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The impact of an action commercial video game on adult non-gamers psychological well-being, cognitive functioning, and sleep

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ABSTRACT

Introduction: The ever-growing diffusion of video games (VG) prompts to investigate their effects on health. While different studies exist on the topic, their results are difficult to interpret, probably because modulating factors have been mostly neglected. Here, we explore VG type and gamers' experience levels by assessing the impact of a violent VG on sleep, cognitive functioning, and psychological well-being in a sample of non-gamers.

Methods: In a within-subjects design, 18 adult non-gamers ($M^{age} = 24.4 \pm 3.68$ years, 12 F) underwent a baseline assessment including sleep logs and actigraphy for one week, one night of home polysomnography (PSG), administration of a cognitive testing battery, and questionnaires on psychological health. The baseline assessment was followed by an experimental condition and an active control condition, in balanced order between participants, each lasting four days: a) three nights of pre-sleep activity manipulation, in which participants either played an action VG or watched a familiar action TV series for an hour before bedtime, with PSG on the last night; b) administration of the cognitive battery and questionnaires on the 4th day.

Results: After video gaming, participants reported better visuospatial working memory and reduced stress levels compared with the baseline and the active-control condition. Except for reduced efficiency in TVW, no between-condition difference emerged for sleep measures.

Conclusions: In contrast to the common assumption that VGs are detrimental to several health-related variables, our data show that controlled, time-constrained video gaming may positively affect next-day cognitive functioning and stress, while not compromising objective sleep quality.

1. Introduction

Annually more than 300 billion U.S. dollars [1] flow into the video game (VG) industry, making it one of the greatest in the world. Several reasons can explain this huge diffusion. First, the ever-growing quality of VG standards in ludic, narrative, and visual aspects has allowed VGs to reach wider populations. Indeed, in 2023 in the United States, 76 % of the population declared to play VGs [2]. Second, VGs are increasingly used in non-recreational contexts, such as for work, sport, and educational purposes. Furthermore, VG players consistently report numerous psychological benefits of playing: for instance, VGs seem capable of bringing joy, providing mental stimulation and stress relief, and creating and increasing connections with others [2].

Unsurprisingly, this remarkable diffusion of VGs has been paralleled by a growing literature on their relationships with health and well-being. However, the wide amount of data produced on the topic is still controversial and does not allow for drawing clear conclusions. For example, while some studies associated VG playing with increased aggressiveness, depression, and anxiety [3–5], others successfully employed VGs to facilitate emotion regulation, showing that, under

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controlled situations, VGs can be used to treat several mental conditions (see Villani et al., and Boldi & Rapp, for reviews [6,7]). In this regard, as we highlighted in our systematic review on the topic [8], studying the possible modulating factors of VGs, such as the type of VG used, the duration of sessions, and the participant's previous level of exposure to VGs appears crucial to reaching a deeper understanding of their effects on several health domains, like psychological well-being, cognition, and sleep.

For example, considering the type of VG used, Aliyari et al. [9] compared the cortisol levels of 4 groups of healthy adults (N = 80) before and after playing different types of VG (i.e., scary, exciting, puzzle, runner VGs), showing that scary and exciting VGs significantly increased cortisol level, whereas the puzzle VG reduced it and the runner VG left it unchanged. These results suggest that stress may be increased or reduced according to the type of VG, with probable indirect effects on sleep and cognitive functions. Moreover, Cerasuolo et al. [10] showed that playing a puzzle VG for 40 min before bedtime may increase sleep quality in terms of continuity, stability, and organization. The same experiment was conducted in a nap design, not only showing positive effects on sleep but also on cognitive functioning [11].

The impact of exciting VGs on sleep and next-day cognitive functioning was mostly assessed in children and adolescents, with mainly negative outcomes on sleep, verbal memory, and sustained attention [12,13]. However, in interpreting these results the duration of gaming sessions should be considered. Indeed, while the mentioned studies [12, 13] only tested the effect of prolonged periods of video gaming (from 2:45 to 5:00 h), in one case, recreating the "typical" adolescent night (bedtime from 01:00 a.m. to 07:00 a.m.) [13], in their polysomnographic study, King and collaborators [14] showed that exciting VG negatively affects sleep efficiency only in prolonged conditions (150 min of VG before bedtime) but not in shorter ones (50 min of VG before bedtime).

Lastly, as we also reported in our survey study [15], the effects of VGs could depend on the participant's previous level of exposure. There are two aspects to consider here: 1) the role of sleep-related memory consolidation processes and 2) that of habituation. Regarding the first point, studies have shown that sleep plays a role in the consolidation of previously learned material and, consequently, that the need to consolidate new information increases those features of sleep associated with these processes, such as continuity, stability, and organization [16–18]. In this sense, as was already hypothesized before [19,20], given the high-demanding learning that playing VGs requires, it is not unreasonable to imagine a positive effect of VG playing on sleep, especially in non-gamers for whom learning demands are greatly increased by novelty. On the other hand, possible negative effects could be more pronounced in individuals with low exposure to VGs because of the lack of habituation processes. This was indeed reported by Ivarsson and collaborators, who compared low-exposed (less than 1 h of VG daily) with high-exposed adolescent gamers, finding that after an exciting-violent VG session, sleep-HR (heart rate) only increased in the low-exposed group [21]. In this perspective, by increasing pre-sleep arousal, exciting VGs may have detrimental effects on sleep quality and interfere with the possible learning-dependent positive effects, a hypothesis that remains to be tested.

Considering all the possible intervening variables, studies involving VGs should monitor several factors to obtain valid and generalizable results. Here, we adopted an experimental design study, monitoring the type of VG by using a high-learning demanding violent-action VG, and the previous level of exposure of participants by using a sample of non-gamers. Meanwhile, the duration of the VG sessions was kept at a non-intensive level (60 min). Furthermore, we used a TV series exposure as an active control condition to determine a) whether the effects we found could be attributed to the VG playing and not to the general experimental situation, b) whether the effects of VG are connected to learning processes, not involved in the TV-condition employing a well-known TV series.

Our purpose is to properly investigate if a controlled, time-constrained pre-sleep exposure to violent-action VG can lead to possible benefits to sleep in a sample of non-gamers, thanks to the sleep-related memory reprocessing triggered by them. Also, we aim to find out whether this kind of gaming affects cognitive functioning and psychological well-being.

Where other studies failed to integrate different modulating factors (*see* De Rosa et al., for a review [8]), by manipulating the previous level of habituation, the VG type, and VG session duration, our work allows for a more in-depth analysis of the effects of VGs on health. Furthermore, as an innovative aspect, we think that considering the possible role of the VG-dependent learning mechanism on subsequent sleep will shed new light on the potential use of VG playing for sleep promotion.

2. Method

2.1. Participants

Eighteen (18) healthy young adults (Mage = 24.4 ± 3.68 years, 12 F) from the cities of Naples, Salerno, and Caserta voluntarily took part in the study, according to the following inclusion criteria: age between 18 and 35 years; being a "non-gamer" (i.e., playing VGs for maximum 1 h a week on average: 3 participants reported playing at most 1 h a week, while 15 participants reported not using VGs at all); absence of any relevant somatic or psychiatric disorder; absence of any sleep apnea or respiratory disorder symptoms; having a regular sleep–wake pattern (average bedtime no later than 00:30); absence of sleep disorders; no history of drug or alcohol abuse; limited caffeine (no more than 150 mg caffeine per day, corresponding to about three cups of espresso or one cup of American coffee) and alcohol (no more than 250 mL per day) consumption.

The local Ethics Committee approved the protocol.

See Table 1 for demographics and sample characterization.

2.2. Procedure

In a within-subject design, each participant underwent a week of baseline assessment (BSA) followed by two conditions (in balanced order between subjects), consisting of the administration of one of two pre-sleep manipulations for three nights in a row, i.e., watching a TV series (active control condition, TVW) and playing a violent action VG (experimental condition, VGP).

In order to minimize confounds linked to experimental settings and preserve ecological validity, the whole procedure was conducted at the participants' homes. Moreover, bedtimes and rise times were not predetermined but defined according to each subject's individual sleep habits. To this end, during the BSA week (see Fig. 1), participants kept a sleep log and wore an actigraph on their non-dominant wrist for 7 consecutive days, in order to verify the regularity of their sleep-wake habits and to determine their average bed- and rise times. Also, during this week, they underwent a night of habituation (a night of sleep recording not included in data analysis) in order to reduce the likelihood of a "first-night effect" on the experimental nights. Finally, this baseline week included a night of polysomnographic recording (maximum 9 h of

Table 1
Characteristics of the sample and their comparisons between genders.

Variable	Men	Women	Total	Test
No.	6	12	18	
Age	26.8 ± 4.45	23.3 ± 2.70	24.4 ± 3.68	U = 18, p = .099
Years of education	16.3 ± 2.80	15.3 ± 1.91	15.6 ± 2.23	U = 27.5, p = .439
PSQI	4.50 ± 2.07	5.17 ± 1.80	4.94 ± 1.86	U = 29, p = .537

Notes. PSQI: Pittsburgh Sleep Quality Index global score.

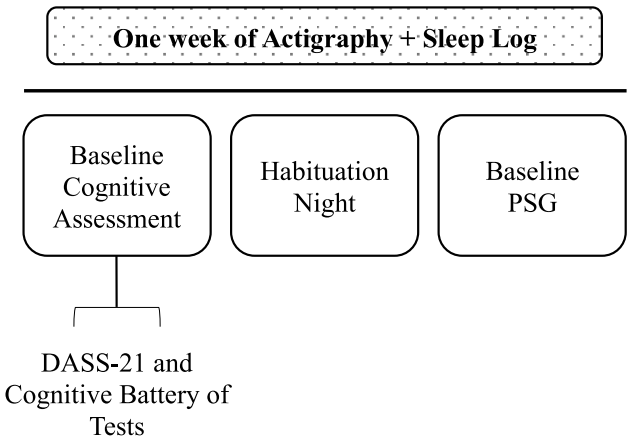

Fig. 1. Detdetailed description of the baseline assessment (BSA).

time in bed) and the administration of cognitive tests (*see* 3.2.3. Cognitive Tests and Performance Measures) and of the Depression, Anxiety, Stress Scales – 21 (DASS-21, Bottesi et al. [22]) a standardized instrument that provides scores for depression, anxiety, and stress levels, as well as a global assessment of psychological health. These latter measures represented the baseline for comparisons with the same measures collected after the pre-sleep manipulation conditions.

After the BSA week, each participant was administered the two conditions (TVW and VGP) over two non-consecutive weeks. Each condition lasted four days (always selected as weekdays rather than weekends), during which participants were required to maintain their sleep-wake habits and daily activities as regular as possible and to fill in a sleep log as well as a diary of daily activities, in order to control for possible between-conditions differences in daily cognitive load and sleep-wake rhythms. To this end, participants also wore an actigraph on their non-dominant wrist across the four days.

On the first, second, and third day, one of the two pre-sleep manipulations was administered in the evening for 1 h, concluding 30 min before their average bedtime. Room illumination (lights on), distance from the screen (at least 150 cm), and sitting posture (between 45 and 90°) during pre-sleep activity sessions were kept constant across conditions. Each participant's personal TV screen was employed in both conditions for the pre-sleep activity in order to further preserve ecological validity.

Across these first three days, subjective sleepiness ratings (through the Karolinska Sleepiness Scale, KSS [23]) were collected at 5:30 p.m. and immediately before and after each pre-sleep activity session. Alertness levels were also monitored before and after each pre-sleep activity session through a Visual Analogue Scale. Moreover, after each pre-sleep activity session, participants were asked to rate on a 5-point scale their subjective enjoyment of the activity (i.e., "How much have you enjoyed the time spent watching the TV-series/playing the video-game?"). Finally, on the third night, participants also underwent a polysomnographic recording (maximum 9 h of time in bed).

The last day of each condition (4th day), 30 min after rise time (to allow for sleep inertia dissipation), participants were administered a Visual Analogue Mood Scale (VAMS, 0 (negative mood) – 10 (good mood) [24]), a DASS-21 [22] and a State-Trait Anxiety Inventory – State (STAI-S) [25] as well as the same set of cognitive tests used in BSA for the assessment of cognitive and executive functioning.

A detailed description of the TVW and VGP conditions is displayed in Fig. 2.

2.2.1. *TVW condition*

In TVW the activity session consisted in watching the action TV series "Money Heist".

Money Heist is an action heist crime drama created by Álex Pina, originally run in 2017, and broadcasted in Italy by Netflix under the title "La casa di carta".

Money Heist was selected, among a range of different action TV series, during the recruitment phase of the study through interviews with the potential participants (i.e., "Have you already watched this tv-series?"). All participants of the final sample declared to have already watched at least the first season of the TV series. This choice was based on the need to create an active control condition (TVW), in which participants could be exposed, as in the VGP condition, to an activating material (the action TV series) but without the activation of the complex cognitive and learning processes which VG playing entails (especially in non-gamers).

Participants were allowed to watch the TV series through an account provided by the experimenter. All the activity sessions were constantly monitored by remote checking.

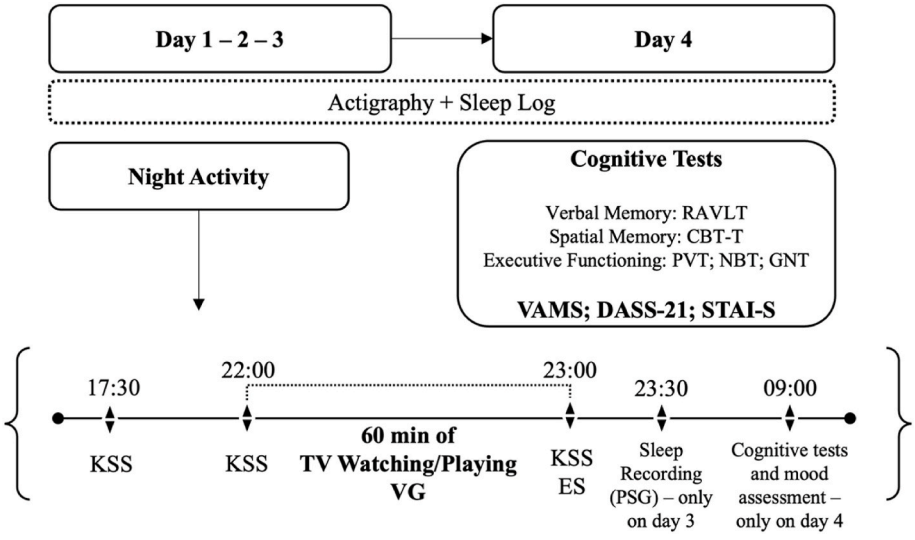

Fig. 2. Schematic description of the experimental conditions.
Notes. RAVLT: Rey Auditory Verbal Learning Test; CBT-T: Corsi Block-Tapping Test; PVT: Psychomotor Vigilance Task; NBT: N-back Task; GNT: Go/No-Go Task; VAMS: Visual Analogue Mood Scale; DASS-21: Depression, Anxiety, Stress Scales – 21; STAI-S: State-Trait Anxiety Inventory – State; KSS: Karolinska Sleepiness Scale; ES: enjoyment scale.

2.2.2. VGP condition

In VGP, the activity session consisted of playing an action VG, i.e., "Call of Duty: Black Ops Cold War".

The VG, which is a 2020 first-person shooter VG developed by Treyarch and Raven Software and published by Activision, was chosen based on its popularity among young adults and due to some specific characteristics: a) it is a commercial VG (able to provide players with goal-driven environments, continuous learning, challenges, and conflicts); b) it is played in first person (to promote engagement); c) it is a highly arousing game (due to its degree of action and to its violent content).

Participants were allowed to play through a software (an Xbox One S) provided by the experimenter, who constantly monitored the activity sessions through a remote connection. Before the beginning of the experimental condition (at least two days earlier), the experimenter visited the participant's home to assemble the Xbox and provide the necessary instructions. The participant was then instructed to use the software and performed a gaming-training session of 20 min.

2.2.3. Cognitive Tests and Performance Measures

The battery of cognitive tests consisted of five tests to be administered, in parallel versions, during the initial assessment (BSA), and the last day of the two experimental (VGP) and active control condition (TVW).

The first test assesses declarative verbal memory, and the other four different domains of executive functioning, i.e., visual and spatial working memory, sustained attention, and response inhibition.

Verbal declarative memory was measured through the Rey Auditory Verbal Learning Test (RAVLT) [26,27]. In this task, the experimenter verbally reads a list of 15 items to the participants. The participants then immediately report as many words as they are able to remember within 30s and the procedure is repeated 5 times. The total number of correct words reported across all 5 trials makes up the Total Immediate Recall (TIR) score. Delayed free recall is assessed after 15 min, yielding the Total Delayed Recall (TDR) score, i.e., the total number of correct words reported within 2 min.

As for executive functioning, we assessed visual working memory (WM), spatial WM, inhibition, and sustained attention through the computerized versions of the N-back task [28,29], Corsi block-tapping Test [30,31], Go/No-Go Task [32], and Psychomotor Vigilance Task respectively [33,34].

The Psychomotor Vigilance Task (PVT) is used to test sustained attention. It requires participants to fixate on a screen and respond to a visual stimulus (a running timer) with a key press as quickly as possible; if the key is pressed before the stimulus appeared, it is considered a "false start"; if pressed >2000 ms it is considered a "lapse" in attention. Stimulus intervals are randomly selected by the software, ranging from 2 to 10 s. In order to test sustained attention, the test lasts 10 min. The outcomes are: average time reaction (lapses and false starts excluded), number of lapses, and number of false starts.

The N-back task (NBT), used to test visual working memory in a condition of cognitive load, requires participants to respond to a sequence of stimuli appearing on the screen when the current stimulus matches the one that appeared *n* steps earlier. In this project, we used a sequence of colored blocks in a 2-back task, in which participants are asked to press a key when the current color of the block matches the one appearing 2 steps earlier. The presentation time for each block is 1500 ms and the test lasts 5 min. The only outcome is the total score (max 150), corresponding to the number of matches correctly identified.

The Corsi block-tapping Test (CBT-T) assesses spatial working memory through a random sequence of blocks briefly appearing on the screen (for 1000 ms). Participants are required to replay the sequences in the same pattern. The length of sequences increases progressively from 2 blocks to 9. When a sequence is correctly replayed, the software starts a new sequence (with one additional item). When the participant is not able to reproduce the correct sequence for two times in a row, the test automatically ends. The score corresponds to the number of items in the last correctly replayed sequence (i.e., SPAN).

In the Go/No-Go Task (GNT), participants are asked to respond to specific targets ("go"), appearing on a screen, while ignoring non-targets ("no-go"). In our version, there are 80 "go" targets, identified by a white triangle, and 40 "no-go" stimuli, identified by a red triangle. Each triangle appears on the screen for 500 ms and is preceded by a fixation point ("+") that lasted 500 ms. Since there are proportionally more "go" targets, the participant has to inhibit the pre-potency to key-press; in this way, the test is able to assess the inhibition response. Outcomes are given by the number of corrected responses (max 120), number of lapses (when the participants don't press the key in correspondence of a white triangle), number of errors (when the participants press the key in correspondence of a red triangle), average reaction time (on the correct responses).

The tests were always performed in the following sequence: RAVLT, CBT-T, PVT, NBT, and GNT. Specifically, RAVLT was verbally administered by the experimenter, whereas all other tests were executed on the same computer (MacBook Air M1) through PsychoPy 2021.2.2 [35]. Except for RAVLT, all the tests were created *ad hoc* based on Python language.

Participants were allowed to take a 2–10-min break between tests.

For data analysis, RAVLT and CBT-T scores were corrected for age and years of schooling, based on the existing Italian normative data [27,30].

2.2.4. Sleep recording

Polysomnographic recordings were performed in the baseline assessment (BSA) and in the two experimental conditions (VGP and TVW) by recording six electroencephalographic (EEG) channels – F3, F4, C3, C4, O1, O2 – referenced against contralateral mastoids (A1 and A2), two electro-oculographic (EOG) channels – LOC-A2, ROC-A1 – and a bipolar submental electromyogram (EMG) channel, according to standard guidelines [36]. Data were acquired through an EMBLA RemLogic Device, with a sample rate of 200 Hz. Sleep recordings were band-passed (0.3–35 Hz) and then visually scored according to standard criteria [36]. by an expert technician, blinded to the conditions. To verify scoring reliability, 10 randomly selected sleep recordings were scored by another technician. The inter-rater agreement was 93 %.

Classical sleep architecture variables considered in the study were: sleep onset latency (SOL), time in bed (TIB, i.e., total amount of time, in minutes, from lights off to final awakening), total sleep time (TST, i.e., total amount of time, in minutes, from the first appearance of N1 to final awakening), actual sleep time (AST, i.e., total time spent in sleep states, expressed in minutes), sleep stage proportions (percentages over AST), sleep efficiency (SE, i.e., percentage of AST over Time in Bed), and percentage of wake after sleep onset over TST (WASO%).

Furthermore, objective sleep quality was evaluated through an additional set of variables assessing:

1. Sleep continuity: Total frequency of awakenings per hour of AST; frequency of brief (<4 epochs) and long (≥4 epochs) awakenings per hour of AST; awakenings mean duration.
2. Sleep stability: Frequency of arousals per hour of AST (here arousals are defined as all transitions to shallower NREM sleep stages and from REM sleep to N1); frequency of state transitions (defined as all transitions from one state to another) per hour of TST; frequency of "functional uncertainty periods" (FU periods; defined as periods in which a minimum of 3 state transitions follow one another with no longer than 1.5 min intervals) per hour of TST; percentage of total time spent in FU (TFU) over TST.
3. Sleep organization: Number of complete sleep cycles, defined as sequences of NREM and REM sleep (each lasting at least 2 min) not interrupted by periods of wake longer than 2 min (as in Conte et al. [37]); percentage of total time spent in cycles (TCT) over TST. A necessary methodological remark concerns our choice of an

extremely conservative definition of the sleep cycle, based on the assumption that a non-marginal amount of each sleep state is required for the NREM-REM cycle to exert its role in sleep-dependent memory processes [36]. With such a definition, the duration of a sleep cycle is remarkably shorter, on average, than that obtained with the more common, less conservative, definitions.

2.3. Statistical analysis

Repeated-measures Friedman ANOVA was conducted to test differences between the baseline, the experimental, and the active control condition (BSA, VGP, and TVW) in sleep measures, cognitive performance, DASS-21 global score, and DASS-21 subscores. Kendall's W was reported as a measure of effect size, and the Durbin-Conover test was used in the case of significance for post-hoc analysis. Further, the same analysis was conducted to test within-conditions differences in subjective sleepiness (KSS).

Differences between VGP and TVW in subjective sleepiness (KSS), activity enjoyment, and last-day mood (VAMS) were assessed with the Wilcoxon rank-sum test, with the point rank biserial correlation (r_{rb}) as effect size. We also tested a possible interaction between pre- and post-condition sleepiness by evaluating the difference in Δ-score (i.e., an aggregate measure, computed as pre-sleep activity (TVW or VGP) KSS score minus post-sleep activity KSS score) by using the Wilcoxon rank-sum test.

All analyses were performed with Jamovi 2.3.21 [38], and the statistical significance level was set at $p \leq 0.05$. Descriptive statistics are reported as mean ± standard deviation.

The averaged data of sleep diaries and actigraphy monitoring during BSA, VGP, and TVW are reported in the supplementary materials (Appendix A).

3. Results

3.1. Sleepiness and subjective ratings of enjoyment of the pre-sleep activities

Sleepiness levels (measured through KSS) at the afternoon recording (05:30 p.m.) and *before* the pre-sleep activity did not differ between the two conditions (afternoon: W = 58, $p = .753$, $r_{rb} = 0.10$, TVW = 3.48 ± 1.34, VGP = 3.69 ± 1.43; *before*: W = 30.5, $p = .309$ $r_{rb} = -0.33$, TVW = 4.59 ± 1.18, VGP = 4.30 ± 1.18). Instead, sleepiness levels were higher *after* TVW compared to VGP (W = 21.5, $p = .010$, $r_{rb} = 0.72$, TVW = 5.74 ± 1.65, VGP = 4.36 ± 1.80). Furthermore, we found a significant interaction effect, with increased change in pre-post TVW sleepiness compared with the change in pre-post VGP sleepiness (W = 132, $p = .045$, $r_{rb} = -0.61$, TVW Δ-score = −1.15 ± 1.53, VGP Δ-score = −0.07 ± 1.56) (*see* Fig. 3).

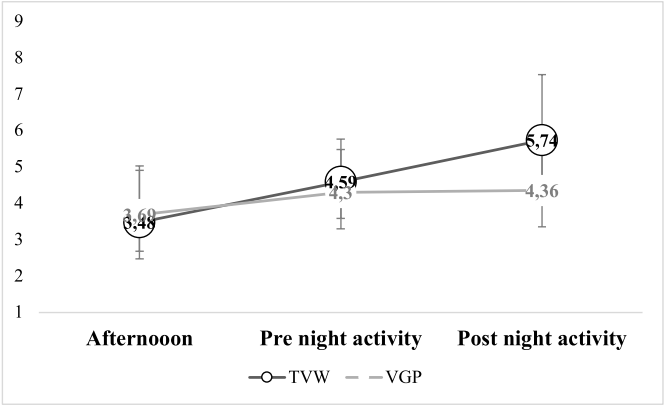

Fig. 3. Sleepiness ratings (evaluated through the Karolinska Sleepiness Scale – KSS) across the three-time points of the two conditions.
Notes. TVW: TV-watching condition; VGP: video game playing condition.

As for within-conditions comparisons, sleepiness did not differ between recording points (afternoon, *before,* and *after* pre-sleep activity) in VGP ($X^2_2 = 1.44$, $p = .486$, Kendall's W = 0.08), whereas in TVW it significantly increased across the three time-points ($X^2_2 = 19$, $p < .001$, Kendall's W = 1.05; afternoon – *before:* Durbin-Conover's $p < .001$; afternoon - *after*: Durbin-Conover's $p < .001$; *before* – *after*: Durbin-Conover's $p = .016$).

Average activity enjoyment did not differ between TWV and VGP (W = 69.5, $p = .959$, $r_{rb} = 0.02$, TVW = 3.59 ± 1.02, VGP = 3.57 ± 1.43).

3.2. Classical sleep architecture variables

Overall, the analysis yielded a between-condition difference in sleep efficiency. Specifically, sleep efficiency was comparable between BSA and VGP (Durbin-Conover's $p = .678$) but significantly lower in TVW compared with the other two conditions (Durbin-Conover's $p = .011$; Durbin-Conover's $p = .029$). No other significant between-conditions differences were found (Table 2).

3.3. Sleep continuity

No between-condition difference emerged for the total frequency of awakenings, frequency of brief awakenings, frequency of long awakenings, or awakenings mean duration (Table 3).

3.4. Sleep stability

No between-condition difference emerged for sleep stability measures (Table 4).

3.5. Sleep organization

No significant difference emerged for sleep organization measures (Table 5).

3.6. Cognitive performance

Participants showed better working memory performance at the N-back task (NBT) in both VGP (Durbin-Conover's $p = .003$) and TVW (Durbin-Conover's $p = .021$) compared to BSA, while it did not differ between VGP and TVW (Durbin-Conover's $p = .461$). Complete results are shown in Table 6.

3.7. Psychological health

The analysis on DASS-21 scores revealed that participants reported lower scores at the stress subscale in VGP relative to TVW (Durbin-Conover's $p = .050$) and BSA (Durbin-Conover's $p = .002$), whereas there was no difference between BSA and TVW (Durbin-Conover's $p = .165$). Though the difference failed to reach significance, scores at the global DASS-21 and at the anxiety and depression subscales were also lower in VGP compared to BSA and TVW (Table 7).

We observed no significant between-condition differences in STAI-S (W = 84, $p = .965$, TVW = 33.61 ± 8.79, VGP = 32.00 ± 10.50) and VAMS scores (W = 82, $p = .484$, TVW = 7.26 ± 1.28, VGP = 7.53 ± 1.99).

4. Discussion

In this study, we assessed the impact of playing a popular VG (i.e., "Call of Duty: Black Ops Cold War") on objective sleep quality, cognitive functions, and psychological health in a sample of healthy non-gamer adults. This VG was selected because of its popularity among young adults and due to some specific characteristics, such as being a

Table 2
Classical sleep measures in the three conditions.

	Descriptives		Statistics		
	Condition	m ± sd	X_2^2	*p*	Kendall's W
Bedtime (hh.mm)	BSA	00:12 ± 1.12			
	TVW	00:24 ± 00:46	0.37	0.831	0.02
	VGP	00:18 ± 00:30			
Risetime (hh.mm)	BSA	07:33 ± 00:46			
	TVW	08:10 ± 01:17	4.32	0.115	0.24
	VGP	08:09 ± 01:03			
Sleep Onset Latency (min)	BSA	7.61 ± 4.28	11.8	0.112	0.25
	TVW	8.50 ± 8.77			
	VGP	8.37 ± 6.75			
Time in Bed (h)	BSA	6.84 ± 1.53	0.87	0.646	0.05
	TVW	7.20 ± 2.14			
	VGP	6.99 ± 2.15			
Total Sleep Time (h)	BSA	7.54 ± 3.15	0.14	0.931	0.01
	TVW	7.35 ± 1.08			
	VGP	7.29 ± 1.20			
Actual Sleep Time (h)	BSA	6.25 ± 1.41	0.47	0.789	0.03
	TVW	6.86 ± 1.15			
	VGP	6.73 ± 1.21			
Stage 1 (%)	BSA	11.08 ± 7.36	1.71	0.424	0.09
	TVW	12.83 ± 7.41			
	VGP	10.31 ± 4.80			
Stage 2 (%)	BSA	46.56 ± 6.10	2.71	0.257	0.02
	TVW	48.48 ± 11.17			
	VGP	48.40 ± 5.84			
Stage 3 (%)	BSA	22.63 ± 8.91	4.00	0.135	0.22
	TVW	18.55 ± 9.10			
	VGP	20.44 ± 5.88			
REM (%)	BSA	19.73 ± 6.41	0.14	0.931	0.01
	TVW	20.13 ± 5.94			
	VGP	20.92 ± 4.60			
Wake After Sleep Onset (%)	BSA	5.97 ± 6.55	1.86	0.395	0.10
	TVW	6.83 ± 4.13			
	VGP	7.79 ± 5.63			
Sleep Efficiency (%)	BSA	91.70 ± 6.43	7.00	**.030**	0.39
	TVW	89.56 ± 4.71			
	VGP	90.60 ± 5.75			

Notes. Significant results are in bold. BSA: baseline assessment; TVW: TV-watching condition; VGP: video game playing condition.

Table 3
Sleep Continuity measures in the three conditions.

	Descriptives		Statistics		
	Condition	m ± sd	X_2^2	*p*	Kendall's W
Total Awakenings Frequency	BSA	2.87 ± 1.35	1.86	0.395	0.10
	TVW	3.51 ± 1.96			
	VGP	2.81 ± 1.62			
Brief Awakenings Frequency	BSA	2.36 ± 1.22	4.00	0.135	0.22
	TVW	2.90 ± 1.67			
	VGP	2.28 ± 1.43			
Long Awakenings Frequency	BSA	0.50 ± 0.54	0.25	0.880	0.01
	TVW	0.62 ± 0.45			
	VGP	0.52 ± 0.48			
Awakenings mean duration (min)	BSA	1.47 ± 1.10	0.14	0.931	0.01
	TVW	1.53 ± 0.67			
	VGP	1.97 ± 1.47			

Notes. BSA: baseline assessment; TVW: TV-watching condition; VGP: video game playing condition.

Table 4
Sleep Stability measures in the three conditions.

	Descriptives		Statistics		
	Condition	m ± sd	X_2^2	*p*	Kendall's W
Arousals Frequency	BSA	3.73 ± 1.49	5.29	0.071	0.29
	TVW	3.06 ± 1.21			
	VGP	3.11 ± 0.76			
State Transitions Frequency	BSA	14.93 ± 5.74	1.00	0.607	0.05
	TVW	15.38 ± 4.42			
	VGP	14.74 ± 5.53			
FU periods Frequency	BSA	0.55 ± 0.30	1.00	0.607	0.05
	TVW	0.45 ± 0.21			
	VGP	0.47 ± 0.27			
TFU (%)	BSA	3.83 ± 2.01	1.29	0.526	0.07
	TVW	3.47 ± 1.92			
	VGP	3.28 ± 1.86			
Fu periods mean duration (min)	BSA	4.17 ± 1.06	0.43	0.807	0.03
	TVW	4.26 ± 1.59			
	VGP	3.98 ± 1.37			

Notes. Significant results are in bold. BSA: baseline assessment; TVW: TV-watching condition; VGP: video game playing condition. Arousals Frequency is computed over Actual Sleep Time, whereas State Transition Frequency, Functional Uncertainty periods Frequency (FU periods Frequency), and Percentage of Total Time spent in Functional Uncertainty (TFU %) are computed over Total Sleep Time.

Table 5
Sleep Organization measures in the three conditions.

	Descriptives		Statistics		
	Condition	m ± sd	X_2^2	*p*	Kendall's W
Number of Cycles	BSA	5.89 ± 2.54	1.96	0.375	0.11
	TVW	7.12 ± 2.50			
	VGP	7.06 ± 3.66			
TCT (%)	BSA	72.64 ± 23.74	1.86	0.395	0.10
	TVW	77.41 ± 20.68			
	VGP	75.84 ± 21.45			
Cycles mean duration (min)	BSA	55.28 ± 15.14	1.43	0.931	0.08
	TVW	52.58 ± 19.00			
	VGP	54.37 ± 21.45			

Notes. BSA: baseline assessment; TVW: TV-watching condition; VGP: video game playing condition. TCT: Percentage of Total Time spent in Cycle (Total Cycle Time).

Table 6
Cognitive performance in the three conditions.

	Descriptives		Statistics		
	Condition	m ± sd	X^2_2	*p*	Kendall's W
RAVLT					
Total Immediate Recall	BSA	45.10 ± 8.10	5.65	0.059	0.31
	TVW	50.35 ± 7.60			
	VGP	48.36 ± 7.67			
Total Delayed Recall	BSA	9.39 ± 2.26	0.45	0.799	0.02
	TVW	9.22 ± 2.51			
	VGP	9.24 ± 1.99			
CBT-T					
SPAN	BSA	4.96 ± 0.78	4.23	0.121	0.23
	TVW	5.07 ± 1.09			
	VGP	5.57 ± 1.06			
PVT					
Number of Lapses	BSA	0.17 ± 0.38	1.00	0.607	0.05
	TVW	0.05 ± 0.23			
	VGP	0.28 ± 0.95			
Number of False Starts	BSA	2.33 ± 2.45	3.37	0.185	0.19
	TVW	2.33 ± 2.70			
	VGP	1.61 ± 1.88			
Average Time Reaction	BSA	0.35 ± 0.04	3.00	0.223	0.16
	TVW	0.35 ± 0.04			
	VGP	0.35 ± 0.04			
NBT					
Total Score	BSA	131.00 ± 11.84	8.78	**.012**	0.49
	TVW	137.78 ± 8.88			
	VGP	138.39 ± 10.38			
GNT					
Number of Corrected Responses	BSA	117.94 ± 2.58	5.25	0.072	0.29
	TVW	118.05 ± 2.96			
	VGP	118.39 ± 10.38			
Number of Lapses	BSA	0.55 ± 0.70	5.64	0.060	0.31
	TVW	0.66 ± 1.41			
	VGP	0.16 ± 0.51			
Number of Errors	BSA	1.50 ± 2.09	1.96	0.375	0.11
	TVW	1.28 ± 1.77			
	VGP	1.167 ± 1.65			
Average Reaction Time	BSA	0.34 ± 0.04	12.3	**.002**	0.68
	TVW	0.32 ± 0.04			
	VGP	0.33 ± 0.03			

Notes. TVW: TV-watching condition; VGP: video game playing condition; RAVLT: Rey Auditory Verbal Learning Test; CBT-T: Corsi Block-Tapping Test; PVT: Psychomotor Vigilance Task; NBT: N-back Task; GNT: Go/No-Go Task. Significant results are in bold.

Table 7
DASS-21 global score and DASS-21 subscores in the three conditions.

	Descriptives		Statistics		
	Condition	m ± sd	X^2_2	*p*	Kendall's W
DASS-21 Global Score	BSA	17.22 ± 11.82	4.11	0.128	0.23
	TVW	13.72 ± 8.97			
	VGP	10.33 ± 7.09			
DASS-21 Depression Subscore	BSA	4.44 ± 4.27	3.66	0.161	0.20
	TVW	3.94 ± 3.81			
	VGP	2.33 ± 2.09			
DASS-21 Anxiety Subscore	BSA	4.28 ± 4.75	3.80	0.149	0.21
	TVW	2.89 ± 3.58			
	VGP	2.33 ± 2.91			
DASS-21 Stress Subscore	BSA	8.50 ± 4.23	9.21	**.010**	0.51
	TVW	6.89 ± 4.40			
	VGP	5.67 ± 4.01			

Notes. TVW: TV-watching condition; VGP: video game playing condition; DASS-21 global score, depression, and anxiety subscores post-hoc analysis was not significant. Post-hoc analysis for stress subscore: VGP < BSA (Tukey's p = **.033**), VGP – TVW (Tukey's p = .173), TVW – BSA (Tukey's p = .212).
Significant results are in bold.

commercial VG (able to provide players with goal-driven environments, continuous learning, challenges, and conflicts), being played in first person (to promote engagement) and being an arousing game (due to its action and violence levels). Furthermore, in order to clearly observe the possible effects of the VG, we employed a sample of non-gamers: indeed, previous studies (e.g., Refs. [15–21]) suggest that the effects of VGs, especially on sleep, tend to be less pronounced, and therefore less noticeable, in habitual players. At the same time, studies on the role of sleep in memory consolidation processes suggest that the need to learn new information and strategies (such as those implied by a new VG) may yield positive effects on sleep and, consequently, on next-day cognitive functioning [17,18].

Our results show that even playing a violent-action commercial VG for an hour before bedtime for three consecutive days was not associated, in our non-gamers sample, with negative consequences on sleep, cognitive functions, and psychological health.

These data are consistent with the most recent reviews on the impact of VGs on psychological health [7,39–43], showing positive effects of VG playing on depression, anxiety, and stress. Although the analysis only yielded a significant decrease in the DASS-21 stress subscore, also anxiety and depression levels were lower after VGP compared to the baseline assessment (BSA) and the active control condition (TVW). Furthermore, our findings seem to confirm our previous hypothesis [15] that VGs might play a protective role against depression, anxiety, and stress. Indeed, as observed in our survey study [15], habitual gamers who reported higher levels of depression (but still out of the clinical range) might use VGs as a source of "coping strategy". This hypothesis is consistent with recent reports on VG use, according to which people use VGs as a means to obtain comfort and relaxation, elicit positive emotions, and stay connected with others, as well as a social timekeeper capable of drawing a line between work and free time [44]. Therefore, in line with the ever-growing employment of VGs in the treatment of psychological disorders (for reviews *see* Refs. [7,45–47]) our work further demonstrates the beneficial effects of VGs on psychological health. Considering the possible positive effects of VG on sleep [20], the beneficial effects of VG playing on psychological health, in our experiment, might also be explained in light of the role of sleep in emotional regulation processes. Indeed, several studies have shown the importance of sleep for next-day social and emotional functioning and the possible negative consequences of poor sleep quality for well-being [48,49]. In this sense, by enhancing sleep quality, VGs could also provide a side effect on emotion regulation.

Positive effects of VG playing were also found for cognitive functions. To our knowledge, this is the first study to objectively investigate the impact of pre-sleep VG playing on cognitive and executive functioning in adults. Our results reveal a positive effect of VG playing, especially on executive functioning, with participants reporting an increased visuospatial working memory performance. Furthermore, we found no significant difference for declarative verbal memory and sustained attention, in contrast with the negative effects on these cognitive functions reported after VG playing in children [50] and adolescents [12,13].

Considering the wide variety of skills required to play a commercial VG (e.g., controlling the first- or third-person view, monitoring the environment, orienting through the game area, memorizing commands, interacting with the game system, etc.), the relationship between VG use and cognitive abilities is not surprising. Indeed, as reported by a recent review [51], VGs could enhance cognitive functions by simulating the same processes that are activated in the real world. Furthermore, as shown by the wide literature on the relationships between sleep and cognitive processes [52,53], sleep could play an important role in enhancing VG-related cognitive abilities, by replaying the same neural circuits triggered during the game. In this regard, the use of VGs has proven more useful than conventional methods to enhance cognitive functions [54,55].

Of note, the absence of between-condition differences in sustained

attention, assessed through the Psychomotor Vigilance Task (PVT), can be considered further evidence of the non-detrimental effect of VGs on sleep. Indeed, PVT has been proven to be highly sensitive even to subtle sleep impairments [56,57].

In line with the latter evidence, in our study sleep duration and architecture did not differ between conditions, except for a reduced sleep efficiency after TVW compared to BSA and VGP. These results are in contrast with Wolfe et al.*'s* study [12], which reported lower total sleep time after nighttime VG playing in older adolescents (i.e., 15–20 years). However, in Wolfe et al.'s study, participants were forced to sleep no later than 1:00 a.m. and to wake up at 7:00 a.m. to recreate the "typical" adolescent's weeknight, a condition that could have biased the results. Moreover, our results are in contrast with the data reported by Higuchi et al. [48], showing a decrease in REM sleep (but no effects on slow wave sleep) after a single VG session.

Consistent with findings on sleep duration and architecture, sleep continuity, stability, and organization variables, which can provide a more sensitive index of sleep quality, also were not altered by the VG sessions, as shown by the absence of between conditions differences.

The latter findings are in agreement with our previous work investigating the impact of cognitive training on objective sleep quality during a nap and a night sleep episode [10,11]. Cognitive training consisted of an intensive playing session at the VG Ruzzle, which requires players to identify as many words as possible in the shortest possible time on a letter grid. As in the current study, Ruzzle playing sessions did not compromise sleep quality but even improved it: after a single VG session of 40 min before bedtime, sleep quality increased in terms of continuity, stability, and organization both compared to a baseline night (no pre-sleep manipulation) and to an active control condition.

To this regard, an important remark regards the fact that the amount of learning involved in playing a VG may be an important, underestimated, variable in determining its effects on sleep [8,20]. In fact, as suggested by literature from the sleep-memory field [16–18], the learning processes usually underlying VG playing (e.g., the necessity to learn commands, read the map, follow the story, develop new strategies to move forward a level, etc.) determine changes in subsequent sleep by promoting those sleep components (e.g., sleep spindles, SWS, sleep continuity, sleep stability, sleep cycles, etc.) that sustain sleep-related learning processes. Indeed, when comparing performance at the Ruzzle VG after a retention period spent asleep or awake, we previously showed that scores (especially those dependent on strategic skills) were enhanced after sleep compared to wake [49]. In this perspective, the arousing aspect of the VG used in the current study could have partly counteracted the learning-related benefits on sleep observed in our previous studies with a non-arousing VG [10,11]. Indeed, here, participants reported higher alertness levels after VGP compared to TVW and BSA. Similarly, other discrepancies between our current results and data from previous studies might also be explained in light of the learning factor. For instance, in the Higuchi et al. study [48], after a training phase, participants played a "passive" shooter VG, where commands were relatively simple, and very limited learning was required. A very interesting point concerns the role of the VG type on the effects on sleep quality. Literature has shown that the majority of VGs used by studies are action-commercial VGs, but also that different types of video games can produce different effects [20], especially in terms of arousal and sleep quality [9–11]. A crucial task of future research will be to investigate more thoroughly the possible mediating role of VG type on sleep quality by involving different kinds of VGs, such as escaping room, investigation, sandbox, etc. Indeed, by making players focus more on planning and reasoning than on action, these types of VGs might elicit different outcomes.

An additional remark should be made on the different effects of VG playing and TV series watching on sleep. Although in our experiment, TV series watching was used only as an active control condition, our data show higher sleep efficiency in VGP compared with TVW. This result may be viewed in light of the discussed positive effects of the VG playing-related learning processes. Indeed, a recent experimental study reported only minor effects on sleep after a binge-watching session of a suspenseful TV series [58]. Future studies may further explore this topic by directly comparing these two types of entertainment.

5. Conclusion

Here, we objectively showed that, if used under controlled conditions, i.e., for a limited time (1 h *per* night) and at regular times (between 9:00 p.m. and 00:30 a.m.), even a violent VG does not impair sleep quality. This is consistent with the work of King and colleagues [14], reporting lower sleep efficiency only after prolonged pre-sleep VG playing (150 min) but not after a shorter session (50 min), and with up-to-date survey studies investigating the effect of VGs on sleep quality [15,59,60]. Further, it is in line with recent reviews that correlated sleep issues only to high-volume VG playing [20,61]. Altogether, these findings highlight the importance of considering several modulating factors in interpreting the effects of VGs on health.

CRediT authorship contribution statement

Oreste De Rosa: Writing – review & editing, Writing – original draft, Visualization, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Paolo D'Onofrio:** Writing – review & editing, Supervision, Methodology, Data curation, Conceptualization. **Francesca Conte:** Writing – review & editing, Writing – original draft, Supervision. **Paola De Luca:** Investigation, Data curation. **Claudia Schiavone:** Investigation, Data curation. **Alessio Lustro:** Investigation, Data curation. **Serena Malloggi:** Writing – review & editing, Methodology, Investigation. **Fiorenza Giganti:** Writing – review & editing, Supervision, Project administration, Methodology. **Torbjörn Åkerstedt:** Writing – review & editing, Supervision, Methodology. **Gianluca Ficca:** Writing – review & editing, Supervision, Project administration, Methodology, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.sleep.2025.03.002.

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