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Just sleep it off. The effects of sleep quality and trait anxiety on working memory.

Tsirimokos, G., Ganotis, A., Ferhati, E., Xanthakou, E., Rapti, M., Afendouli, P., Louka, P.

Mediterranean College, School of Psychology, Greece

Abstract

Working memory (WM) is a fundamental cognitive system responsible for the concurrent processing, temporal storage, and manipulation of information. Typical function of WM reflects the capacity to perform sequence-based, goal-oriented tasks; however, interference in this cognitive structure, can extensively hinder task's performance and completion. Literature suggests that sleep quality and trait anxiety are two of the most prominent factors, that seemingly influence WM's overall functionality; yet to the best of the researchers' current knowledge, no study has examined the possible interaction effects of these parameters towards WM. The current research by examining those variables, concluded to partially significant results, indicating that trait anxiety significantly effects WM, to a magnitude proportionate of 26,2%. Similarly, sleep quality significantly affects WM, approximately by 25,1%. However, the interaction effect of trait anxiety and sleep quality on WM, produced non-significant results. Several implications of synergistic and even counteractive effects among these variables are discussed.

Keywords

working memory (WM), trait anxiety, sleep quality, cognitive impairment, executive control.

Corresponding author: Georgios Tsirimokos, T.Tsirimokos@mc-class.gr)

Introduction

Working memory (WM) is a fundamental cognitive system responsible for the concurrent processing, temporal storage, and manipulation of information[1, 2,3]; extending from the ability of successfully inhibiting interference of irrelevant stimuli[4], to the capacity of performing complex and demanding day-to-day cognitive functions underpinning reasoning, learning, problem-solving, comprehension, and conceptual decision-making[5, 6]. The structural basis of WM consists of four complementary components; the visuospatial sketchpad, which temporally stores and regulates visuospatial cues[7], the phonological loop, capable of maintaining verbal and auditory information through repetitive subvocalization rehearsal mechanisms[8], the episodic buffer, a limited-capacity storage system that binds visuospatial and phonological information with long-term memory traces, and reconstructs them into coherent, and consciously retrievable memory episodes [9], and lastly, the central executive, which possess the supervisory function of regulating attentional control, and coordinating the flow of information within the visuospatial, phonological, and episodic buffer, subsystems [10]. Typical function of this integral cognitive structure reflects the capacity of the individual to maintain awareness and selectively allocate attention, towards the execution of sequence-based, goal-oriented tasks[11, 12]. Yet, intrusion in WM's underlying dimensions of short-term storage, attention, and executive control, can extensively hinder task's performance and completion[13, 14]; resulting in pervasive aftereffects, including impairments in interpersonal communication[15], affective modulation[16], academic performance[17], or workplace productivity[18].

Trait anxiety, appertaining to a personality characteristic associated with enduring predisposition tendencies, in which the processing of threatening, or perceived as threatening information, is prioritized [19, 20]; is consistently presented as a disruptive factor of WM[21, 22, 23]. Besides from certain exclusions[24], literature abounds with evidence indicating that, elevated levels of anxious-oriented personality traits and their correlates, are significantly associated with deficits in WM, including impairments in cognitive tasks concerning analogical, spatial, and inferential reasoning[25], reading performanc[26], mathematics[27], and attentional processing[28]. These data stand in cogent grounds, as individuals with elevated levels of trait anxiety present substantial attentional bias to threat, even in mild, non-threatening cues[29]; which, consequently, prompts a shift of WM's activity, from attentional processing of task-relevant information, towards processing of perceived threats[19]. This dysregulation, coupled with circumstances characterized by high cognitive load (e.g., academic exams), overwhelms the limited-capacity storage of the WM system, as, a significant portion of cognitive resources are devoted in managing anxiety per se; thus, resulting to impediments of relevant ongoing tasks, due to hinderance of central processing executive functions[25]. Of particular interest, effects of trait anxiety have been correlated with disturbances in sleep quality; an area with considerable magnitude to WM's overall functionality[30].

Sleep quality, mainly signifying to the self-satisfaction prospects of sleep's duration, efficiency, latency, and probable interruption [31, 32], is widely presumed as a factor with unequivocal effects on WM[33, 34]. While high sleep quality fosters widespread restorative bio-neurological benefits to cognitive functions related to WM, including attention, learning, concentration, memory consolidation, or audiovisual awareness, to name a few[35, 36]; low sleep quality is linked with reduced accuracy and speed, in relatively simple attention tasks [37], decreased visuospatial attentiveness and auditory diligence[38], and impaired verbal recollection[39]. These effects are also demonstrated in longitudinal studies, which suggest that the effects of chronic, non-optimal daily sleep (i.e.,<7 hours) tend to accumulate gradually, and eventually correspond to the more direct effects of –occasional– total sleep deprivation; resulting in significantly poor performance in nearly all cognitive tasks[40]. However, surprisingly enough, the largest polysomnographic study so far (N=477.529), demonstrated that insomnia patients, presented enhanced objective cognitive functioning[41]. The implications of these data suggest that sleep quality affects all facets of WM (e.g., phonological, visuospatial), and sometimes, in overlooked, oblique and ambiguous ways[34].

The current study, therefore, by examining the effects of trait anxiety and sleep quality on WM, attempts to provide insights to possible synergistic or even counteractive effects among those variables; as, although ample research has inspected the effects of trait anxiety and sleep quality on WM in isolation, to the best of the researchers' current knowledge, no other study has examined the possible interaction effects of these parameters. This reasoning is analogous to the implications for future research proposed by Horváth and colleagues (2016). Lastly, the current study does not produce, directly–or–indirectly, any form of diagnosis of the understudied paradigms, whatsoever. The (two-tailed) experimental hypotheses are: (H_1) there is a significant main effect of sleep quality on WM. (H_2) There is a significant main effect of trait anxiety on WM. (H_3) There is a significant interaction effect of sleep quality and trait anxiety on WM. Non-typical population (i.e., individuals with health complications) are beyond the scope of this study.

Method

Design

A factorial (2x2) independent measures ANOVA was implemented, consisting of one dependent variable (working memory scores) and two independent variables (Sleep quality–Trait anxiety). Based on their questionnaire responses participants were divided (median split) and allocated to the appropriate experimental setting; namely, High sleep quality–Low sleep quality (median=2,281), and High trait anxiety–Low trait anxiety (median=2,293).

Participants

The current study conducted with a total number of 178 participants, of which 124 were females and 54 were males, with ages spanning from 18 to 49 (Mean=28.5,/St.D.=8,005). Participants recruited opportunistically (non-probability-based sampling), with exclusions including individuals under 18 or over 49 years old, people exhibiting attention impairments and sleep discrepancies, are under medication, or suffering from severe physio-psychological conditions.

Materials

Three Likert scale questionnaires were utilized. The questionnaire assessing working memory (*a*=0,89;[14]), consisted of 30 items with responses ranging from 0 (not relevant) to 4 (almost always). The questionnaire assessing trait anxiety (*a*=0.89;[42]), comprised of 21 items, with responses extending from 1 (not-at-all) to 4 (almost always). Lastly, the scale evaluating sleep quality (*a*=0.92;[43]), included 28 items, with responses spanning from 1 (rarely) to 4 (almost always). Overall scores for each questionnaire were computed (SPSS v.25) by summing the scores of each item, for each participant; while reversed items were reverse coded.

Procedure

The procedure initiated with the provision of information to the participants, regarding the aim of the study, its exclusions, procedure, and duration (approximately 12 minutes), privacy and confidentiality affairs, and data use conduct (GDPR). Participants were informed that their participation is voluntary and that they can withdraw from the procedure, without giving any excuse. Lastly, contact information (emails) of the research team, were provided. After informed consent, participants were prompt to successively answer the three questionnaires. Ensuing that, participants were debriefed and reminded that they can retract their data, up to 15 days, following the experimental date. Ethics form was approved by the academic leader, prior to any research activity.

Results

A factorial independent measures ANOVA was implemented to investigate possible effects of sleep quality and trait anxiety on WM. After adjusting (winsorizing) the outliers, data screening, graphs, and normality tests, presented symmetrical distribution. Table 1 exhibits descriptive information concerning mean (St.D.) scores in each experimental setting.

Table 1. Mean (St.D.) scores of independent variables in each experimental setting.

	High-Sleep quality	Low-sleep quality	Total
High-Trait Anxiety	2,073(0,474)	2,342(0,418)	2,267(0,449)
Low-Trait Anxiety	1,694(0,389)	2,043(0,397)	1,791(0,419)
Total	1,800(0,446)	2,257(0,432)	

Analysis conducted via the (2x2) factorial independent measures ANOVA. There was a significant main effect of sleep quality on WM, $F(1,174)=19.794$, $p<0.0001$, $\eta^2=0.078$, demonstrating that high sleep quality participants produce better (reduced) WM scores, than their low sleep quality counterparts. Similarly, there was a significant main effect of trait anxiety on WM, $F(1,174)=24.401$, $p<0.0001$, $\eta^2=0.096$, indicating that participants with high levels of trait anxiety exhibit worse (elevated) WM scores, than low-trait anxiety participants. However, there was no interaction effect of sleep quality and trait anxiety on WM, $F(1,174)=0.316$, $p=0.575$. The complete statistical analysis or the corresponding forms and scales can be presented upon request.

Discussion

The current study examined the probable effects of sleep quality and trait anxiety on WM. Conclusions corroborate partially significant results, suggesting that sleep quality significantly effects WM, therefore supporting hypothesis[1]. Likewise, there is a significant main effect of trait anxiety on WM, thus supporting hypothesis[2]. However, analysis indicate a non-significant interaction effect of sleep quality and trait anxiety on WM; ergo, hypothesis[3] is rejected.

Preceding findings, in the light of the data yielded in the current study, produce several probable implications. Initially, the findings of the current study concur with the bulk of previous literature concerning trait anxiety[21, 22, 23, 25, 26, 27, 28], and suggest that individuals with elevated anxious characteristics are 26,2% more susceptible to experience significant impairments in cognitive functions related to WM. Similarly, prior studies in the sleep quality paradigm[33, 34, 35, 36, 37, 38, 40, 41], also coincide with this paper, which demonstrates that individuals with inadequate sleep quality, are 25,1% more exposed to poor WM functionality. These substantially analogous estimates, entail that, trait anxiety and sleep quality, possess related mirroring effects, meaning that, in isolation, they retain roughly the same potential to adversely influence WM. To a greater extend, these approximations, accompanied by literature indicating that key characteristics of elevated trait anxiety, such as excess worry or fear to actual or perceived threats, can entangle falling or staying asleep, and sequentially, sleep deprivation can aggravate those anxious incentives [30]; imply that, individuals with elevated trait anxiety have increased susceptibility to low quality sleep, which combined with the current findings, may aggregate to impairments proportional to nearly 50% of WM's overall functionality.

Nonetheless, these assumptions contradict the non-significant interaction effect produced by the current research, which are puzzling results, considering that, in isolation, trait anxiety and sleep quality, produced substantial statistical significance (<0.0001) towards WM. One plausible interpretation to these somewhat contradictory findings, stands to the (independent measures) design employed in the current research, in which, different participants were allocated in each setting. Correspondingly, the interaction effect on WM, is not actually measured with respect to the possible reciprocal effects between the independent variables, within each individual, but is rather assessed separately across the four experimental conditions (High/Low trait anxiety–High/Low sleep quality). In other words, the existence of possible interaction effects of those variables on WM could not be observable, as individuals were allocated only in one experimental setting, regardless if they were simultaneously experiencing both increased trait anxiety and low quality sleep; which consequently could imply potential "false negative" results, alias, a type II error [44]. This assumption is further entrenched by the almost identical total scores of high trait anxiety (2,26) and low sleep quality (2,25). However, one should not undervalue the non-significant interaction effect produced in this study, as it could also imply the existence of possible countereffects or even coping mechanisms utilized by individuals within the WM, trait anxiety, and sleep quality triumvirate, akin to the study of Kyle, and colleagues (2017); yet further research is needed for these assumptions to be worth considering.

Lastly, one specific advantage of the current paper, lies to the data collection approach, as compared to traditional score collection methods, which are generally considered as stressful and resource demanding equation-oriented procedures; this study utilized a simple, yet widely acknowledged, multi-questionary standardized scale[14]. Throughout the questions, this method evaluates longitudinally, key underlying dimensions of WM, concerning executive control, attentional distribution, and short-term storage, and is probably more inclined to integrated results, and therefore towards increased internal analytic validity [44]. However, one drawback of this research, is that volunteers participated without any specification to biological gender, which resulted to disproportionate female (69,4%) to male (30,3%) ratio. These aberrations of frequently overlooked demographic differences, could have influenced the analysis, as women are generally more prone than men towards anxious traits, while men are more susceptible than women to adverse sleep complications[32].

To conclude, the current research investigated the effects of trait anxiety and sleep quality on WM. Analysis indicates that sleep quality and trait anxiety, in isolation, significantly affects WM; however, the interaction of these factors towards WM, produces non-significant results. Several implications of synergistic and even counteractive effects among these variables are discussed. Further research is suggested to re-evaluate these parameters, to provide better insights regarding early intervention.

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