Ironic processes of concentration and suppression under pressure: A study on rifle shooting in Norwegian elite biathletes

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Abstract
In rifle shooting, suppressing unwanted thoughts can backfire in one’s performance, causing athletes to behave contrary to their desired intention and further deteriorate their performance.

Purpose: This study examined how priming attentional and negative cues affected participants’ shooting performances toward ironic error targets under cognitive load conditions in Stroop task across two experiments.

Methods: Semi-elite biathletes (Experiment 1, n = 10; Experiment 2, n = 9) participated in the study. The study used a within-subject quasi-experimental design, particularly a one-way repeated measures multivariate analysis of variance and a 2 × 2 fully repeated measures analysis of variance, to determine the participants’ hit rates and shooting response times (RTs). In both experiments, the participants completed the reverse-Stroop-based target shooting performance under low- and high-cognitive load conditions while receiving frequent priming attentional and negative cues.

Results: The findings from Experiment 1 suggest that regulating repetitive priming attentional thoughts is efficacious in mitigating the likelihood of ironic performance errors and interference effects. The results of Experiment 2 show that repetitive priming negative cues resulted in negligible ironic error hit rates and slower RTs in target hits under high-cognitive load conditions. The Bayesian analyses provided evidence supporting the null hypotheses.

Conclusion: Trying to control repetitive priming attentional and negative thoughts reduces ironic performance errors to a similar degree under cognitive load conditions among biathletes, regardless of interference effects. Further research is needed to determine the effectiveness of suppressing task-relevant negative instructions in reducing the likelihood of ironic performance errors under pressure.

KEYWORDS
interference effect, ironic error, negative instruction, priming, rifle shooting, Stroop task
1 | INTRODUCTION

Unwanted intrusive thoughts permeate various facets of modern life, not only professional and private lives but also the realm of sports. People devote much of their “mental life” to wrestling with seemingly inconceivable paradoxical thoughts. Processing unwanted thoughts detrimentally affects individuals’ capacity to concentrate on and accomplish mundane tasks. Athletes may encounter significant consequences when they process unwanted thoughts, namely internal distractions in elevated-pressure settings. During the 2004 Olympic Games in Athens, Matthew Emmons blew a gold medal opportunity in the 50-meter three-position rifle shooting event when he momentarily lapsed in his target thoughts and shot at the wrong target. The management of unwanted thoughts by athletes during significant sporting events has received considerable scholarly attention owing to its detrimental effects, such as performance breakdowns and unwanted errors in the sport and performance psychology literature.

To often, attempting to repress and banish unwanted thoughts can ironically result in their subsequent resurgence, with greater intensity and force that render them challenging to disregard. Ironic Processes of Mental Control Theory (henceforth “Wegner’s Theory”; Wegner7–10) offers an explanatory framework for understanding what happens when individuals attempt to control unwanted thoughts under cognitive load conditions.

1.1 The duality of intentions and ironies

According to Wegner’s theory, the maintenance of the desired mental state (attentional control) involves the interplay of two hypothetical cognitive processes: an intentional operating process (henceforth “the operator”) and an ironic monitoring process (henceforth “the monitor”). The operator, which is effortful, interruptible, and conscious, directs attention away from unwanted thoughts to achieve the desired state. By contrast, the monitor, which is effortless, uninterruptible, and unconscious, inhibits the intrusion of unwanted thoughts into the conscious mind to detect and signal lapses in the intended control. The operator and monitor function together to ensure the exclusion of unwanted thoughts from awareness and produce the desired mental control.

When individuals make a conscious effort to suppress intentions (such as unwanted thoughts) while their attentional resources are taxed by cognitive loads, distractors, stressors, or other mental demands, the monitor not only becomes prominent but also redirects the unwanted thoughts to the operator rather than merely monitoring them. Consequently, the conscious mind becomes hypersensitive to the to-be-suppressed thoughts, leading individuals precisely to engage in a behavior contrary to their original intentions—counterintentional errors, which are commonly called ironic errors10 (for full details on the mechanisms of ironic processes, see8,11). The implications of ironic errors have been the subject of meta-analytic studies in several domains of psychology, including reviews conducted on clinical and non-clinical populations.12–14 Similarly, the potential consequences of ironic errors in sporting tasks were highlighted in the systematic review, which established a link between cognitive load-induced negative instructions and ironic errors.

1.2 “Don’t miss!” Motor performance ironies

The evidence from the systematic review offered critical insights into advancing the understanding regarding the phenomenon of ironic performance errors, encompassing the cognitive, verbal, and behavioral domains. A central aspect of the investigation of Wegner’s theory in sports is the concept of instruction, specifically negative or negatively self-generated instructions, given by the coaches or athletes themselves in the verbal domain. This is especially relevant during critical moments of performance, such as when making a final decisive shot or serve, where athletes may act contrary to their original intentions. An illustrative instance involves a tennis player who, during an important Grand Slam, tells himself: “Whatever you do, don’t make double fault” during his match point at 30–40, and then he does so, resulting in a defeat in the match (for more examples in the sports world, see11(p208)). More specifically, when instructed “Try not to shoot the right corner of the target,” elite pistol shooters precisely shot to the to-be-forbidden spot. This suggests that ironic performance errors arose from a lack of concordance between the athletes’ original intention to regulate the unwanted thoughts and their subsequent behaviors. Thus, the reason athletes make ironic performance errors when instructed not to do specific actions is not because of their physical, physiological, and technical limitations, but because they are unable to effectively regulate unwanted thoughts, particularly when their attentional resources are under cognitive strain. Investigating how athletes manage unwanted thoughts and reduce the occurrence of ironic errors during important sporting events is crucial, even though there is still limited understanding of the precise strategies they use to regulate such thoughts.
1.3 Interrupting ironic performance errors

Given the dynamic synergy between cognitive-motor processes, cognitive and sport psychologists have proposed a range of self-regulation strategies and implement interventions to optimize athletes’ performances by effectively managing their cognition when confronted with high pressure-provoking settings. Considering Wegner’s theory, approaches to interrupt the occurrence of ironic errors have been suggested in mainstream psychology. In the sports domain, Janelle offered recommendations based on an in-depth analysis of the literature in the field of sport psychology, whereas Bartura and colleagues suggested ways to reduce the prevalence of ironic performance errors. While Janelle’s and Bartura et al.’s propositions continue to hold relevance, research focus on applied sport psychology has shifted to investigating theory-matched strategies for reducing the likelihood of paradoxical performance breakdowns. Over the past two decades, however, challenges have arisen concerning the potential strategies to minimize the occurrence of ironic performance errors. The main obstacle is the dearth of empirical evidence available to assess the proposed intervention strategies. Developing effective intervention programs based on Wegner’s theory has added to the challenge.

While extensive research studies have examined the relationship between cognitive-induced negative instructions and the likelihood of ironic errors in sporting tasks, the question of how to mitigate the occurrence of ironic errors has received comparatively less research attention. The notion proposed by Wegner regarding mental control strategy merits consideration. Wegner postulated that decreasing the operator’s level of awareness, effort, susceptibility to interruptions, and inhibition may mitigate the occurrence of ironic errors. Such propositions have been substantiated by recent empirical findings, offering the initial theory-matched potential remedy to the ironic performance problem in a novel externally paced reactive motor task.

1.4 Limitations of previous research studies

The application of Wegner’s theory in the context of sport performance has encountered notable limitations. To begin, given the importance attributed to the use of negative instructions in investigating ironic motor processes, two notable drawbacks must be recognized and addressed. First, no clear method has been developed for using negative instruction, despite its pivotal role in triggering ironic processes. Proctor and Xiong expressed comparable criticism of Langfeld’s and Geissler’s thought suppression experimental studies conducted between 1910 and 1913, particularly on the methods of implementing negative instructions. Second, whether the priming negative instruction, such as “Do not stop the ball,” or the explicit negative instruction causes the increased likelihood of ironic performance errors remains ambiguous. Wegner and Smart introduced the notion of accessibility, also later referred to as priming by Sparrow and Wegner. The term priming describes “the influence a stimulus has on subsequent performance of the processing system.” Wegner et al. contended that once suppressed, unwanted thoughts often return, regardless of priming of the very thoughts repetitively. Hence, early thought suppression research studies by Wegner did not prioritize the frequent priming of unwanted thoughts. Research by Beilock et al. offers the initial evidence about the influence of regulating repetitive priming suppressive imagery on participants’ golf putting accuracy in relation to Wegner’s theory. Furthermore, concerns over the relevance of the methods used to manipulate cognitive load and measure ironic performance errors are at the center of studies that examined Wegner’s theory using the dual-task paradigm. Most importantly, although cognitive load in the form of concurrent cognitive tasks or time pressure tends to impair the operator more than the monitor, studies that manipulated time pressure as a cognitive load-inducing variable have not included it in their analyses. Consequently, it is plausible to doubt the efficacy of research studies on the ironic processes of motor actions given the absence of clear approaches to negative instructions and failure to take into account the manipulated cognitive load in the analyses.

2 THE PRESENT STUDY

To assess the applicability of laboratory-based dual-task manipulations for exploring Wegner’s theory in “real-world” contexts, the potential impact of cognitive load manipulation on the participants’ motor actions must be ascertained through concurrent cognitive tasks. One typical type of cognitive task used in dual-task paradigms is the Stroop color-word task. Despite receiving criticism, the Stroop task has been widely used as a neuropsychological assessment tool and a hallmark in attention
research, primarily owing to its versatility and “ecological validity” for assessing cognitive processes such as attentional control or inhibition alongside motor demands. Researchers have recently conducted reverse-Stroop experiments using a visuomotor task: the target shooting task. Despite the novelty of these studies, their investigations relied on novice participants, plastic handguns, short shooting ranges (i.e., approximately 2.5 m), and fixed presentations of congruent and incongruent stimuli, among others. Furthermore, Wood et al. found a correlation between elevated anxiety, specifically due to ego-threatening instructions, and decreased shot accuracy in incongruent trials. However, whether this could be attributed to the actual Stroop (interference) effect remains unclear.

The purpose of the present study was threefold. Firstly, Experiment 1 aimed to investigate the role of cognitive load-induced priming attentional thoughts, as the operator is more amenable to verbal instruction than the monitor. Therefore, if controlling repetitive priming attentional thoughts could influence motor actions in a manner consistent with the intended direction of control. Wegner’s theory could potentially account for the reduced ironic errors and interference effects under cognitive load conditions.

3 | EXPERIMENT 1

Experiment 1 employed Wegner’s proposition of implementing concentration strategies designed to enhance cognitive regulation. The concentration strategy encompasses a broader array of monitored thoughts less likely to cause more interference effects, consequently preventing the potential inefficiency of the operator’s function and minimizing ironic errors. This strategy facilitates the achievement of the desired outcomes.

In the reverse-Stroop target shooting task, the participants were instructed to pay attention to the target while ignoring the meaning of the distractor (i.e., the written colored word). The instructions were further primed repetitively by task-relevant attentional cues (e.g., “Ignore blue”). Experiment 1 was designed to determine whether the operator could reduce effort by focusing on repetitive priming attentional thoughts, as the operator is more amenable to verbal instruction than the monitor. Therefore, if controlling repetitive priming attentional cues results in reducing errors and interferences under cognitive load conditions, mental control of attentional thoughts could influence motor actions in a manner consistent with the intended direction of control. Wegner’s theory could potentially account for the reduced ironic errors and interference effects under cognitive load conditions.

4 | METHODS

4.1 | Participants

The participants were 10 semi-elite biathletes (five females) with a mean age of 16.90 (±0.88) years. They were members of various Norwegian biathlon clubs at the Norwegian Elite Sports High School (NTG, Geilo). The mean lengths of their training and competition experiences were 7.10 (±2.48) years and 6.30 (±2.83) years, respectively. All participants were right-handed and had normal eyesight. Additional sample demographic information is presented in Table S1.

4.2 | Measures and materials

4.2.1 | Anxiety

Cognitive anxiety, somatic anxiety, and self-confidence were measured immediately before each trial block using the mental readiness form (MRF-3) to assess the effectiveness of the cognitive load manipulation. The MRF-3 assesses anxiety on three bipolar 11-point Likert scales anchored between not worried—worried, not tense—tense, and not confident—confident. The MRF-3 is one of the most widely used subjective tools in the investigations of the pressure-attention relationship.
in far-aiming motor task performance. The participants’ physiological arousal in response to the cognitive load manipulation across trial blocks was measured by recording heart rate (HR) and heart rate variability (HRV) using the polar H10 transmitter (Polar Electro Oy, Professorintie, FI-90440, Kempele, Finland). The participants’ baseline HR and HRV were measured. Furthermore, HRV has been widely used in sports and exercise psychology research studies that use cognitive tasks such as the Stroop task.

4.2.2 | Workload

The participants’ workload demands on the Stroop target shooting task were assessed using the multidimensional NASA task load index (NASA-TLX), which has been used to assess perceived workload demands in cognitive, visual search, and Stroop tasks.

4.2.3 | Manipulation checks

Pre- and post-manipulation checks were conducted throughout the experiments to ensure that the participants comprehended the instructions correctly and to assess the effectiveness of the instruction manipulation, respectively. The post-manipulation survey included the clarity of task instructions, task difficulty, and participants’ adherence to the instructions. Using a four-point Likert scale, the participants rated their level of agreement with the statements, ranging from strongly disagree (1) to strongly agree (4).

4.2.4 | Color blind test

The 24-plate Ishihara edition was used to screen for red-green color vision deficiency, including 15 prompts. The original plates were produced using Microsoft PowerPoint (PPT; Microsoft 365 Apps for Enterprise) on Microsoft Windows 11. The participants had to correctly answer 10 plates to participate in the experiments.

4.2.5 | Stimuli

Each stimulus consisted of a 24-cm-diameter central black circle with a word (henceforth “distractor”) written (Arial font size 40) in green, red, blue, or yellow. With each stimulus, a projected slide featured four colors (henceforth “targets”), one in each of the four corners (see Figure 1). The reverse-Stroop stimuli were prepared by adopting the design by Wood and colleagues, with the following changes: (1) The centralized distractor was written in Norwegian, the native language of the participants. (2) Each colored target consisted of two concentric circles: an outer colored target (30-cm in diameter) and an inner white target (12-cm in diameter). (3) After every fifth target shooting, an extra blank slide was introduced to replace the magazine, and (4) The proportion between the congruent and incongruent stimuli was 50:50.

**FIGURE 1** Incongruent stimulus showing conceptualization of target, ironic error, and non-ironic non-target error.
4.2.6 | Presentation of the stimuli

Unlike Wood and colleagues, 30 who used fixed placement, we used a counterbalancing strategy for the presentation of stimuli, including targets and distractors. The congruent and incongruent stimuli were randomized across trial blocks based on the randomization sheet generated using Microsoft Excel. Details of the presentation are found in the experimental procedure video (see Video S1).

4.2.7 | Performance measures

The target, ironic error target, and non-ironic error target were defined according to Woodman and colleagues. 28 Figure 1 shows the conceptualization of the target and ironic and non-ironic error targets. Consequently, ironic error in the reverse-Stroop shooting task was defined as hitting the target compatible with the distracting word. A target hit occurs when the participant hits the target incompatible with the distractor or if the hit lands on the center of the target (i.e., the white zone within the target). A non-ironic error** is defined as hitting any target other than the intended target. This could involve missing the target, not shooting at all, or missing a bullet from the magazine. Shooting RT was also used as a measure of performance, with a slower shooting RT indicating greater interference when shooting at the intended target.

The numbers of shots that hit the target, ironic errors, and non-ironic errors were recorded for each trial block. A video camera with a high acquisition frequency (fps) was used to determine whether a bullet successfully hit the target and RTs for each shot. Two observers independently reviewed the video recordings. The intraclass coefficient (ICC) results showed excellent reliability of 0.91 (95% confidence interval [CI], 0.90–0.93).

4.3 | Apparatus

The Camtasia software (version 21.0.19 [Build 35860] 1999–2022 TechSmith Corporation) was used to analyze the recorded video footage of the participants' shooting performances and RTs frame by frame.

The Polar Equine Android app (version 1.2.1 using a secured Samsung Galaxy S10 with Android version 12) was used to export the participants’ cardiac data to the HRV analysis software (Kubios HRV Standard version 3.5.0). The participants’ HR and HRV data were transferred to the institution’s encrypted email (Microsoft Outlook version 2109), with their unique identification numbers†† clearly indicated.

4.4 | Experimental procedures

Data were collected quantitatively using attention-demanding reverse-Stroop-based target shooting performance during week 48, from November 28 to December 2, 2022. Ethical approval was initially obtained from the Norwegian School of Sport Sciences (NIH; reference No. 148-270820) and the Norwegian Center for Research Data (NSD; reference No. 236743). The experiments were piloted on two (male and female) adult biathletes from a local sports team to assess the feasibility of the experimental protocol before data collection. The NTG, Geilo, arranged specific appointment times for the participants to participate in the experiments based on their study and training schedules.

During a preliminary session, all participants were informed regarding the experiments and that they would be using their own rifles to complete the task at the school’s indoor shooting range facility. Upon arrival at the experiment site, the second experimenter provided the participants with detailed information about the experiment and directed them to follow a specified sequence of tasks before the experiment, including reading the consent form carefully, thereby providing written informed consent and demographic data. The participants were then instructed to wear the Polar chest strap with the H10 transmitter attached to measure their baseline HR and HRV for 5 min while sitting. Lastly, the participants completed the color blindness test.

The participants were told to collect their equipment and were granted access to the indoor shooting range. Each participant attended a single 45- to 60-min indoor target shooting experimental session. Upon entering the indoor shooting range, the participants received a comprehensive briefing about the experiment. A standardized script with textual and graphical directives presented the instructions using a secure Apple iPad 11 Pro (iOS 15, 2020, Apple Inc.). Initially, the participants received the instructions and subsequently engaged in 12 familiarization shots (see Data S1). The familiarization block acquainted the participants with the scoring criteria and the process of swapping magazines.

††During the process of acquiring informed consent, we generated a pseudo-identification number (ID) by the summation of the participants’ birthdate and the last two digits of their mobile number. As such, the experimenters distinguished the participants based on their distinct IDs rather than their names.

**Based on the categorization of ironic and non-ironic errors. 24, 28
Subsequently, each participant completed 20 shots under a low-cognitive load condition and 20 shots under a high-cognitive load condition.

### 4.5 Instructional manipulation

The low-cognitive load condition included explicit task-relevant instructions that involved attentional instructions and a scoring system for hitting the target, and ironic and non-ironic error targets. The participants were given attentional cues and instructed to shoot a target while ignoring the meaning of a distractor in the incongruent stimulus. The instructions specifically directed the participants to concentrate on identifying a color that matched between the distractor and the target and to shoot as quickly and accurately as possible. Furthermore, the instructions were summarized and presented using pictorial illustrations. The participants were reminded to carefully follow the priming attentional cues (e.g., “Ignore blue”) on the canvas before the presentation of each incongruent stimulus. In the congruent stimuli, the participants were instructed to shoot while attending only the target compatible with the distractor. Priming cues (e.g., “Attend blue”) were displayed before every third congruent stimulus presentation.

Furthermore, the participants were informed of the scoring criteria: 10 and 5 points for hits on the white and colored zones of the target, respectively. Hits on ironic error targets received 0 points, while hits on non-ironic error targets were penalized with a 5-point deduction. The high cognitive load condition was accompanied by instructions analogous to those used in the low-cognitive load condition. The instructions specifically directed the participants to concentrate on identifying a color that matched between the distractor and the target and to shoot as quickly and accurately as possible. Furthermore, the instructions were summarized and presented using pictorial illustrations. The participants were reminded to carefully follow the priming attentional cues (e.g., “Ignore blue”) on the canvas before the presentation of each incongruent stimulus. In the congruent stimuli, the participants were instructed to shoot while attending only the target compatible with the distractor. Priming cues (e.g., “Attend blue”) were displayed before every third congruent stimulus presentation.

The instructional methods used in this research were based on thought suppression experiments. Priming and thought accessibility paradigms within the dual-process system also formed the basis of instructional manipulation. A comprehension checklist was administered before commencing the target shooting task in each condition to ensure that the participants adhered to the given instructions. If the participant provided an incorrect response, the instructional script and graphical illustrations were reiterated until the participant comprehended the task instructions.

The MRF-3 was administered after the participants received the first instruction in each condition. The HR and HRV recordings were restarted before the commencement of each experimental condition. Upon the completion of each trial block, the participants were promptly given the NASA-TLX questionnaire. A 5-min break was allocated for them to respond to the NASA-TLX items and load the magazine for the next trial block. The experimental session was concluded by administering a post-manipulation check, followed by a debriefing, and thanking the participants (see Table S2 and the experimental procedure Video S1).

### 4.6 Data reduction

The HR and HRV measures were obtained independently for each condition. For our analysis, HR and HRV data were calculated from 5000 milliseconds before the presentation of the first stimulus to 7000 milliseconds after the presentation of the final stimulus. We adhered to the task force’s HRV analysis procedure.

### 4.7 Data analysis

Data management and analyses were performed using IBM SPSS 28 (Chicago, IL, USA). A normality test was conducted to assess the distribution of the data and identify any outliers. No outliers were detected in the experimental data. However, missing data for one participant’s subjective workload in the high cognitive load was addressed by computing the mean values of the independent subscales within the condition. Consequently, the normal data distribution was verified before the analyses. All measurements were described as groups. Descriptive summary data are presented as the mean and standard deviation for each variable.

Two dependent variables were used: shooting performance, which included three distinct performance levels (target, ironic error target, and non-ironic error target), and shooting RTs. For shooting performance, the hit rate (mean percentage of hits $M_{hit} = \sum hit\_scores / \sum hit\_scores\_target$) and the mean shooting RTs $M_{RTs} = \sum RTs\_target\_hit / n$ of congruent and incongruent stimuli under each cognitive load condition divided by the $n$ of incongruent stimuli under each cognitive load condition multiplied by 100. To calculate the mean shooting RTs $M_{RTs}$ for the target hits, we initially measured the temporal differences between the presentation of each stimulus and the marking hits on the canvas using the Camtasia software (see the Apparatus section). Overall, $M_{RTs} = \sum RTs\_target\_hit / n$ of congruent and incongruent stimuli under each cognitive load condition.

We conducted a one-way repeated measures multivariate analysis of variance (RM MANOVA) to assess the effects of cognitive load on target, ironic error, and non-ironic error hits. To examine the RTs toward the target
hits, we conducted a 2 x 2 repeated-measures analysis of variance (RM ANOVA) with two dependent factors: condition (low and high cognitive loads) and cognitive task (incongruent and congruent).

To address the issue of low statistical power in our study resulting from a suboptimal sample size, a Bayesian analysis was conducted in JASP statistics. The Bayesian approach, as an alternative to frequentist methods, is a useful tool for drawing probabilistic inferences, especially when dealing with small sample sizes in elite sports research. The primary focus of the Bayes factor (BF) test is to quantify the robustness of the evidence supporting or refuting the presence of an effect. This is achieved by comparing the predictions of two competing statistical models, such as the null hypothesis and the alternative hypothesis. In particular, the BF01 measures the predictive accuracy of the ratio between the probabilities of the null and the alternative hypotheses.

Furthermore, a one-way MANOVA was performed to determine the influence of participants’ perceived exertion (workload) on their target shooting performance. Our analysis focused on the three most significant subscales of the NASA-TLX index: mental demand, temporal demand, and effort. The Cohen’s $d$ effect size was computed for each statistically significant value. The significance level was set at $\alpha = 0.05$. Experimental designs and analyses were not preregistered.

5 | RESULTS

5.1 | Subjective and psychophysiological manipulations of cognitive load

Table 1 presents the descriptive statistics for subjective and objective measures of cognitive load. No significant differences in objective and subjective measures, except for cognitive anxiety, were found across cognitive load conditions. The increased root mean square of the successive difference between normal heartbeats (r-MSSD) was detected only under high cognitive load. The results indicated partial success in manipulating cognitive load.

<table>
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<tr>
<th>Measure</th>
<th>Condition (M ± SD)</th>
<th>High cognitive load</th>
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<tr>
<td></td>
<td>Low cognitive load</td>
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<tr>
<td>Cognitive anxiety</td>
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<td>0.01*</td>
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<td>Somatic anxiety</td>
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<td>7.90 ± 2.02</td>
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<td>Heart rate (beats/min)</td>
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<td>82.07 ± 11.50</td>
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<td>r-MSSD (ms)</td>
<td>51.53 ± 22.92</td>
<td>52.40 ± 22.64</td>
<td>0.80</td>
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</tbody>
</table>

*p < 0.05.

5.2 | Shooting performance (hit rate)

Figure 2A shows the mean target and ironic and non-ironic error hits across cognitive load conditions. The one-way multivariate effect was nonsignificant for condition [$F (3,16) = 1.05, p = 0.39, \eta^2_p = 0.17$]. Univariate analyses revealed a nonsignificant effect on target hits [$F (1,18) = 0.21, p = 0.65, \eta^2_p = 0.01$], ironic error hits [$F (1,18) = 2.25, p = 0.15, \eta^2_p = 0.11$], and non-ironic error hits [$F (1,18) = 0.34, p = 0.57, \eta^2_p = 0.02$] under low and high cognitive load conditions. The number of ironic error hits was absent under low cognitive load and negligible (only two shots) under high cognitive load conditions when given repetitive priming attentional cues.

5.2.1 | Shooting RTs

Figure 2B shows the mean shooting RTs for target hits at congruent and incongruent stimuli under low and high cognitive load conditions. The RM ANOVA performed on these data showed a nonsignificant main effect for cognitive tasks [$F (1,9) = 0.80, p = 0.39, \eta^2_p = 0.08$], condition [$F (1,9) = 0.01, p = 0.92, \eta^2_p = 0.01$], and cognitive task x condition [$F (1,9) = 0.72, p = 0.42, \eta^2_p = 0.07$]. The participants’ attention to task-relevant cues did not make them take longer to hit targets in the high-cognitive load condition than in the low-cognitive load condition. The paired samples $t$-test results revealed that the participants responded slower to congruent stimuli (1491.80 ± 226.48 milliseconds) than to incongruent stimuli (1471.90 ± 163.24 milliseconds) under a high-cognitive load condition [$t (9) = 0.42, p = 0.68$]. The
results of the shooting performance and RTs are summarized in Table 2.

5.2.2 | Bayesian

We used a noninformative Cauchy prior $r = 0.707$ to assess a non-directional null hypothesis. The Bayes Factor ($BF_{01}$) values for target hit rates and RTs toward target hits were $2.477 \pm 0.008\%$ and $3.210 \pm 0.005$, respectively. These values indicate that the BF is about 2.477 times (for target hit rates) and 3.210 times (for RTs toward target hits) in favor of the null hypothesis.

A BF robustness check reveals that the BF remains consistent, with target hit rates ranging from about $1.001 \pm 5e-04$ to $4.273 \pm 5e-04$ and RTs toward target hits ranging from about $1.001 \pm 5e-04$ to $5.802 \pm 5e-04$, which still falls within the range of the null hypothesis, even though the width of the specified prior is varied. Based on Cohen’s $\delta$ rule-of-thumb, the Cohen’s $\delta$ values for the target hit rates and RTs toward target hits were $0.25$ (a small-to-medium effect) with 95% credible interval $[-0.35, 0.78]$ and $-0.05$ (negligible effect) with 95% credible interval $[-0.59, 0.51]$, respectively. This suggests that participants’ suppression of priming attentional cues leads to good target hit performance and faster shooting responses toward the intended targets under low- and high-cognitive load conditions.

5.2.3 | Workload

The one-way multivariate effect was nonsignificant for condition [$F_{(4,15)} = 0.19, p = 0.94, \eta^2_p = 0.05$]. The univariate test results indicated a nonsignificant effect for mental demand [$F_{(1,18)} = 0.39, p = 0.54, \eta^2_p = 0.02$], temporal demand [$F_{(1,18)} = 0.09, p = 0.77, \eta^2_p = 0.01$], and effort [$F_{(1,18)} = 0.00, p = 0.99, \eta^2_p = 0.00$] across cognitive load conditions (Figure 3).
5.2.4 | Social evaluation survey

The descriptive statistics on the post-manipulation check revealed that the participants not only reported that the given instructions were unambiguous (80% strongly agree and 20% agree) but also demonstrated diligent adherence to the instructions (90% strongly agree and 10% agree). Furthermore, the participants indicated that the task was not tedious (100% strongly agree) and was challenging (60% agree), although some (40%) strongly disagreed.

6 | DISCUSSION

Experiment 1 examined how cognitive load-induced priming attentional cues influenced the likelihood of ironic errors and interference effects of reverse-Stroop target shooting motor task performance. The observed nonsignificant pattern for target and ironic error hits aligns with the proposed hypothesis. The participants exhibited a minimal hit rate (2%) toward the ironic error targets. When intentional concentration was applied to relevant thoughts, the targets became more activated than the ironic and non-ironic error targets under high cognitive load. As such, the motor actions were guided in line with the intended direction of control. Consistent with Wegner’s theory, the observed consistent trend in the number of hits toward the non-ironic targets (4%) indicates that the participants did not demonstrate a uniform decline in non-ironic shooting performance under low and high cognitive load conditions when given repetitive priming attentional cues.

The absence of interference in Experiment 1, as indicated by the nonsignificant main and interaction effects of the condition and cognitive task in RTs toward target hits, suggests that task-relevant repetitive priming attentional cues moderated the reduction of interference effects across the cognitive load conditions. The priming of attentional cues (i.e., ignoring the distractor) consistently compelled the participants to regulate relevant thoughts, which led to fast responses to relevant targets. Consequently, this might have reduced the likelihood of ironic shooting errors.

7 | EXPERIMENT 2

Existing literature on the ironic processes of cognitive control over motor actions suggests that skilled athletes may encounter a decline in performance when they direct their attention toward negative or negatively self-generated instructions while executing complex motor skills (see Bartura et al. for a review). Conversely, there is conflicting evidence about how exactly negative instructions affect performance. For example, elite pistol shooters and highly skilled dancers showed contradictory motor actions and movements when instructed not to perform specific actions. However, experienced volleyball players did not exhibit this phenomenon. There is still uncertainty regarding the influence of athletes’ level of expertise on their propensity to ironic behavior in response to negative instructions. According to Wegner’s theory, the monitor surfaces to undermine mental control while focusing on unwanted thoughts when the stakes are high, yielding an increase in the likelihood of ironic errors and greater interference effects in Stroop tasks. Whereas Experiment 1 revealed that the participants achieved the desired outcome by attempting to control repetitive priming attentional cues while subjected to cognitive load conditions, Experiment 2 explored alternative explanations using priming negative cues equivalent to the paradigm used in Experiment 1. If suppressing repetitive priming negative cues activates the monitoring process under high cognitive load, intentions of the motor actions would be contrary to the desired control, which results in slower RTs and causing more ironic errors to the intended targets.

8 | METHODS

8.1 | Participants

This experiment included 11 semi-elite biathletes from NTG, Geilo, who did not participate in Experiment 1. However, the data from two participants (one male and one
female) could not be analyzed because of technical problems. Consequently, the sample consisted of nine participants (five females) with a mean age of 16.89 (±0.93) years and mean lengths of training and competition experiences of 8.33 (±2.00) years and 7.22 (±2.05) years, respectively. All participants (two left-handed) exhibited normal eyesight. Further demographic information is provided in Table S1.

8.2 | Materials and measures

The materials and measures were consistent with those used in Experiment 1.

8.3 | Experimental procedure

The procedure was identical to that of Experiment 1, except that the participants received negative instructions.

8.4 | Instructional manipulation

Each participant was instructed to pay particular attention to trying not to shoot the target that matched the meaning of the color of the written word (distractor) in the incongruent stimuli. They were reminded to carefully follow the priming negative cues (e.g., “Don’t shoot blue”) that appeared on the canvas before the presentation of each incongruent stimulus. No instructions were linked to congruent stimuli. A new randomization sheet was generated using Excel to randomize congruent and incongruent stimuli. Furthermore, the stimuli, presentation of stimuli, cognitive load manipulation, delineation of the target, ironic error target, non-ironic error target, and scoring system were analogous to Experiment 1.

8.5 | Data reduction and analyses

The mean measure ICC result revealed that the two observers reached excellent agreement with a value of 0.91 (95% CI, 0.89–0.93). The data reduction for HR, HRV, and shooting RTs, as well as the statistical analyses, were performed using the same methodology as described in Experiment 1.

9 | RESULTS

9.1 | Subjective and psychophysiological manipulations of cognitive load

Paired-samples t tests were performed to analyze psychophysiological data (Table 3). The subjective variables supported our hypothesis, except for self-confidence. However, the objective variables were statistically nonsignificant. The results of both measurements showed that the manipulation of cognitive load was effective to some degree.

9.2 | Shooting performance (hit rate)

Figure 4A shows the mean target, ironic error, and non-ironic error hits across cognitive load conditions. The one-way RM multivariate effect was nonsignificant for condition [F(3,14)=0.15, p = 0.93, η²p = 0.03]. The univariate analyses revealed a nonsignificant effect for target and ironic error hits [F (1,16)=0.00, p = 1.00, η²p = 0.01], and non-ironic error hits [F (1,16)=0.09, p = 0.77, η²p = 0.01] under low- and high-cognitive load conditions.

9.2.1 | Shooting RTs

Figure 4B shows the mean RTs for the target hits at congruent and incongruent stimuli across cognitive load conditions. The RM ANOVA performed on these data revealed a significant main effect for cognitive task [F (1,8)=6.44, p = 0.04, η²p = 0.45], a nonsignificant main effect for condition [F (1,8)=0.05, p = 0.83, η²p = 0.01], and a nonsignificant interaction effect for cognitive task and condition [F (1,8)=2.86, p = 0.13, η²p = 0.26]. The observed

<table>
<thead>
<tr>
<th>Measure</th>
<th>Condition (M ± SD)</th>
<th>t (9)</th>
<th>d</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Low cognitive load</td>
<td>High cognitive load</td>
<td></td>
</tr>
<tr>
<td>Cognitive anxiety</td>
<td>4.44 ± 1.81</td>
<td>6.00 ± 2.83</td>
<td>0.02*</td>
</tr>
<tr>
<td>Somatic anxiety</td>
<td>6.11 ± 2.15</td>
<td>7.11 ± 2.57</td>
<td>0.07</td>
</tr>
<tr>
<td>Self-confidence</td>
<td>6.22 ± 1.86</td>
<td>6.78 ± 1.78</td>
<td>0.46</td>
</tr>
<tr>
<td>Heart rate (beats/min)</td>
<td>86.77 ± 9.24</td>
<td>87.20 ± 7.55</td>
<td>0.80</td>
</tr>
<tr>
<td>r-MSSD (ms)</td>
<td>40.48 ± 11.01</td>
<td>39.46 ± 10.37</td>
<td>0.71</td>
</tr>
</tbody>
</table>

*p < 0.05.
main effect for cognitive task indicates that the participants demonstrated a significant delay in target hits at incongruent stimuli, as opposed to congruent stimuli, across cognitive load conditions when given repetitive priming negative cues. A summary of the shooting performance and RTs results is provided in Table 4.

### 9.2.2 | Bayesian

We observed a $BF_{01}$ of $3.109 \pm 0.004$% for target hit rates and $1.894 \pm 0.001$% for RTs toward target hit, indicating that the Bayes Factor is about 3.109 and 1.894 times in favor of the null hypotheses, respectively. A Bayes Factor Robustness check reveals that the BF remains consistent, with target hit rates ranging from about $1.001 \pm 5e \cdot 04$ to $5.587 \pm 5e \cdot 04$ and RTs toward target hits ranging from about $1 \pm 5e \cdot 04$ to $3.094 \pm 5e \cdot 04$, which still falls within the range of the null hypothesis, even though the width of the specified prior is varied. The Cohen’s $\delta$ of 0.21 with 95% credible interval $[-0.58, 0.58]$ for the target hit rates and Cohen’s $\delta$ of $-0.37$ with 95% credible interval $[-0.92, 0.29]$ for the RTs indicates a small-to-medium effects, implying that participants’ suppression of priming negative cues result in good target hit performance and slower responses toward the intended targets under high cognitive load compared to low-cognitive load conditions.

### 9.2.3 | Workload

The one-way RM multivariate analysis revealed a non-significant effect for condition [$F_{(3,14)} = 0.46$, $p = 0.71$, $\eta^2 = 0.09$]. The univariate test results indicated a non-significant effect for mental demand [$F_{(1,10)} = 0.18$, $p = 0.68$, $\eta^2 = 0.01$], temporal demand [$F_{(1,10)} = 0.27$, $p = 0.61$, $\eta^2 = 0.02$], and effort [$F_{(1,10)} = 0.02$, $p = 0.90$, $\eta^2 = 0.00$] across cognitive load conditions (Figure 5).
9.2.4 | Social evaluation survey

The descriptive statistics on the post-manipulation check revealed that the participants not only responded that the given instructions were unambiguous (100% strongly agree) but also demonstrated diligent adherence to the instructions (100 strongly agree). Furthermore, seven participants indicated that the task was not tedious (77.8% strongly agree), and five participants perceived the task as overly challenging (55.5%), although three (33.3%) disagreed and one (11.1%) strongly disagreed.

10 | DISCUSSION

Experiment 2 examined the impact of cognitive load-induced priming negative cues on the likelihood of ironic errors and interference effects in reverse-Stroop target shooting motor task performance. The results showed that the participants’ hit rate toward ironic errors (2.2%) was comparable with that in Experiment 1 (2%). However, the intention to control repetitive priming negative cues yielded an interference effect. This means that the participants’ response toward the intended targets was slower at incongruent stimuli than at congruent stimuli across cognitive load conditions. This effect, however, was clouded by the nonsignificant interaction effect for condition and cognitive task.

The observed results for RTs partially supported the interference effect assumption but did not validate our hypothesis of the likelihood of ironic errors, suggesting that motor actions were not in line with the direction opposite the intended control when given repetitive priming negative cues under cognitive load conditions. The results of Experiment 2 provide further evidence that the participants’ non-ironic error hit rates did not change across cognitive load conditions when given priming negative cues, which is consistent with Wegner’s theory. The findings of both experiments have implications for the understanding of the mechanisms underlying the effects of priming attentional and negative cues on ironic processing and Stroop interference under cognitive load conditions in elite participants. Hence, the findings of both experiments can be explained by considering Wegner’s theory, the impact of repeated priming cues, and the participants’ level of expertise.

11 | GENERAL DISCUSSION

The findings of the experiments provide insights into the interplay of mental-motor processes involved in the dual-task manipulation of target shooting performance under cognitive load conditions among elite biathletes. Motor control is achievable in the direction of thought control when given task-relevant instructions under cognitive load conditions. Experiment 1 results show that attempts to exert control over the given repetitive priming attentional cues resulted in faster RTs toward target hits when subjected to a high-cognitive load condition.

By contrast, controlling repetitive priming negative cues resulted in slower RTs toward target hits at incongruent stimuli than at congruent stimuli across cognitive load conditions in Experiment 2. This supports Wegner’s theory. Comparatively, the participants in Experiment 1 demonstrated a swifter response (1472 milliseconds) to the target hits at the incongruent stimuli than the participants in Experiment 2 (1517 milliseconds) under the high-cognitive load condition. Moreover, the participants in Experiment 2 demonstrated a twofold increase in non-ironic error target hit rates under high cognitive load compared to those in Experiment 1 (8% versus 4%), although these effects were not statistically significant. Collectively, the results suggest that mental control of reverse-Stroop target shooting performance does not produce the likelihood of ironic errors, regardless of the interference effects, when the mind is preoccupied with task-relevant priming attentional and negative cues.

11.1 | Insights on ironic processes and interference effects

The findings of Experiment 1 provide the first empirical evidence of the beneficial impact of priming attentional cues on reducing the likelihood of ironic errors and interference effects in a reverse-Stroop target shooting performance under cognitive load conditions. These results
mirror the findings of the second experiment by Wegner et al.\textsuperscript{41} on mood and mood-related thoughts, supporting Wegner’s theory.\textsuperscript{8} Furthermore, the results of Experiment 1 partially corroborate the findings of Gorgulu et al.,\textsuperscript{24} indicating that the participants’ ironic performance errors were reduced when “positive action-based” instructions such as “Let the ironic color balls go” were given under high- and low-anxiety conditions.

A plausible reason is that the implementation of attentional cues, which encompass positive attributes, enables the operator to prevail in searching for the intended targets efficiently, reducing the likelihood of ironic shooting errors and interference effects. Elsewhere, a study showed that repetitive positive priming reduced the likelihood of errors and contributed to a faster reaction to stimuli.\textsuperscript{65} Conversely, it is unlikely that the monitor was in attendance or capable of effectively monitoring the unwanted targets prompted by attentional cues under conditions of cognitive load, thus resulting in minimal influence on the conscious mind.\textsuperscript{8,42}

In Experiment 2, the participants’ ironic error hit rates were insignificant when given negative cues (e.g., “Do not shoot blue”) under cognitive load conditions, challenging Wegner’s hypothesis of ironic processes in the sample of elite biathletes. This contradicts previous research studies in sports domains that reported ironic errors occur when suppressing negative thoughts under high-cognitive load conditions. Although the interference effect results support Wegner’s theory,\textsuperscript{8} the findings from Experiment 2 should be interpreted with caution.

11.1.1 | Insights on the repetition of priming thoughts

In Experiment 1, intentionally suppressing priming attentional cues before every incongruent stimulus might have enhanced the accessibility of the intended targets compared with the ironic and non-ironic error targets. Consequently, the participants demonstrated effective shooting performance and faster RTs when shooting at the intended targets under cognitive load conditions. The dual-process theory, upon which Wegner’s theory was founded, suggests that the frequency of priming plays a significant role in determining the accessibility and usability of a construct.\textsuperscript{1,66} Moreover, Higgins et al.\textsuperscript{53} reported that “the more frequently a construct is primed, the more likely its action potential will remain sufficiently high to give it an advantage in subsequent processing.”

The duration of the priming cues before the shooting action cannot be ruled out as a factor contributing to the reduced likelihood of ironic errors in both experiments. When exposed visually to priming attentional and negative cues for an extended duration of 2000 milliseconds, its activation level would already be significantly elevated. As such, the implementation of repetitive priming cues such as “Do not shoot blue” or “Ignore blue” would be sufficient to uphold the cognitive process of selective attentional focus. This would effectively shift the focus from negative information to positive information,\textsuperscript{57} even when participants’ cognitive resources are taxed with ecologically valid stressors.

One potential reason for the decrease in ironic errors observed in both experiments may be the delivery of instructional material. Research on cognitive load has shown that incorporating diagrams or cues into instructional materials can enhance and accelerate the cognitive assimilation and processing of the given information.\textsuperscript{88}

11.1.2 | Insights on expertise

The participants’ cognitive processing efficacy, even when confronted with multiple demands, may be attributed to the observed decrease in ironic error hit rates in Experiment 2.\textsuperscript{8,69} Furthermore, elite performers usually demonstrate refined cognitive and motor processing efficiency,\textsuperscript{70} including the ability to inhibit task-irrelevant information,\textsuperscript{71,72} maintain selective functional activation of task-relevant cues such as visual search patterns,\textsuperscript{73–76} and attain a higher degree of automaticity.\textsuperscript{77} As such, they are less susceptible to distractions owing to their increased attentional resources to manage high situational demands and secondary task loading than novices.\textsuperscript{11,78}

Athletes frequently use a range of self-regulatory strategies to effectively manage their cognitive processes when striving for peak performance in high-pressure settings.\textsuperscript{79,80} The thought suppression strategy, including the focused self-distraction strategy,\textsuperscript{32,81} is commonly used by athletes and strongly endorsed by coaches.\textsuperscript{82} It entails consciously blocking out unwanted thoughts, effectively redirecting the cognitive focus away from these distractions, particularly in heightened stress and pressure conditions.\textsuperscript{83} Liu et al.\textsuperscript{84} revealed that the act of suppression resulted in increased priming and diminished conscious presence of unwanted thoughts among a cohort of elite athletes who had reported experiencing personalized choking thoughts.

11.1.3 | Insights on cognitive load manipulations

The reported significant effect of cognitive anxiety in Experiment 1 does not inherently imply that the participants are worried and have negative thoughts. Instead, it
signifies their recognition of the significance and challenging nature of the Stroop task at hand, prompting them to actively mobilize their cognitive resources to effectively manage the situation.\textsuperscript{85}

The integration of the NASA-TLX tool was another pivotal element in our study for uncovering additional cognitive workload factors, including the allocation of attention (mental effort\textsuperscript{‡‡}), which may not necessarily be represented by the shooting performance and cognitive load measurements.\textsuperscript{86} According to NASA-TLX, workload is “the cost incurred by a human operator to achieve a particular level of performance.”\textsuperscript{48(p140)} Mental effort has traditionally been characterized as a direct measure of attention allocation to the task.\textsuperscript{87} Besides, individuals with limited cognitive capacity are likely to compensate for increased pressure by exerting greater mental effort\textsuperscript{88} to maintain their performance at a constant level.\textsuperscript{86} Despite the nonsignificant effects, the NASA-TLX results show that the participants in both experiments perceived that the Stroop target shooting task was more mentally demanding yet effortless under high-cognitive load conditions. The participants in Experiment 2 differed from those in Experiment 1 in that they reported the task was time-demanding under high-cognitive load conditions compared to low-cognitive load conditions. The findings on mental de-

visual focus of attention is unclear.\textsuperscript{71} Furthermore, several empirical studies have concluded that elite shooters have a longer aiming time, commonly called the quiet eye, than novices.\textsuperscript{74,91–93} Thus, whether the observed interference effect in Experiment 2 was the actual Stroop effect or just the result of the participants’ visual focus of attention is unclear.

In Experiment 2, it is uncertain whether the participants used a focused self-distraction strategy,\textsuperscript{82} intention-
ally diverting their attention away from irrelevant targets, including ironic and non-ironic error targets. During the experimentation, before each shooting attempt, the participants were observed consistently using a breathing technique that they had acquired from the initial stages of their professional path.\textsuperscript{94} Therefore, not monitoring the participants’ benefits of self-devised or learned thought control techniques or other cognitive skills to manage the cognitive load might have potentially confounded our results.

11.2 | Methodological limitations and future research considerations

The absence of counterbalancing the cognitive load conditions in our study may be regarded as a limitation because it attenuated the potential impact of ordering the cognitive load manipulations on the participants’ shooting performance. The lack of counterbalancing could potentially facilitate learning effects.\textsuperscript{89} However, the findings of the two experiments showed no variations in mean hit rates toward target, ironic error, and non-ironic error targets under high-cognitive load compared to low-cognitive load conditions. Furthermore, the Stroop stimuli were randomized, with the distractor and target(s) counterbalanced under each cognitive load condition. Consequently, this invalidates the notion of any learning effects being present.

While attempting to maintain the task’s “ecological validity”, the number of incongruent stimuli per condition (n = 10) might not sufficiently evaluate the ironic and interference effects in comparison to the conventional Stroop task, which entails the administration of numerous incongruent stimuli over a prolonged duration. Moreover, despite including cognitive load and cognitive task as within-subject factors in both experiments, the statistical power is inadequate to effectively highlight the diminished ironic errors due to the small sample size. A sensitivity power analysis using G*Power\textsuperscript{90} suggests that we needed a total of 54 participants to detect $f = 0.25$ (small-to-medium effect size; referring to Gorgulu et al.’s study\textsuperscript{24}) with $\alpha = 0.05$ and $\beta = 0.2$ in a one-way MANOVA repeated measures, within factor design. Given the inherent challenges in sample size in elite sport research,\textsuperscript{59} we confronted a mismatch between the required sample size and the feasible number of biathletes available at NTG, Geilo for our study. Future studies should collect data from various biathlon clubs, thereby increasing the overall sample size, to enhance the empirical support for or against Wegner’s theory and facilitate the drawing of meaningful inferences. Furthermore, several empirical studies have concluded that elite shooters have a longer aiming time, commonly called the quiet eye, than novices.\textsuperscript{74,91–93} Thus, whether the observed interference effect in Experiment 2 was the actual Stroop effect or just the result of the participants’ visual focus of attention is unclear.

11.2 | Future research possibilities

The nature of the Stroop task in Experiment 2 was manipulated in an effort to assess whether the participants perceived the task as high or low cognitive load, and whether their performance was affected by the task’s manipulation. The findings indicate that the participants perceived the task as more mentally demanding under high-cognitive load conditions, yet effortless under low-cognitive load conditions. The post-manipulation social evaluation survey revealed that the participants’ diligent adherence to the given instructions indicates the effectiveness of instructional manipulations. According to the participants’ reports, they did not experience feelings of boredom while completing the task, despite most of them perceived the task as challenging. Lastly, the participants reported notable enthusiasm and active engagement in the task. The effectiveness of instructional manipulation in altering cognitive load relies on individuals’ motivation and genuine commitment to exert mental effort.

\textsuperscript{‡‡}”The cognitive capacity that is actually allocated to accommodate the demand imposed by the task.”\textsuperscript{86(p4)}
Potential bias was inherent in our attempt to explain the findings from a cognitive process standpoint, as it lacks a foundation in objective metrics. Although our explanations for the observed findings were confined to Wegner’s theory, other theoretical accounts with the potential to elucidate the Stroop (interference) effects may have been overlooked.

11.3 | Practical implications

Our research yielded two practical implications. First, to optimize the executive function of elite and professional athletes, it is crucial to engage them in highly cognitively demanding tasks and multitasking performance. Cognitive tasks accompanied by task-specific cues and motor actions that require executing the response against distracting stimuli, such as the Stroop task, may provide greater benefits, like a significant enhancement in their cognitive-motor responsiveness and capacity for inhibitory control of unwanted thoughts.

Second, our research suggests that coaches and sport psychology practitioners can promote a concentration strategy to eliminate unwanted thoughts during important competitions for their elite athletes. Recommending thought suppression as a mental control strategy to elite athletes appears appealing based on the finding of Experiment 2, however our sample size did not provide sufficient statistical power to support this claim. Nevertheless, it is important for coaches, sport psychologists, and mental performance consultants to know what effects thought suppression strategies have on individuals who are neurotic, possess high-achieving mindsets, and perceive themselves as perfectionist athletes. These individuals may be susceptible to experiencing unwanted intrusive thoughts and heightened levels of anxiety. Thus, it is vital to protect these groups of athletes from factors that can have harmful effects on their mental health and well-being, such as distressing thoughts. Researchers and coaches should consider using task-relevant priming cues that can facilitate athletes’ focus on processing relevant information rather than irrelevant information.

12 | CONCLUSION

The present study provides initial evidence that attempting to control repetitive priming attentional cues effectively reduces the occurrence of ironic performance errors under cognitive load conditions. Thought suppression may be regarded as an effective mental control strategy for mitigating the likelihood of ironic errors in elite athletes. However, this conclusion necessitates further research investigation that employs a more rigorous scrutiny on several aspects, including the theoretical and methodological approaches to thought suppression within the context of Wegner’s theory as it relates to sports.

13 | PERSPECTIVES

On occasion, one of the most extreme mishaps that could often takes place: When an athlete, in an ironic twist, precisely hits the unwanted target not just once, but twice during high-performance settings when processing self-generated unwanted thoughts. Elite athletes performing in high-pressure settings often experience unwanted intrusive thoughts. Efforts to intentionally control and suppress unwanted thoughts under high-pressure conditions can paradoxically lead to the occurrence of counter intentional errors, which can have a significant impact on athletes’ overall performance, increasing the risk of ‘chocking’ and emotional distress. These adverse consequences may potentially harm the psychological well-being of the athletes. The significance of priming strategies to control attentional and negative thoughts to interrupt ironic errors has been overlooked until now, particularly in elite athletes. The findings from our study indicate for the first time that intentional control of task-relevant priming attentional and suppressive thoughts can mitigate the incidence of ironic performance errors under high-cognitive load conditions. Moreover, the study offers relevant and practical insights for high-performing athletes, skilled professionals like medical personnel, flight crew members, drivers, and others who encounter a significant amount of sensory-motor information in intense pressure conditions, which make them susceptible to ironic errors while their occupation demands them to make instantaneous decisions and react to various stimuli.

AUTHOR CONTRIBUTION


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**CONFLICT OF INTEREST STATEMENT**
The authors disclosed no conflict of interest in the authorship and unanimously approved the final manuscript for submission and publication.

**DATA AVAILABILITY STATEMENT**
The complete set of raw data, and research materials of the present study are available upon request for at least the next 5 years.

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**SUPPORTING INFORMATION**

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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