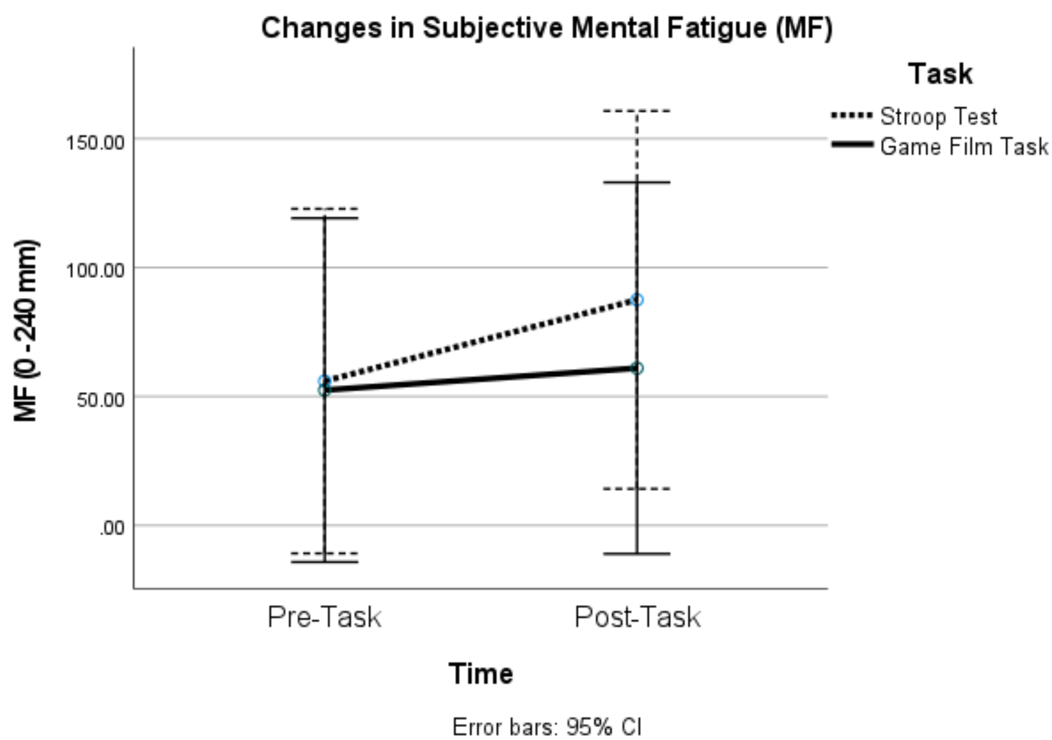

Figure 3. Interaction Between Time and Task of Subjective Mental Fatigue
Note: Overlap of the respective error bars are representative of the lack of significant interaction.

DISCUSSION

The purpose of this study was to compare changes in subjective mental fatigue (MF) following completion of a task designed to replicate the observation of game film in soccer to changes in MF following completion of the Stroop test. Results supported the hypothesis that changes in MF following the observation of game film task did not significantly differ from changes in MF following the Stroop test. Explanations for this finding along with study limitations and directions for future research will be discussed below.

Subjective Mental Fatigue: As stated above, changes in MF following completion of the game film task did not significantly differ from changes in MF following completion of the Stroop test. Given that the observation of game film is a task commonly completed prior to training or competition across a wide variety of sports, and the Stroop test has successfully been used to induce MF in past research (23, 38), the results of the present study take initial steps towards identifying tasks in real-world sport environments that contribute to the development of MF. Since no time or task main effects were observed in the present study, explanations are offered for the lack of observed changes in MF pre- to post-task.

Contrary to past research (2, 26, 32), the Stroop test did not generate a significant increase in MF within the current study. One possible explanation for the lack of change in MF following completion of the Stroop test, as well as that following the game film task, may be related to the instrument used to measure MF. Although initial pilot testing was conducted, the larger 240 mm VAS with additional markings every 2 mm used may have introduced a wider variability in scores not observed in previous research (31, 32, 40) using the smaller 100 mm VAS.

An additional explanation for the lack of changes in MF following completion of the Stroop test is the structure of the Stroop test protocol used in the current study. Although a majority of previous researchers do not explicitly describe the timing of their experimental protocols, the directions reported to research participants (e.g., the need to complete as many trials as possible within a time period), imply that the tasks were continuous (25, 26, 32). Those researchers that have provided the timing of their protocols (2, 24, 28, 40), describe periods of rest that only lasted between 1 and 15 s. As researchers have suggested (35), periods of rest away from the cognitive task may reduce perceptions of MF; the extended and repeated periods of rest lasting 60 s in the Stroop test protocol in the current study may have prevented significant changes in MF. Similarly, the periods of rest within the game film task protocol of the same length of time may have prevented significant changes in MF following completion of the game film task.

In addition to the lack of changes in MF following each task, the moderate effect sizes are considerably lower than the large to very large effect sizes found in previous MF research (26, 32). One explanation for this finding is that participants in the current study were not recruited from the same sport team or organization, thereby increasing variability in scores as indicated by the high *SD*s (Table 1) and decreasing the observed effect size. It has previously been argued that within research on ego-depletion, a concept similar to MF, the use of increasingly heterogenous samples have brought into question the replicability of results and similar issues may arise when failing to use homogenous samples in MF research (19). A similar influence of participant heterogeneity may have reduced the observed effect size in comparison to what has been demonstrated in past research.

Limitations & Future Directions: Several limitations exist in the current study that may guide future research into MF generally and the mentally fatiguing nature of the observation of game film specifically. First, no attempt was made to account for participants' past experiences with the observation of game film or frequency of exposure to self-regulatory tasks, such as the cognitive demand of one's occupation. As it has been previously hypothesized that frequent self-regulation may decrease individuals' susceptibility to MF (19), the daily cognitive demand of a college student may have contributed to the reduced effect sizes observed in the present study. Thus, future researchers looking to investigate MF following the observation of game film should consider delimiting participation to control for athletes' history observing game film or with other self-regulatory tasks that may decrease their susceptibility to MF (19).

Second, provided the aforementioned explanations for the lack of changes in MF following each task and the reduced effect sizes, in conjunction with the relative infancy of MF research, it is premature to offer professional practice recommendations regarding MF and the observation of game film in the real-world sport environment. As such, and given the lack of differences found between the two tasks and the comparable moderate effect sizes, further research into MF following the observation of game film is warranted. The present study compared changes in MF following completion of a task simulating the observation of game film in soccer to changes in MF following completion of the Stroop test. Thus, to provide additional context for present results, future researchers should look to measure MF following the real-world observation of game film in sport, where accessible. In addition, future researchers should look to establish conformity in the assessment of MF (37), including validation of a VAS to account for a wider range of responses of MF, as was used in this study. Finally, investigations to determine if *continuous* bouts of cognitive control theorized to induce MF are necessary for the development of MF, as well as continued efforts to identify tasks in real-world sport environments that may contribute to the development of MF are encouraged.

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