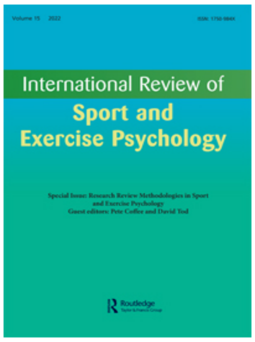


International Review of Sport and Exercise Psychology

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/rirs20

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**To cite this article:** Khelifa Bartura, Recep Gorgulu, Frank Abrahamsen & Henrik Gustafsson (11 Apr 2023): A systematic review of ironic effects of motor task performance under pressure: The past 25 years, International Review of Sport and Exercise Psychology, DOI: 10.1080/1750984X.2023.2193966

**To link to this article:** https://doi.org/10.1080/1750984X.2023.2193966

INTERNATIONAL REVIEW OF SPORT AND EXERCISE PSYCHOLOGY
https://doi.org/10.1080/1750984X.2023.2193966

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# A systematic review of ironic effects of motor task performance under pressure: The past 25 years

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**ABSTRACT**

Wegner's theory of ironic processes of mental control emphasizes how the implementation of cognitive load-induced avoidant instructions can cause inefficient motor cognition in sports, thereby inducing so-called ironic effects where an individual—ironically—does precisely what s(he) intended not to do. This systematic review synthesizes relevant existing research and evaluates the effectiveness of experimental manipulations and cognitive load measurements for investigating ironic effects on motor task performance under pressure conditions. This review identified twenty-four empirical studies published before January 2022, including studies with experimental (21%) and quasi-experimental (79%) within- and between-subject designs. The most common reported pressure (i.e., cognitive load) manipulations fell into two categories: anxiety (77%) and dual-task (33%) techniques. The review also identified positive action-oriented instructional interventions to reduce ironic errors. Although most reported findings supported Wegner's assumptions about ironic performance effects, the review also identified inconclusive evidence (8%), which indicates a need for more research with a greater focus on: robust experimental design; the inclusion of competitive stressors; expert athletes; elite athletes; and intervention-based studies. These additions will clarify the mechanisms of ironic effects and assist in the development of interventional programs to diminish the likelihood of ironic effects in sports performance.

**ARTICLE HISTORY**
Received 21 July 2022
Accepted 16 March 2023

**KEYWORDS**
Avoidant instruction; cognitive load; ironic effects; ironic processes; mental control; pressure performance

## Introduction

In 2021, Novak Djokovic, the winner of 20 Grand Slams, prepared to play the US Open Final against second-seed Daniil Medvedev. Djokovic was keen to become the first player since Rod Laver in 1969 to win all four majors in the same calendar year. Djokovic also knew that he would be ranked as one of the greatest tennis players of all time if he

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Supplemental data for this article can be accessed online at https://doi.org/10.1080/1750984X.2023.2193966.

won this match (Walker-Roberts, 2021). Djokovic arrived at the court under overwhelming pressure. He played fraily and apprehensively—in the first two sets—struggling to fight back both physically and emotionally. Despite his efforts, he lost the Grand Slam (Berman, 2021). After the match, Djokovic admitted that he could not cope with the pressure and expectations and acknowledged that he made many unforced errors (a total of 38), the category of errors he had most wanted to avoid.

In his theory of ironic processes of mental control (hereafter, Wegner's theory), Wegner (1994, 1997a, 2009) explains that Djokovic's wish to prevent such unwanted errors often, ironically, produces unintended effects—also known as *ironic effects*, later called *ironic errors* (Wegner, 1994; Wegner et al., 1998). According to Wegner, the more the attempt is to reduce pressure or avoid negative and intrusive thoughts while under high-pressure settings, the greater the likelihood of ironic effects. This incidence is viewed as the core assumption of Wegner's theory. Maintaining a desirable mental state (attentional control) involves the coexistence of two cognitive processes: the intentional operating process (hereafter, 'the operator') and an ironic monitoring process (hereafter, 'the monitor').

## Dual-process system

The operator is characterized as conscious, effortful, slow, responsive to verbal instruction, and interruptible by competing resources such as perceived pressure, intrusive thoughts, anxiety, cognitive load, distractions, and others. It is responsible for maintaining the desired goal-related outcomes. As a result, it requires considerable cognitive resources. In contrast, the monitor is nonconscious, effortless, quick, unresponsive to verbal instruction, and uninterruptible by competing resources (Frankish, 2010; Wegner, 1994). Consequently, it does not depend on the availability of cognitive resources. It does, however, control the competing resources that lead to the operator's failure, such as goal-irrelevant outcomes (Wegner, 1994). Depending on the operator's and monitor's activities, mental control can either be strengthened, resulting in the desired goal-related outcomes, or undermined, thus increasing the likelihood of ironic effects (Wegner, 1994).

## Mental control mechanism

Usually, mental control is successful when sufficient cognitive resources are available to achieve goal-related outcomes. However, the efficiency of cognitive resources is significantly depleted in some way, namely by competing resources. Consequently, the operator's capacity to simultaneously counter unwanted thoughts and search for desired thoughts is restricted. Meanwhile, the monitor becomes more salient, making the operator particularly susceptible to the contents of unwanted thoughts. Is it not paradoxical that the monitor, which essentially keeps the undesirable thoughts at bay, brings those very thoughts into consciousness? As a result, the operator's hypersensitivity to unwanted thoughts not only weakens the mental control, but also increases the likelihood that the to-be-avoided thoughts will emerge—a phenomenon known as *ironic effect* (Wegner, 1994; for details of an explanation on the mental control mechanism, we refer to Janelle, 1999; Wegner, 1994). Therefore, the effective interplay of the operator and monitor, as well as the availability of cognitive resources, are the two most important differentiating variables between the intentional mental control and the likelihood of ironic effects (Wegner, 1994).

Another crucial component of Wegner's theory is the use of avoidant instructions, which include directives like 'try not to think of the white bear' (Wegner et al., 1987). The likelihood of ironic effects when given avoidant instructions have been researched in various disciplines of psychology, most notably using Wegner et al. (1987) 'white bear' thought suppression paradigm (for the meta-analysis, see Wang et al., 2020). Avoidant instructions have real-world applications in coaching and athletic performance, as related to Wegner's theory. Continuing with the preceding example of Djokovic, who intentionally focused specifically on his self-statement, 'don't screw this up by hitting the second serve into the net,' and then did just that—over and again, committing many unwanted errors.

Furthermore, when coaches express negative behaviors with negative remarks, frustration, or distress during high-performance events, athletes feel more tension and worry, draining their cognitive resources (Williams et al., 2003). This makes athletes more prone to engage in unwanted thoughts, including talking negatively to themselves (cf. Hardy et al., 2009; Zourbanos et al., 2006, 2007), resulting in a significant increase in errors (Moll & Davies, 2021). Attempts by sportsmen like Djokovic to avoid these unwanted thoughts and feelings during high-stakes competitions often backfire, making the operator less effective, the monitor more prominent while simultaneously reminding the athletes of the very thoughts and feelings they are trying to avoid. That is why Djokovic made multiple unforced errors, which he had intended to avoid and why Wegner calls them ironic errors (1994). Wegner argues that athletes' ironic errors in response to avoidant instructions may be the result of control attempts while cognitively taxed and subsequently under-resourced, rather than poor motor skills (1994).

Wegner and colleagues (1998) conducted the first investigation on the links between mental control and performance when given avoidant instructions under pressure conditions. Since then, Wegner's theory has become a subject of research in the field of sports psychology, albeit slowly. One potential reason for the slow adoption of Wegner's theory is the existence of some professional reservations about its significance to the field due to the difficulties inherent in testing the theory empirically, especially in elite athletes (Hall et al., 1999; Janelle, 1999). Another issue is whether the theory provides insightful information to coaches, researchers, and sport psychologists (Hall et al., 1999). Concurrently, concern has been expressed about the lack of a comprehensive investigation into the precise nature of performance breakdown, which highlights the pressure and performance relationship (Janelle, 2002). In the absence of scientific literature that systematically evaluates and summarizes the current knowledge of Wegner's theory in the sports domain, these questions still remain.

Empirical studies on the ironic effects of motor performance have not been evaluated systematically, apart from one Japanese paper (Tanaka & Karakida, 2019). Indeed, systematic reviews are widely recognized as the most effective tool in sports psychology for critically assessing the quality of evidence, gaining an understanding of current knowledge, and providing practical recommendations for real-world applications (Ely et al., 2021; Tod, 2019). Given the growing research interest in Wegner's theory and its applications in coaching and sport psychology, a systematic review of the existing evidence on the ironic effects of motor performance is both timely and important.

Therefore, this paper aimed to review the quality of published primary research studies that examine the ironic effects of motor task performance when given avoidant instructions under conditions of pressure, such as cognitive load. The review specifically sought to answer the following research questions: (1) What kinds of samples, motor tasks, manipulation techniques, and measurements are used to test ironic errors[1]? (2) How effective are manipulation techniques and measurements? (3) What are the included studies' methodological quality? While seeking to address the research questions, this systematic review helps athletes and coaches become aware of the incidence of ironic errors, and sport psychologists and researchers advance Wegner's theory in sports performance, and beyond. Furthermore, it also highlights research gaps and future directions and offers athletes and professionals evidence-based recommendations to reduce the incidence of ironic errors.

## Method

The review adhered to, but was not limited to, the following guidelines: (1) the PRISMA 2020 statement, an updated guideline for reporting systematic reviews (Page et al., 2021); and (2) guidance on conducting and reporting systemic reviews (Campbell et al., 2020; Popay et al., 2006; Siddaway et al., 2019). The review includes supplementary files (labeled as Table S1, Table S2, etc.) for methodological specifics (Gunnell et al., 2020) and a systematic mapping (Haddaway et al., 2016). The review was registered prospectively in PROSPERO with the registration number CRD42021266655.

### *Literature search strategy*

An electronic literature search was undertaken across 10 databases: APA PsycInfo, CINAHL, Embase, ERIC, MEDLINE, PsycArticles, PubMed, SPORTDiscus with Full-Text, Web of Science (Core Collection), and Google Scholar. We ran the comprehensive search twice. The first search was conducted in July 2021. In each distinct database, the search was conducted by using the following Boolean search string: [('ironic process*' OR 'mental control') AND ('ironic effect*' OR 'ironic error*' OR 'avoidant* instructi*' OR 'motor* task*' OR 'pressure* perform*')]. An updated search, using the same search string, was conducted in January 2022. The first author carried out all searches, and critical discussions were conducted between the first and second authors throughout the search process. The titles and abstracts retrieved from the databases were imported into Rayyan QCRI web-based program (Ouzzani et al., 2016; see Table S1 for a complete search strategy).

### *Selection criteria*

Before screening the literature search, the first author formulated the preliminary eligibility criteria. After critical appraisal and feedback from the second author, the criteria were revised. This review looked at studies that (a) included novice, trained, highly trained, and elite participants; (b) attempted to induce cognitive load when giving avoidant instructions experimentally and quasi-experimentally in motor task performance[2]; (c) compared how ironic performance changed between low-cognitive load and high-cognitive load conditions, or between baseline (neutral) and experimental conditions; and (d) reported primary outcomes; and (e) were peer-reviewed and published in English between 1998 (the first available empirical data in sports performance) and January 1, 2022 (see Table S2 for additional details of eligibility criteria).

### Screening procedure

The retrieved articles were screened in three stages: In the first stage, the first and second authors thoroughly and independently compared all titles and abstracts against the eligibility criteria. At this stage, we resolved minimal doubts in determining whether to retain or exclude one 'borderline case', which was included in the full-text review to ensure improved specificity (Siddaway et al., 2019). We then obtained the full-text manuscripts of all relevant articles addressing the experimental manipulations of cognitive load when given avoidant instructions in sports performance. In the second stage, the first author conducted a hand-search accompanied by website and online resources (Stansfield et al., 2016) to find relevant articles that might have been omitted from the database search. We used here two consecutive methods to refine the results of hand-searching: first, we searched reference lists of all relevant studies that had been identified; second, we performed the so-called citation tracking from the identified studies using Google Scholar, and we tracked all 'related' or 'similar' articles until no more relevant articles were identified. The results of each of the two methods were then assessed for eligibility against the inclusion criteria and full-text review. In the third stage, the same authors independently reviewed the remaining full-text studies for eligibility. Disagreements were discussed and resolved by reaching consensus (for further details on the screening procedure, see Table S2).

### Data extraction

Data extraction was developed after retrieving all full-text studies. The extracted data from full-text studies was then systematized. The first author performed the initial data extraction, and the second author double-checked it for correctness, clarity, and completeness. The following data were extracted from the included studies: reference, study design, motor task, sample characteristics, setting, experimental manipulation procedures, outcome measures, cognitive load measurements, and main outcomes.

### Synthesis approach

Following the completion of data extraction, pivotal tables were constructed to summarize the characteristics of the included studies and prepare the main findings for synthesis (see Tables 2, 3, 4 and S4). According to McKenzie et al. (2019), we grouped studies into two categories based on the techniques that their authors employed to manipulate cognitive load: anxiety-based and dual-task-based. To describe the direction of the manipulation effects reported, we used the statistical approach—combining the reported levels of $p$ values for the outcome measures from each trial of the reviewed studies. This choice was made because almost all experimental trials in the reviewed studies investigated a similar question: whether cognitive load when given avoidant instructions induced the likelihood of ironic errors. Although many studies attempted to address the same question, they were considerably diverse in the samples, motor tasks, study designs, manipulation techniques, outcome measures, and outcome reporting. Consequently, we decided to synthesize the reviewed studies using a narrative synthesis approach (Popay et al., 2006) without meta-analysis (Campbell et al., 2020) given its potential to address the review questions (Thomas et al., 2012) and 'summarize and describe the findings from the included studies using verbatim' (Popay et al., 2006, p. 5). Furthermore, the narrative approaches to synthesis have been used in quantitative systematic review studies, including experimental and quasi-experimental studies when a meta-analysis is unfeasible (Snilstveit et al., 2012). The efficacy of the categorized manipulation techniques was then assessed to examine whether the techniques applied were appropriate for the objective in question, as well as to inspect any potential factors that influenced the results across the reviewed studies (Popay et al., 2006). We then critically reflected on the evidence's methodological and conceptual flaws. Finally, all authors virtually met to discuss the synthesis's strengths and limitations. An overview of the review process is presented in Figure 1.

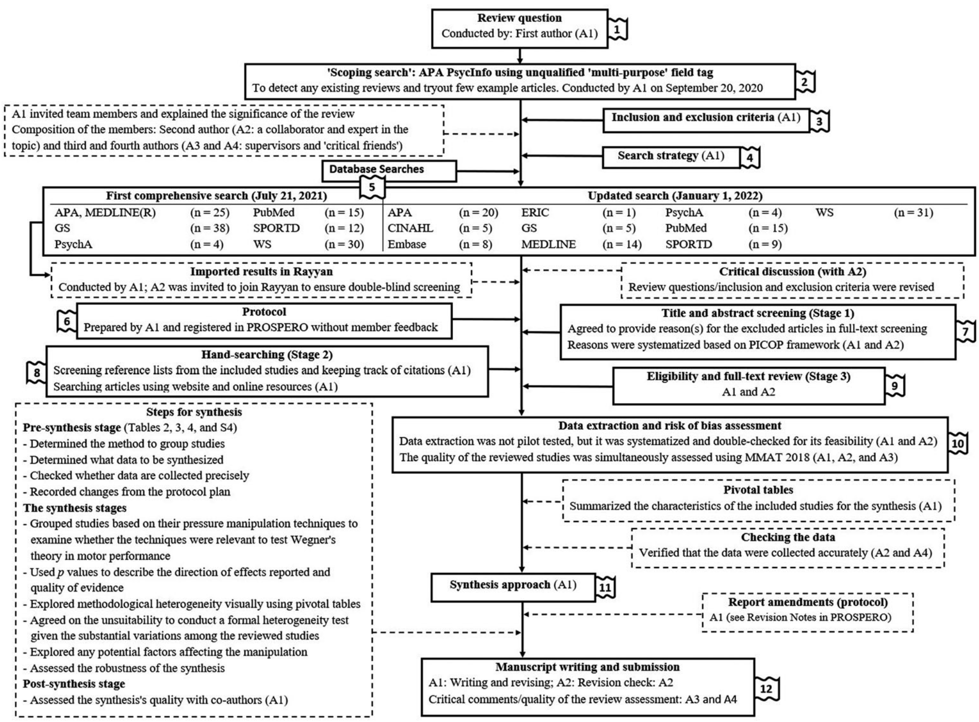



**Figure 1.** The systematic mapping review process flow diagram.

### *Quality assessment*

The quality of the reviewed studies was assessed using the Mixed Methods Appraisal Tool, version 18 (MMAT 2018; Hong et al., 2018). The MMAT provides detailed information about the quality of the reviewed studies, and it has been used previously for systematic reviews in sports and exercise psychology (Gayman et al., 2017; Gledhill et al., 2018; Goddard et al., 2021; Gröpel & Mesagno, 2019). The MMAT 2018 includes 25 methodological criteria for the following study designs: (1) qualitative, (2) quantitative—randomized controlled studies (RCT), (3) quantitative—non-randomized controlled studies, (4) quantitative—descriptive studies, and (5) mixed-methods studies. Using the MMAT 2018 guidelines, the reviewed studies were categorized as experimental and quasi-experimental. The rating of each methodological criterion was based on a nominal scale (*yes*, *no*, *can't tell*). The first author appraised the reviewed studies, while the second and third authors assessed all the included studies independently. Disagreements were resolved through critical discussion between the three authors, or arbitration with the fourth author if needed. Table 1 summarizes the MMAT quality assessment (for details, see Table S3).

## Results

The results of the screening procedure are shown in Figure 2. The comprehensive search yielded 17 articles covering 24 separate studies that met the inclusion criteria. During the screening stage, 19 articles were excluded for failing to meet manipulation and publication eligibility criteria. In the eligibility stage, an additional 13 studies were excluded (for additional details on why these articles were excluded, see Table S2). A summary of all sample and study characteristics, and manipulations procedures are presented in Table 2.

### *Sample characteristics*

There were 1152 participants across the 17 studies. Of the overall participants, 701 (61%) were male, and 420 (36%) were female. K = 1 excluded 31 (3%) participants for not meeting their inclusion criteria (Liu et al., 2015). The mean age of the participants across all studies was 21.78 ± 3.07, although this descriptive analysis excluded two studies by Wegner et al. (1998), which did not report participant ages. K = 1 reported participants younger than 18 (Gorgulu & Gokcek, 2021). In terms of gender, k = 7 (29%) included only male participants, k = 2 (8%) included only female participants (Dugdale & Eklund, 2003; Gorgulu & Gokcek, 2021), and the remaining k = 15 (63%) included participants of mixed genders. For participants' skill levels, k = 12 (50%) included novices (n = 683), k = 3 (13%) included trained participants with limited skills to perform the motor tasks (n = 155; Barlow et al., 2016, Study 1; de la Peña et al., 2008, Study 1; Woodman et al., 2015, Study 1), k = 8 (33%) included highly trained participants with proficient skills competing at national level (n = 226), and k = 1 (4%) included elite athletes with highly proficient skills competing at international level (n = 57; Gorgulu, 2019a). In addition, k = 2 included neurotic participants (Barlow et al., 2016, Studies 1–2; Table S7 provides further details of sample characteristics).

### *Study characteristics*

#### *Types of motor tasks*

Thirteen motor tasks[3] were represented across the reviewed studies. K = 16 used perceptual-motor tasks (football penalty shooting [k = 4], golf-putting [k = 3], dart throwing [k = 3], hockey penalty shooting [k = 1], air-pistol shooting [k = 1], baseball pitching [k = 1],

**Table 1.** Summary of study quality assessment using mixed methods appraisal tool[1].

| | | Methodological quality criteria[2] | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Reference(s) | Category of study designs | SI | SII | 1 | 2 | 3 | 4 | 5 |
| Bakker et al. (2006, Study 2) | Quantitative (nonrandomized) | Yes | Yes | Can't tell | Yes | Yes | No | Yes |
| Barlow et al. (2016, Study 1) | Quantitative (nonrandomized) | Yes | Yes | Can't tell | Yes | Yes | Can't tell | Yes |
| Barlow et al. (2016, Study 2) | Quantitative (nonrandomized) | Yes | Yes | Can't tell | Yes | Yes | Can't tell | Yes |
| Binsch et al. (2010a) | Quantitative (nonrandomized) | Yes | Yes | Can't tell | Yes | Yes | Can't tell | Yes |
| Binsch et al. (2010b) | Quantitative (nonrandomized) | Yes | Yes | Can't tell | Yes | Yes | Can't tell | Yes |
| de la Peña et al. (2008, Study 1) | Quantitative (randomized) | Yes | Yes | Can't tell | Yes | Yes | No | Yes |
| Dugdale and Eklund (2003) | Quantitative (nonrandomized) | Yes | Yes | Can't tell | Yes | Yes | Can't tell | Can't tell |
| Gorgulu (2019a) | Quantitative (nonrandomized) | Yes | Yes | Can't tell | Yes | Yes | Can't tell | Yes |
| Gorgulu (2019b) | Quantitative (nonrandomized) | Yes | Yes | Can't tell | Yes | Yes | Can't tell | Yes |
| Gorgulu (2019c) | Quantitative (nonrandomized) | Yes | Yes | Yes | Yes | Yes | Can't tell | Yes |
| Gorgulu et al. (2019, Study 1) | Quantitative (nonrandomized) | Yes | Yes | Can't tell | Yes | Yes | Can't tell | Yes |
| Gorgulu et al. (2019, Study 2) | Quantitative (nonrandomized) | Yes | Yes | Can't tell | Yes | Yes | Can't tell | Yes |
| Gorgulu et al. (2019, Study 3) | Quantitative (nonrandomized) | Yes | Yes | Can't tell | Yes | Yes | Can't tell | Yes |
| Gorgulu et al. (2019, Study 4) | Quantitative (nonrandomized) | Yes | Yes | Can't tell | Yes | Yes | Can't tell | Yes |
| Gorgulu et al. (2019, study 5) | Quantitative (nonrandomized) | Yes | Yes | Can't tell | Yes | Yes | Can't tell | Yes |
| Gorgulu and Gokcek (2021) | Quantitative (nonrandomized) | Yes | Yes | Can't tell | Yes | Yes | No | Yes |
| Gray et al. (2017) | Quantitative (randomized) | Yes | Yes | Can't tell | Yes | Yes | No | Yes |
| Liu et al. (2015) | Quantitative (randomized) | Yes | Yes | Yes | Yes | Yes | No | Yes |
| Oudejans et al. (2013) | Quantitative (nonrandomized) | Yes | Yes | Can't tell | Yes | Yes | Can't tell | Yes |
| Wegner et al. (1998, Study 1) | Quantitative (randomized) | Yes | Yes | Can't tell | Yes | Yes | No | Yes |
| Wegner et al. (1998, Study 1) | Quantitative (randomized) | Yes | Yes | Can't tell | Yes | Yes | No | Yes |
| Woodman and Davis (2008) | Quantitative (nonrandomized) | Yes | Yes | Can't tell | Yes | Yes | Can't tell | Yes |
| Woodman et al. (2015, Study 1) | Quantitative (nonrandomized) | Yes | Yes | Can't tell | Yes | Yes | Can't tell | Yes |
| Woodman et al. (2015, Study 2) | Quantitative (nonrandomized) | Yes | Yes | Can't tell | Yes | Yes | Can't tell | Yes |

Notes: (1) The quality of the reviewed studies were assessed according to the methodological criteria developed by Hong et al. (2018) using the mixed methods appraisal tool (MMAT) version 18. Table S3 provides a comprehensive evaluation of the included studies' quality; (2) The response category 'Yes' means the study satisfied the methodological criterion, 'No' means the study does not satisfy the methodological criterion, and 'Can't tell' means cannot tell whether the study satisfied the methodological criterion. The response category 1, 2, 3, 4, 5 corresponds to 2.1, 2.2, 2.3, 2.4, 2.5 and 3.1, 3.2, 3.3, 3.4, 3.5 of MMAT methodological quality criteria for randomized control trial and nonrandomized trial studies, respectively; (3) Abbreviation as follow: S = screening question.

tennis serving [k = 1], volleyball serving [k = 1], and basketball free-throwing [k = 1]). K = 3 used stability motor tasks (upper limb motion steadiness [k = 1], balance [k = 1], and pendulum holding [k = 1]). K = 5 used reactive-motor tasks.

### *Research design*

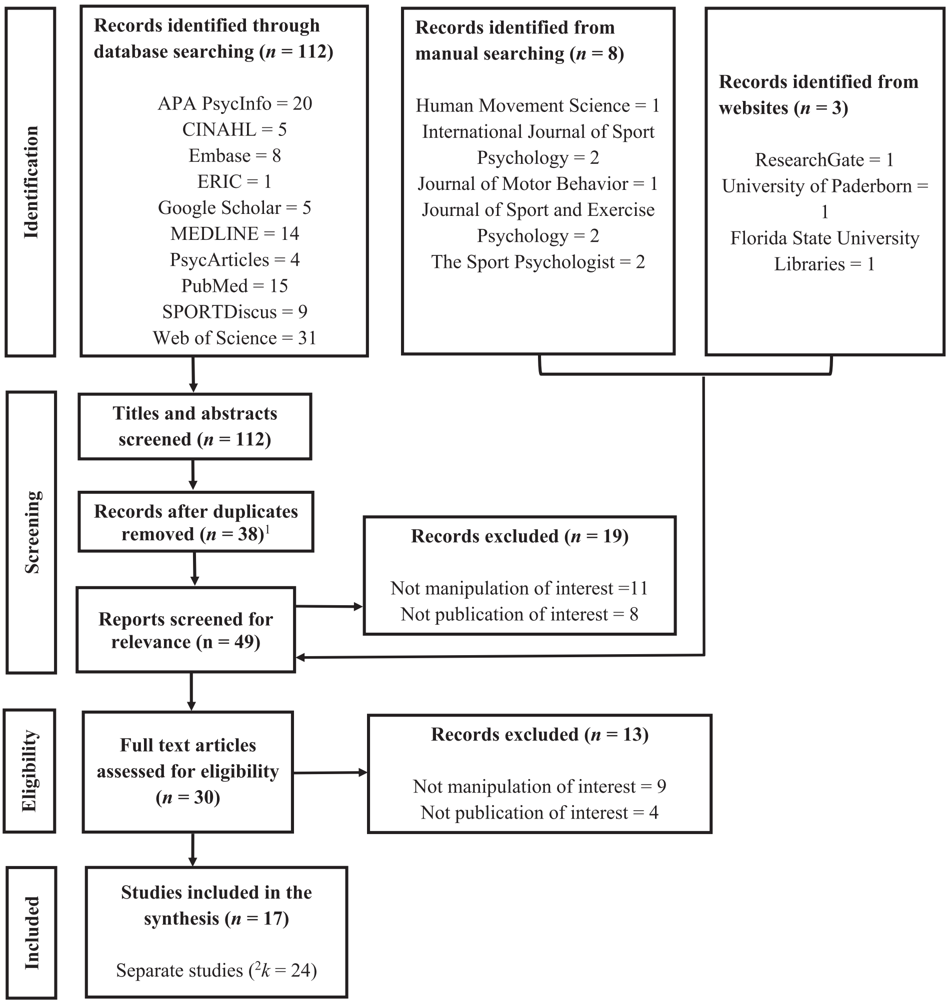
The reviewed studies employed quantitative approaches, including experimental within- and between-subject designs. K = 5 (21%) were experimental and included 350 participants, with an average sample size of 70.00 ± 34.08. K = 19 (79%) were quasi-experimental and included 903 participants, with an average sample size of 42.21 ± 18.78.

### *Risk of bias assessment*

In accordance with Fleiss (1971), Fleiss' kappa (κ) was calculated to examine the interrater reliability (IRR) between the three authors for the MMAT 2018 using SPSS software, version 28.0 (SPSS Inc., Chicago, IL). The IRR result revealed nearly a perfect level of agreement (κ = .83).

### *Cognitive load manipulation techniques*

The most widely used cognitive load manipulation technique was anxiety-based ($k = 16$, 67%), in which researchers artificially induced cognitive load, such as anxiety by using a




Note: (1) Total duplicates removed (n = 74): manually = 1 and via Rayyan = 73; (2) *k* = the unit of analysis

**Figure 2.** PRISMA 2020 screening process flow diagram.

combination of financial incentives ($k = 14$) and videotaping ($k = 1$) along with anxiety-inducing instructions, such as ego-threatening instructions ($k = 14$), and social evaluation instructions ($k = 11$). Also, two studies created single anxiety-inducing stressors, such as performing at height (Oudejans et al., 2013), and financial incentives (Woodman & Davis, 2008). The second manipulation technique identified was dual-task-based ($k = 8$; 33%), in which researchers taxed participants' attentional resources through concurrent tasks. Cognitive load was induced by a combination of time constraints and visually distracting stimuli ($k = 3$), rehearsing a digit-number and visual distracting object ($k = 1$; Wegner et al., 1998, Study 1), rehearsing a digit-sequence aloud, visual, and auditory distracting object, and incentive for self-presentation ($k = 1$; de la Peña et al., 2008, Study 1), rehearsing cue aloud, time pressure, and incentive ($k = 1$; Liu et al., 2015), and counting a digit-number backward mentally and holding a load in an outstretched nondominant

**Table 2.** Summary of sample characteristics, study characteristics, and experimental manipulations procedures of the included studies.

| Reference(s) | Study design | Motor task | Sample characteristics: Sample size (F/M) | Mean age (SD) | Participant skill level: [1]Mean (SD) | Competitive standard | Settings (lab/ field) | Experimental manipulation procedures |
|---|---|---|---|---|---|---|---|---|
| *i. Anxiety-based manipulations* | | | | | | | | |
| Barlow et al. (2016, Study 1) | Within-subject | Soccer penalty shooting | 67 M | $20.55 \pm 1.92$ | Trained | Colligate | 'Field' (Flat Astroturf surface) | *Content*: players completed IPIP before the experiment. Players took penalty kicks towards three distinct penalty shooting zones (target, ironic, non-ironic) under HA and LA conditions after receiving AI. Before their first shot under LA and HA, similar procedures (i – iii) to the Woodman et al. (2015, Study 1) were used. *HA manipulation*: AI (' … not to hit the ball to the right post'), financial incentive (FI[2]), ego-threatening instructions (ETI). A human observer recorded players' performance. *Order effects*: fixed non-ironic zone. *Trial Block*: 2 (LA: 20, and HA: 20). *Duration*: 2-min break between conditions. *Testing:* players completed the test individually. *Conditions*: HA and LA; Neurotic and non-neurotic participants. |
| Barlow et al. (2016, Study 2) | Within-subject | Dart- throwing | 45 M 28 F | $22.82 \pm 4.07$ | Novice | Not applicable | Lab | *Content*: similar content as Study 1 in dart-throwing but participants completed the task while they wore Polar HR. A human observer recorded participants' performance. *HA manipulation*: AI (' … not to hit the top right quarter of the dart board'), FI, ETI ('you will score zero point … ') and social evaluation instructions (SEI). *Order effects*: counterbalanced zones. *Trial Block*: 3 (warm-up: 15, LA: 24, and HA: 24). *Duration*: 2-min break between conditions. *Testing:* participants completed the test individually. *Comparator*: HA and LA; Neurotic and non-neurotic participants. |
| Gorgulu (2019a) | Within-subject | Air-pistol shooting | 33 M 24 F | $27.49 \pm 3.45$ | Elite $9.59 \pm 6.48$ | International union | 'Field' (indoor shooting range) | *Content:* participant shot air-pistol from 10 meters range towards three distinct zones (target, ironic, non-ironic) under LA and HA condition after receiving AI while they wore Polar HR. Before their first pistol shooting, similar procedures (i – iii) used in Woodman et al. (2015, Study 1). They completed RSME right after their final shot in each condition. *Anxiety manipulation*: AI (' … not to shoot the top … ', FI, and ETI. *Order effects*: counterbalanced ironic error zone across participants. *Trial Blocks*: 3 (Warm-up: 15; LA: 30; & HA: 30). *Duration*: 60-min (5-min break between |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | | trial blocks). *Testing*: participants completed the test individually. *Conditions*: HA and LA. |
| Gorgulu (2019b) | Within-subject | Basketball free-throw | 37 M | 22.30 ± 2.89 | Highly trained 8.74 ± 2.45 | Colligate | 'Field' (at players' training indoor facilities) | *Content:* players threw free throw task towards three distinct zones (target, ironic, non-ironic) from the free throw line under HA and LA conditions after receiving AI. Before their first free throw, similar procedures (i – iii) used in Woodman et al. (2015, Study 1 & 2). *HA manipulation*: AI (' … not to miss the shot … '), FI, ETI and SEI. *Order effects:* unreported. *Trial Blocks*: 3 (Warm-up [meant for familiarizing players with the scoring system]: 10 throws; LA: 15 throws; HA; 15 throws). *Duration*: 5-min break between each trial block. *Testing*: players completed the test individually. *Conditions*: HA and LA. |
| Gorgulu (2019c) | Within-subject | Tennis serving | 20 M 12 F | 20.81 ± 2.20 | Highly trained 8.37 ± 2.32 | Colligate | 'Field' (Indoor facilities) | *Content:* players served towards three distinct zones under HA and LA conditions after receiving AI. Before their first pistol shooting, similar procedures (i – iii) used in Woodman et al. (2015, Study 1). Instructions repeated halfway through. A video camera recorded players' performance. *HA manipulation*: AI (' … not to serve into the net or out'), FI, ETI and SEI. *Order effects*: Counterbalanced the right and left serving sides. *Trial blocks*: 3 (Warm-up [meant for acquainting players with the scoring system and serving zones]: 10; LA: 20; HA: 20). *Duration*: 10-min break between each trial. *Testing*: players were tested individually. *Conditions*: HA and LA. |
| Gorgulu et al. (2019, Study 1) | Within-subject | Reactive motor task | 32 M 21 F | 19.62 ± 2.09 | Novice | Not applicable | Lab | *Content*: participants reacted to a series of color balls (target and ironic error balls) using a table tennis racquet under HA and LA after receiving AI while they wore ECG and EMG electrodes. Before participants reacted to their first ball, similar procedures (i – iii) to Woodman and colleagues (2015, Study 1) were used. *HA manipulation*: AI (' … not to stop the blue balls'), FI, ETI, and SEI. Like Gorgulu (2019c), the instructions reiterated halfway through across anxiety conditions. *Order effects*: randomized balls before the start of the test and then fixed as the same random order. *Trial Blocks*: 3 (Familiarization: 10 balls; LA: 30 balls; HA: 30 balls). *Duration*: 60-min (5-min break between the two trial blocks). *Testing*: participants completed the test individually. *Conditions*: HA and LA. |

(*Continued*)

**Table 2.** Continued.

| | | | Sample characteristics | | | | | |
|---|---|---|---|---|---|---|---|---|
| Reference(s) | Study design | Motor task | Sample size (F/M) | Mean age (SD) | Participant skill level: [1]Mean (SD) | Competitive standard | Settings (lab/ field) | Experimental manipulation procedures |
| Gorgulu et al. (2019, Study 2) | Within-subject | Reactive motor task | 21 M 19 F | 22.65 ± 6.3 | Novice | Not applicable | Lab | *Content:* the tasks, materials, measures procedures and anxiety manipulation were analogous to Study 1, but new ball was introduced as non-ironic error ball, which contained no instruction. *Order effects:* fully counterbalanced balls. *Trial Blocks*: 3 (Familiarization: 15 balls; LA: 45 balls; HA: 45 balls). *Duration*: 75-min. *Testing*: participants completed the test individually. *Conditions*: HA and LA. |
| Gorgulu et al. (2019, Study 3) | Within-subject | Reactive motor task | 24 M 17 F | 22.63 ± 3.92 | Novice | Not applicable | Lab | *Content:* the tasks, materials, measures procedures and anxiety manipulation were analogous to Study 1 and 2, but the AI was flipped into ' … not to let go the blue balls.' The third ball was neither accompanied by instruction nor point value. *Order effects, trial Blocks, duration, testing,* and *comparator*: like Study 2. |
| Gorgulu et al. (2019, Study 4) | Within-subject | Reactive motor task | 17 M 7 F | 25.58 ± 4.52 | Novice | Not applicable | Lab | *Content:* the tasks, materials, measures procedures and anxiety manipulation were analogous to Study 1, 2, and 3. The third ball was attached with instruction and point-value, introducing dual-error scoring system simultaneously with the ironic error ball. *Order effects, trial Blocks, duration, testing,* and *Conditions*: like Study 2. |
| Gorgulu et al. (2019, Study 5) | Within-subject | Reactive motor task | 16 M 7 F | 23.43 ± 3.62 | Novice | Not applicable | Lab | *Content:* the tasks, materials, measures procedures and anxiety manipulation were like Study 1, 2, 3, and 4. The AI was analogous to Study 3. The third ball was attached with scoring values like Study 4. *Order effects, trial Blocks, duration, testing,* and *Conditions*: like Study 2. |
| Gorgulu and Gokcek (2021) | Within-subject | Volleyball serving | 43 F | 14.51 ± 1.35 | Highly trained 5.40 ± 2.38 | Colligate | 'Field' (indoor volleyball court) | *Content*: before testing, players wore a polar HR. Players served a series of balls towards three distinct serving zones (target, ironic, non-ironic) under HA and LA conditions after receiving AI. Prior players' first serving the ball under both anxiety conditions, similar procedures (i – iii) to Woodman and colleagues (2015, study 2) were used. *HA manipulation*: AI (' … not to hit the net or the ball out'), reward, ETI, and SEI. *Order effects*: Unreported. *Trial Blocks*: 3 (Warm-up [to familiarize the task and instructional sets]: 5 servings, LA: 10 servings and HA: 10 servings). *Duration*: 60-min. (5-min. |

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|---|---|---|---|---|---|---|---|---|
| | | | | | | | | break between HA and LA). *Testing*: players completed the test individually. *Conditions*: HA and LA. |
| Gray et al. (2017) | Within-subject RCT | Baseball pitching | 24 M | 23.25 ± 1.5 | Highly trained 12.0 ± 1.8 | Colligate | Field (a wall projected batter) | *Content*: before testing, pitchers assigned randomly to two groups (ironic, target pitchers), wore HR Polar, equipped with motion trackers. The target zone was illustrated to target pitchers and both the target and ironic zone were displayed to the ironic pitchers graphically against a virtual batter standing under LA (2 low-pressure phases) and HA (pressure phase) conditions after receiving AI. Before pitchers first ball under all pressure phases, pitchers: (i) received instructions; (ii) completed the self-reported IAMS twice; and (iii) received specific instructions including the set-up of a video camera under HP. *HA manipulation*: AI (' … avoid trying to throw the ball in … '), FI, ETI, SEI, and video filming instructions. Pitchers received verbal feedback regarding their pitching score (not their pitching speed) and could see their final ball hitting location. *Order effects*: target (black quadrant) and the red ironic zone locations were randomized across trials. *Trial Blocks*: 3 (pretest: 30 throws, pressure: 30 throws, and posttest: 30 throws *Practice*: 5 throws). *Duration*: unspecified but pitchers were given 15-min break between each trial block. *Conditions*: HA and 2 LA, ironic and target pitchers. |
| Oudejans et al. (2013) | Within-subject | Climbing a wall and Dart-throwing | 20 M 20 F | 21.3 ± 1.85 | Novice | Not applicable | Lab | *Content:* participants threw a series of darts under HA (high positions on the wall) and LA (low positions on the wall) after receiving NI and AI conditions. They wore a HR polar after baseline dart-throw. Participants' dart hits were attached with scoring points. Instructions repeated following every third throw across anxiety conditions. Participants completed a new anxiety thermometer (VAAS) after each trial condition and STAI A-Trait inventory after they come down of the wall. They completed a warm-up dart-throw (between 6 to 18 darts). *HA manipulation*: AI (' … not to hit less than … '), NI (' … try to hit the bullseye') and climbing the wall at high position. *Order effects:* counterbalanced height and instruction conditions. *Trial blocks*: 2 (baseline: 24 darts; trial/test: 98 darts). *Duration:* 60-min with unspecified break time. *Testing:* participants completed the test individually. *Conditions:* HA and LA; NI and AI. |

(*Continued*)

**Table 2.** Continued.

| | | | Sample characteristics | | | | | |
|---|---|---|---|---|---|---|---|---|
| Reference(s) | Study design | Motor task | Sample size (F/M) | Mean age (SD) | Participant skill level: [1]Mean (SD) | Competitive standard | Settings (lab/ field) | Experimental manipulation procedures |
| Woodman and Davis (2008) | Within-subject | Golf-putting | 38 M<br>31 F | 21.1 ± 4.77 | Novice | Not applicable | Lab | *Content:* before testing, participants wore HR polar. Participants completed the putting task under LA (baseline) and HA (test) conditions after receiving AI. Before testing participants (i) received the task instructions; (ii) filled MRF-3; (iii) their HR was recorded again; and (iv) completed 5 familiarization putts. Instructions repeated just before their first putt in the test condition. *HA manipulation*: FI. *Order effects*: unreported. *Trial Blocks*: 2 (Baseline: 10 putts; test putt: 10 putts). *Duration*: unreported. *Testing*: participants completed the test individually. *Conditions*: HA and LA, high and low anxious. |
| Woodman et al. (2015, Study 1) | Within-subject | Hockey penalty shooting | 40 M | 20.25 ± 1.06 | Trained | Colligate | Field | *Content:* participants kicked hockey penalty shots towards three zones (target, ironic, non-ironic) under LA and HA conditions after receiving AI. Before their first shot, participants (i) received their first instruction; (ii) completed self-reported MRF-3; and (iii) reminded the instructions once again. They completed 15 warm-up shots. A human observer recorded participants' performance. *HA manipulation*: FI and ETI. *Order effects:* HA and LA counterbalanced. *Trial Blocks*: 2 (LA: 30 shots; HA: 30 shots). *Duration*: 2-min break between blocks. *Testing*: participants completed the test individually. *Conditions*: HA and LA |
| Woodman et al. (2015, Study 2) | Within-subject | Dart- throwing | 45 M<br>28 F | 22.82 ± 4.07 | Novice | Not applicable | Lab | *Content:* before testing, participants wore HR Polar. The procedures were analogous to Woodman et al. (2015, Study 1). They completed 15 practice dart-throws. *HA manipulation*: FI, ETI, and SEI. *Order effects*: the ironic error zone was rotated clockwise by one quadrant for the succeeding participants. *Trial Blocks*: 2 (LA: 24; HA: 24 throws). *Duration*: 2-min break between blocks. *Testing*: participants completed the test individually. *Conditions*: HA and LA. |
| *ii. Dual task-based manipulations* | | | | | | | | |
| Bakker et al. (2006, Study 2) | Within-subject | Soccer penalty shooting | 10 M | 21.2 ± 2.10 | Highly trained<br>11.8 ± 2.66 | League | Lab | *Content:* players took penalties from 2.48 meters against a virtual stationary goalkeeper without run-up with foam ball under CL after receiving PI and two AIs while players wore |

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| | | | | | | | | an eye-tracker. Players had time to get used to the experiment. A camera recorded participants performance. *CL manipulation*: time pressure (1 second), AIs (' … the goalkeeper could not reach the ball'; ' … not to shoot next to the goal'), and positive instruction (PI; 'make sure to hit the open space'). *Order effects*: counterbalanced the three experimental instruction conditions. *Trials:* 30 fully randomized (5 clips-by-6). *Duration*: unspecified. *Testing:* players completed the test individually. *Conditions*: NI, PI, 2 AIs condition. |
| Binsch et al. (2010a) | Within-subject | Soccer penalty shooting | 32 M | 24.2 ± 7.4 | Highly trained 14.6 ± 10.2 | League | Lab | *Content*: players took penalties from 2.83 meters towards a virtual goal and goalkeeper on a large screen under CL after receiving two experimental instructional conditions while they wore an eye-tracker. Instructions repeated to players before their first shot in each trial. Players completed 20 warm-up shots on a black screen A video camera recorded participants performance. *High-CL manipulation*: time constraint (1 second), AI (' … not to shoot within reach of the keeper'), and PI (' … to pass the keeper'). *Order effects*: randomized trials and counterbalanced the experimental instruction conditions. *Trial blocks*: 3 (TB1: 10 shots; TB2: 10 shots; TB3: 10 shots). *Duration:* unspecified. *Testing*: players completed the test individually. *Conditions*: NI, PI, and AI conditions. |
| Binsch et al. (2010b) | Within-subject | Soccer penalty shooting | 32 M | 21.8 ± 2.1 | Highly trained 12.6 ± 4.7 | League | Lab | *Content:* players took a penalty against a virtual goal and goalkeeper from 2.83 meters without run up while they were equipped with eye-tracker under CL after receiving AI and PI. Players received the experimental instruction conditions before each trial followed by a presentation of stimuli. Players completed 20 warm-up shots followed by 10 practice shots. A video camera recorded participants performance. *High-CL manipulation*: time constraint (1.5 seconds), AI ('be careful not to shoot within reach of the keeper'), and PI ('be careful to shoot into the open space'). *Order effects*: randomized trials and counterbalanced the experimental instruction conditions. *Trials:* 5 clips-by-5 trials). *Duration*: unspecified. *Testing*: players completed the test individually. *Conditions*: NI, PI, and AI conditions |
| de la Peña et al. (2008, Study 1) | Within-subject RCT | Golf putting | 24 M 24 F | 21.5 ± 3.8 | Trained | Colligate | Lab | *Content:* before 'load block', participants received extra information and AI. They completed 4 practice putts. *High-'load' manipulation:* visual distracters, audio distracters, CL |

(*Continued*)

**Table 2.** Continued.

| | | | Sample characteristics | | | | | |
|---|---|---|---|---|---|---|---|---|
| Reference(s) | Study design | Motor task | Sample size (F/M) | Mean age (SD) | Participant skill level: [1]Mean (SD) | Competitive standard | Settings (lab/ field) | Experimental manipulation procedures |
| | | | | | | | | (i.e., to 'memorize an 8-digit sequence of random numbers and rehearse the sequence of numbers loudly' while putting), self-presentation/incentive (they would 'receive extra class credit for video recording of their putting accuracy'), and AI ('don't putt the ball short'). *Order effects*: 'load' and 'no-load' trial blocks were counterbalanced. *Trial Blocks*: 3 (baseline: 10 putts, 'load'/Block 2: 10 putts, and 'no-load'/Block 3: 10 putts). *Conditions*: baseline 'load' and 'no-load' conditions. |
| Dugdale and Eklund (2003) | Within-subject | Stability (balance) task | 16 F | 19.25 ± 1.06 | Highly trained 12.66 ± 3.87 | Colligate | Lab | *Content:* dancers completed balance task on the wobble board under CL after receiving AI and PI. They completed familiarization wobble board training for 3 days under the supervision of a dance instructor before the experiment. *High-CL manipulation*: arithmetic task (i.e., 'counting backward from 1,000 by sevens mentally', in which they were asked to report the lowest digit and received verbal feedback on their rehearsal accuracy), AI ('try not to let the wobble board wobble'), and PI ('hold the wobble board as steady as possible'). They were asked to reiterate the given instruction before each trial. *Order effects:* counterbalanced conditions. *Trial Blocks*: 5 trials-by-4 conditions. *Duration*: within-conditions: 50 seconds break; between-conditions: 30-min break; each trial lasted for 20 seconds. *Testing:* dancers completed the test individually. *Conditions*: HCL and LCL; AI and PI. |
| Liu et al. (2015) | Within-between subject (RCT) | Upper limb motion steadiness | 40 M 40 F | 20.20 ± 1.52 | Novice | Not applicable | Lab | *Content*: participants assigned randomly to four groups. They completed the task under CL after receiving positive and negative self-talk cues with their dominant hand while their fingers were attached to SCL sensors. Before testing, they completed 10 practice trials and were requested to state the aim of the task and repeat aloud the given self-talk cues for 10 seconds. After they started the experiment, they were instructed to 'try to hear the cue words.' They completed a short post-experimental attentional focus manipulation survey and received temporal feedback on their |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | | performance at the end of the experiment. A video camera recorded participants' performance. *High-CL manipulation*: fake time constraint, extrinsic reward (i.e., gift card), AI (i.e., suppressive self-talk—'don't shake'), and PI ('Go steady'). *Order effects*: baseline and test trials were counterbalanced. *Trial Blocks*: 2 (baseline: 10 trials, test: 10 trials). *Duration*: between trials: 30 seconds break; between blocks: 5-min break. *Testing*: participants completed the test individually. *Conditions*: baseline, HCL and LCL; AI, PI; F, M. |
| Wegner et al. (1998, Study 1) | Within-subject RCT | Golf putting | 42 M<br>41 F | Not reported | Novice | Not applicable | Lab | *Content*: participants completed putting task under CL and two visual monitoring (VM) conditions following AI. Participants completed undisclosed amount of warm-up putts with no instruction condition before testing. *High-'load' manipulation:* CL—concurrent memory task (i.e., rehearsal of a six-digit number, in which participants were asked to recall right after each trial block), distracter (i.e., VM), and AI ('don't overshoot the glow spot'). *Order effect*: counterbalanced baseline and experimental trials. *Trial Blocks*: (Baseline: 15 putts; Trial: 15 putts). *Testing*: participants completed the test individually. *Conditions*: baseline, 'load', 'no-load', VM, no-VM. |
| Wegner et al. (1998, Study 2) | Within-subject RCT | Swinging of a handheld pendulum | 42 M<br>42 F | Not reported | Novice | Not applicable | Lab | *Content*: participants completed a body movement task by holding a pendulum steady over the center spot following AI. *High-'Load' manipulation:* PL (i.e., holding a 2.2 kg brick in the non-pendulum hand), CL (i.e., 'count digit number backward mentally from 1,000 by threes', in which they were asked to report the last number), AI ('do not move it sideways'), and PI ('hold the pendulum as steady as possible'). Participants in the prevent-sideway-movement condition were shown the to-be-avoided direction. *Order effects*: unreported. *Trial Blocks*: 5 trials (single block trial). *Duration*: each trial lasted 30 seconds and 30 seconds break after each trial. *Conditions*: 'load', 'no-load', PL, CL, AI, PI. |

Note: (1) Mean and Standard Deviation in years of playing experience; (2) Participants were informed that they will receive monetary award if they accumulate the highest point in the condition or if they perform entirely on the target; (3) Abbreviations used as follows: F/M = female/male; LA = low anxiety; HA = high anxiety; H*P* = high pressure; L*P* = low pressure; IPI*P* = international personality item pool; HR = heart rate; RSME = rating scale of mental effort; MRF = mental readiness form; IAMS = immediate anxiety measurement scale; STAI = state-trait anxiety inventory; VAAS = visual-analogue anxiety scale; ECG = electroencephalography; EMG = electromyogram; SCL = skin conductance level; CL = cognitive load; PL = physical load; AI = avoidant instruction; NI = neutral instruction.

hand ($k = 1$; Wegner et al., 1998, Study 2). Only one study used a single form of cognitive load, such as counting a digit backward mentally ($k = 1$; Dugdale & Eklund, 2003). Depending on the specifics of their manipulation techniques, the reviewed studies presented their experimental conditions differently. In quasi-experimental studies, for example, cognitive load conditions were either presented in a counterbalanced ($k = 7$) or fixed order ($k = 8$; for additional information about the manipulations characteristics, see Table S4).

In terms of instructional manipulations, k = 24 used avoidant instructions with negative priming phrases ('please be particularly careful not to putt the ball short') consisting of both short (composed of 8 words) and long words (composed of 197 words). Five out of twenty-four studies used action-oriented ('don't stop the ball') and inaction-oriented avoidant goals ('don't let the ball go'; Gorgulu et al., 2019, Studies 1–5). In addition, k = 3 used directional avoidant instructions (de la Peña et al., 2008, Study 1; Wegner et al., 1998, Study 1; Woodman & Davis, 2008), k = 3 incorporated positively constructed instructions (Bakker et al., 2006, Study 2; Binsch et al., 2010a, 2010b), and k = 3 used positive self-focus cues (Dugdale & Eklund, 2003; Liu et al., 2015; Wegner et al., 1998, Study 2). Most of the reviewed studies formulated standardized instructional scripts. The instructional manipulations are presented in a mixed manner. Most studies presented their instructional manipulations to participants verbally ($k = 23$), while k = 1 presented graphic and verbal instructions (Gray et al., 2017). The frequency with which the instructions were presented varied significantly among the reviewed studies (for further information about characteristics of instructions, see Tables S5 and S6).

Most studies conducted their experiments in a laboratory setting ($k = 17$, 71%). The remainder conducted their experiments in the field ($k = 7$, 29%), which included standard indoor sporting facilities. However, none of the studies were conducted during actual games or in competitive settings.

Most of the studies ($k = 22$; 92%) investigated how ironic errors occur when given avoidant instructions under conditions of cognitive load. Although several studies aimed to examine the ironic errors mechanism, the purposes of their investigations were varied. Three studies, for example, investigated whether personality traits moderate the likelihood of ironic errors (Barlow et al., 2016, Studies 1–2; Woodman & Davis, 2008); three studies looked into the precise ironic performance breakdown within the ironic zone, focusing on hits that land within the ironic error zones but are just slightly off the target zone (Barlow et al., 2016, Study 2; Gorgulu, 2019a; Woodman et al., 2015, Study 2); one study investigated kinematics (Gray et al., 2017); one study investigated performance decrement and choking (Oudejans et al., 2013); three studies examined the likelihood of ironic errors in externally timed reactive-motor tasks (Gorgulu et al., 2019, Studies 1, 2, and 4); three studies assessed how gaze behavior influences the incidence of ironic errors (Bakker et al., 2006, Study 2; Binsch et al., 2010a, 2010b); and one study examined the impact of gender differences on the likelihood of ironic errors (Liu et al., 2015). Few studies ($k = 2$; 8%) have investigated whether task instructions moderate the likelihood of ironic errors (Gorgulu et al., 2019, Studies 3 and 5).

### *Cognitive load measurement*

Within the anxiety-based, the most common subjective anxiety measure was the Mental Readiness Form-3 (MRF-3; Krane, 1994), which was used in 14 studies. Additionally, Gorgulu (2019a) incorporated the Rating Scale of Mental Effort (Zijlstra, 1993), and Barlow et al. (2016, Studies 1–2) used the International Personality Item Pool (Goldberg, 1999). The most reported objective measures of anxiety were heart rate and heart rate variability, in which researchers used heart rate monitors ($k = 7$) and electrocardiography ($k = 5$). Moreover, Gorgulu et al. (2019) used electromyography to measure muscle activity linked to anxiety (Studies 1–5).

Of the dual-task-based, k = 3 included direct measures of visual attention using eye-tracking devices (Bakker et al., 2006, Study 2; Binsch et al., 2010a, 2010b). Furthermore, Liu et al. (2015) reported cognitive load measurement using skin conductance level and Likert-scale surveys. Table 4 provides summaries of cognitive load measurements.

## *Performance measures*

Within anxiety-based ($k = 16$), k = 10 measured performances in clearly defined zones labeled as target, ironic, and non-ironic in different perceptual-motor tasks. These studies recorded ironic errors by counting the number of motor actions that landed in the ironic zones (Barlow et al., 2016, Studies 1–2; Gorgulu, 2019a, 2019b, 2019c; Gorgulu & Gokcek, 2021; Gray et al., 2017; Oudejans et al., 2013; Woodman et al., 2015, Studies 1–2). K = 5 recorded participants' responses to ironic stimuli in reactive-motor tasks (Gorgulu et al., 2019, Studies 1–5). K = 1 measured ironic error (overshooting) by recording the ball's distance in centimeters traveled past the target (Woodman & Davis, 2008). The fifteen studies also included the following performance measures: (1) thirteen studies recorded the non-ironic errors (except Gorgulu et al., 2019, Study 1; Oudejans et al., 2013); (2) three studies calculated the arc length from the closest non-ironic error zone and the radial distance from the target zone to determine the precision of ironic errors (Barlow et al., 2016, Study 2; Gorgulu, 2019a; Woodman et al., 2015, Study 2); and (3) one study measured ironic movement errors by calculating the mean standard deviations of distinctly defined pitching kinematics (Gray et al., 2017).

Within the dual-task-based ($k = 8$), k = 3 measured ironic errors based on where participants kicked the ball and fixed their gaze in relation to the experimental instruction conditions in a simulated penalty settings (Bakker et al., 2006, Study 2; Binsch et al., 2010a, 2010b). K = 3 recorded ironic errors based on participants' body instability when given avoidant instructions under cognitive load (Dugdale & Eklund, 2003; Liu et al., 2015), as well as under physical load conditions (Wegner et al., 1998, Study 2). K = 2 measured ironic errors (i.e., overshooting or undershooting) by recording the difference between the experimental and baseline or control putts in centimeters traveled behind or in front of the target spot (de la Peña et al., 2008, Study 1; Wegner et al., 1998, Study 1).

## *Manipulation outcomes*

This section discusses the reported primary outcomes of the manipulations in the following order: anxiety-based, followed by dual-task-based. This grouping is based on the most frequently used manipulation techniques in the reviewed studies. Under each manipulation technique, subheadings are used to divide the summary of the findings into manageable sections. Table 3 summarizes the key findings of the manipulations.

### *Anxiety-based manipulation techniques*

Of the reported anxiety-based manipulation techniques ($k = 16$), ten studies involved target, ironic, non-ironic-oriented motor tasks; five studies included action- and inaction-oriented goals in reactive-motor tasks; and one study included a direction outcome-based motor task.

### *Zone (target, ironic and non-ironic)-oriented motor tasks*

Nine out of ten studies reported that participants performed fewer motor actions in the target zones and more motor actions in the to-be-avoided (ironic) zones when given avoidant instructions under high-anxiety compared to low-anxiety conditions (Barlow et al., 2016, Studies 1–2; Gorgulu, 2019a, 2019b, 2019c; Gray et al., 2017; Oudejans et al., 2013; Woodman et al., 2015, Studies 1–2). Notably, Oudejans et al. (2013) found that giving avoidant instruction in high-anxiety conditions not only caused participants to perform ironically in the to-be-avoided areas but also had detrimental effects on performance. However, Gorgulu and Gokcek (2021) reported that highly trained volleyball players performed similarly in the target and ironic error zones when given avoidant instructions across anxiety conditions. Furthermore, twelve of the fifteen studies reported that performances in relation to the non-ironic zones were unaffected when given avoidant instructions under high- and low-anxiety conditions; however, two studies did not measure the non-ironic performances (Gorgulu et al., 2019, Study 1; Oudejans et al., 2013). Gorgulu and Gokcek (2021), on the other hand, found significant performance differences in the non-ironic error zone when given avoidant instructions under high-anxiety compared to low-anxiety conditions.

Regarding the precision of ironic errors, two studies reported that when given avoidant instructions under high-anxiety compared to low-anxiety conditions, novice participants' performances in the ironic error zones were significantly farther away from the target zones and significantly closer to the specifically to-be-avoided zones (Barlow et al., 2016, Study 2; Woodman et al., 2015, Study 2). Specifically, Barlow and colleagues (2016) found that when anxious, neurotic participants, who feel often stress and anxiety, performed more precisely in the ironic error zone than their non-neurotic counterparts (Study 2), despite showing a greater likelihood of ironic errors (Studies 1–2). Conversely, Gorgulu (2019a) found that elite participants' precision of ironic performances was unaffected by anxiety conditions, regardless of when they made ironic errors.

It was found in one of the fifteen studies by Gray et al. (2017) that ironic groups' performances were unaccompanied by changes in movement kinematics when given avoidant instructions under high-anxiety compared to two low-anxiety conditions. This finding indicated that despite being analyzed at the group level, ironic groups broke their performances precisely when anxious.

### *Action- and inaction-oriented goals*

Three studies found that when participants were given action-oriented avoidant goals (i.e., 'not to stop the ironic color balls'), they responded with fewer target color balls and more ironic color balls under high-anxiety compared to low-anxiety conditions (Gorgulu et al., 2019, Studies 1, 2, and 4). Two of the five studies focused on inaction-

**Table 3.** Summary of outcome measures and primary outcomes reporting under cognitive load manipulation when given avoidant instructions.

| Reference | Outcome measures | Overall scores ([1]*p* values, effect size[2]) | Cohen's $d^2$ | Mean and SD |
|---|---|---|---|---|
| *i. Anxiety-based approach* | | | | |
| Barlow et al. (2016, Study 1) | Soccer penalty shooting | [3]$p < .001$ (for target performance)<br>[3]$p < .01$ (for ironic error)<br>*ns.* (for non-ironic error) | | $M_{TP} = 11.17$ (2.91)<br>$M_{IPE} = 3.91$ (2.09)<br>$M_{NIPE} = 4.62$ (2.29) |
| Barlow et al. (2016, Study 2) | Dart throwing | [3]$p < .001$ (for target performance)<br>[3]$p < .001$ (for ironic error)<br>*ns.* (for non-ironic error)<br>$p < .05$ (for POI) | | $M_{TP} = 3.92$ (2.72)<br>$M_{IPE} = 2.87$ (1.83)<br>$M_{NIPE} = 7.44$ (2.74) |
| Gorgulu (2019a) | Air-pistol shooting | $p = .001$, $\eta_p^2 = .23$ (Anxiety × Zone)<br>*ns.* (for non-ironic error)<br>[4]$p = .54$ (ns. for POI) | | |
| Gorgulu (2019b) | Free throw shooting (basketball) | $p = .05$, $\eta_p^2 = .19$ (Anxiety × Zone)<br>*ns.* (for non-ironic error) | | $M_{TP} = 6.43$ (1.58)<br>$M_{IPE} = 4.43$ (1.53)<br>$M_{NIPE} = 4.13$ (1.47) |
| Gorgulu (2019c) | Tennis serving | $p = .001$ (Anxiety × Zone)<br>*ns.* (for non-ironic error) | | $M_{TP} = 10.12$ (2.53)<br>$M_{IPE} = 4.92$ (1.85)<br>$M_{NIPE} = 4.91$ (2.08) |
| Gorgulu et al. (2019, Study 1) | Reacting to color balls | $p = .001$, $\eta_p^2 = .34$ (Anxiety × Zone)<br>*ns.* (for non-ironic error) | | |
| Gorgulu et al. (2019, Study 2) | | $p = .19$, $\eta_p^2 = .04$ (Anxiety × Zone)<br>*ns.* (for non-ironic error) | | |
| Gorgulu et al. (2019, Study 3) | | [5]$p = .25$ (*ns.*), $\eta_p^2 = .03$ (Anxiety × Zone)<br>*ns.* (for non-ironic error) | | |
| Gorgulu et al. (2019, Study 4) | | $p = .001$, $\eta_p^2 = .31$ (Anxiety × Zone)<br>*ns.* (for non-ironic error) | | |
| Gorgulu et al. (2019, Study 5) | | [5]$p = .19$ (*ns.*), $\eta_p^2 = .07$ (Anxiety × Zone)<br>*ns.* (for non-ironic error) | | |
| Gorgulu and Gokcek (2021) | Volleyball serving | [6]$p < .001$, $\eta_p^2 = .31$ (Anxiety × Zone)<br>*sig.* (for non-ironic error) | | $M_{TP} = 2.38$ (1.38)<br>$M_{IPE} = 2.54$ (1.54)<br>$M_{NIPE} = 5.07$ (1.90) |
| Gray et al. (2017) | Pitch throwing performance | [7]$p < .001$, $\eta_p^2 = .66$<br>(for both groups)<br>*ns.* (Group × Pressure)<br>$p < .001$, $\eta_p^2 = .67$ (for ironic pitchers) | | $M_{PRP} = 2.1$ (1.2)<br>$M_P = 5.8$ (1.4)<br>$M_{POP} = 2.8$ (1.5) |
| | Pitching velocity | *ns.* (Group × Pressure) | | |
| | Pitching kinematics | [8]$p = .001$, $\eta_p^2 = .75$<br>(Group × Pressure)<br>[9]$p = .002$, $\eta_p^2 = .25$ (for target pitchers' LFLP)<br>[9]$p < .001$, $\eta_p^2 = .32$ (for target pitchers' EFA)<br>[9]$p < .001$, $\eta_p^2 = .49$ (for target pitchers' PAAD)<br>[10]*ns.* (Group × Pressure) | | |

(*Continued*)

**Table 3.** Continued.

| Reference | Outcome measures | Overall scores ([1]p values, effect size[2]) | Cohen's $d^2$ | Mean and SD |
|---|---|---|---|---|
| Oudejans et al. (2013) | Climbing a wall and dart throwing | $p < .01$(Position × Instruction)<br>[11]$p < .01$, 95% CI [-.50, -.11] | $f = .53$ | $M_{NILA} = 5.68$ (1.25)<br>$M_{NIHA} = 5.56$ (1.30)<br>$M_{AILA} = 5.78$ (1.20)<br>$M_{AIHA} = 5.25$ (1.34) |
| Woodman and Davis (2008) | Putting distance (in cm) | $p < .005$, $\eta^2 = .24$<br>(Coping style × Condition)<br>$p < .05$, $\eta^2 = .39$ (for repressors) | $d = .99$ | $M_{BB} = 9.51$ (12.51)<br>$M_{TB} = 44.18$ (47.92) |
| Woodman et al. (2015, Study 1) | Hockey penalty shooting | $p = .01$ (Anxiety × Zone)<br>*ns.* (for non-ironic error) | | $M_{TP} = 10.78$ (3.53)<br>$M_{IPE} = 7.86$ (3.48)<br>$M_{NIPE} = 11.53$ (4.25) |
| Woodman et al. (2015, Study 2) | Dart throwing | $p < .001$, $\eta^2 = .25$ (for Anxiety × Zone)<br>*ns.* (for non-ironic error)<br>[4]$p < .001$ (for POI) | | $M_{TP} = 3.92$ (2.72)<br>$M_{IPE} = 2.87$ (1.83) |
| *ii. DT-based approach* | | | | |
| Bakker et al. (2006, Study 2) | Gaze location | [12]$p < .0001$ (under AIs and PI) | | |
| Binsch et al. (2010a) | Shooting distance<br>Fixation duration | [13]$p < .00$, $r^2 = .50$ (from the keeper)<br>[14]$p < .00$, $r^2 = .43$ (on the keeper) | | |
| Binsch et al. (2010b) | Shooting distance | [15]$p < .001$, $\eta_p^2 = .30$ (from the keeper)<br>(Group × Condition) | | |
| | Onset of final fixation (in ms) | [16]$p > .25$<br>(Group × Condition) | | $M_{IR} = 214$<br>$M_{NIR} = 225$ |
| | Duration of final fixation (in ms) | $p < .01$, $\eta_p^2 = .18$ (on the open-goal space)<br>(Group × Condition)<br><br>[17]*ns.* (compared to ironic participants) | | $M_{NI} = 224$ (79)<br>$M_{AI} = 129$ (68)<br>$M_{PI} = 206$ (56) |
| de la Peña et al. (2008, Study 1) | Putting performance (in cm) | $p < .001$, $\eta_p^2 = .40$ (under 'load' plus AI)<br><br><br>[18]$p < .001$, $\eta_p^2 = .29$ (for first putt) | | $M_{BB} = 197.99$ (13.93)<br>$M_{TB2} = 215.14$ (21.94)<br>$M_{TB3} = 205.20$ (18.74)<br>$M_{BB} = 193.60$ (43.43)<br>$M_{TB2} = 231.20$ (48.57)<br>$M_{TB3} = 203.82$ (48.73) |
| Dugdale and Eklund (2003) | Balance performance (in SI) | $p < .025$, $\eta_p^2 = .29$ (for Instruction)<br>$p < .001$, $\eta_p^2 = .70$ (for CL)<br>$p < .171$, $\eta_p^2 = .12$ (*ns.* Instruction × CL) | <br><br>[19]$d = .72$<br>[20]$d = .30$ | <br><br><br>$M_{PI} = 1486.33$ (430.96)<br>$M_{AI} = 1611.30$ (408.96) |
| Liu et al. (2015) | Stability performance | [21]$p < .11$, $\eta_p^2 = .04$ (*Attention × CL × Phase)<br>$p < .05$ (for high CL AI group)<br>$p < .03$ (for high CL PI group)<br>[22]$p = .08$ (for low CL AI group)<br>[23]$p < .12$ (for low CL PI group) | <br>$d = .38$<br>$d = .44$<br>$d = .34$<br>$d = -.30$ | <br>$M_{TB} - M_{BB} = .38$<br>$M_{TB} - M_{BB} = .29$<br>$M_{TB} - M_{BB} = .30$<br>$M_{TB} - M_{BB} = .23$ |

| | | | | |
|---|---|---|---|---|
| | | [24] $p < .004$, $\eta_p^2 = .11$ (for Phase × Gender) | | |
| | | $p < .39$ | | $M_{MBB} = 4.47$ (.83) |
| | | | | $M_{FBB} = 4.42$ (.81) |
| | | $p < .75$ (for female) | | $M_{TB} = 4.39$ (.87) |
| | | [25] $p < .002$ (for male) | $d = .44$ | $M_{TB} = 4.86$ (.92) |
| Wegner et al. (1998, Study 1) | Putting distance (in cm) | [26] $p < .06$, $MSE = 5523.13$ | | $M_{M} = -11.67$ |
| | | | | $M_{F} = 19.61$ |
| | | $p < .05$ | | $M_{CL} = 20.79$ |
| | | (under CL plus AI for first putt compared to without CL) | | $M_{nCL} = 11.43$ |
| | | $p < .07$ ('Load' × VM) | | $M_{VML} = 32.87$ |
| | | | | $M_{VMnL} = -9.07$ |
| | | | | $M_{nVML} = 8.71$ |
| | | | | $M_{nVMnL} = -13.78$ |
| Wegner et al. (1998, Study 2) | Stability performance | $p = .05$ ('Load' × Instruction × Direction) | | |
| | | [27] $p = .01$, $MSE = .01$ | | $M_{L} = .59$ |
| | | | | $M_{nL} = .50$ |
| | | [28] $p = .01$, $MSE = .01$ | | $M_{L} = .59$ |
| | | | | $M_{L} = .47$ |
| | | [29] *ns.* (for 'Load' types) | | |

Notes: (1) We adhered to specific regulations for extracting *p* values, i.e., we extracted interaction effect *p* values for the statistically significant main effects. But for the nonsignificant interaction *p* values, we extracted mean scores if studies conducted and reported post-hoc analysis; (2) We did not calculate effect sizes for any study's primary outcome, we rather presented the effect sizes as reported by each study; (3) The significant *p* values for regression on neuroticism moderation as per Judd et al. (2001) methodology; (4) The reported nonsignificant *p* value showed that elite athletes' shooting performance in the ironic error zones were neither significantly far away from the target zone nor significantly too close to the ironic error zone across both anxiety conditions regardless of ironic effects; (5) The nonsignificant *p* value showed that participants let more target balls go than ironic error and non-ironic error balls across anxiety conditions; (6)The significant *p* value showed that Participants' target and ironic performance were unchanged regardless of ironic effects; (7) Pitch thrown in the target zone; (8) The significant interaction *p* value for MANOVA on four kinematic variables; (9) The significant interaction *p* values for follow-up ANOVA analyses on each kinematic variables (except for the maximum upper torso rotational velocity); (10) For ironic pitchers; (11) Post-hos analysis for performance under HA when given AI; (12) The significant *p* value for chi-square on group level; (13) Under both experimental instruction conditions compared to NI condition; (14) Players fixated longer under AI compared to PI and NI conditions; (15) Post-hoc analysis revealed that ironic participants shot the ball closer to the keeper under AI compared to PI and NI conditions compared with no-ironic participants; (16) Post-hoc analysis showed that participants who showed ironic effects tended to start their final fixation earlier (before ball contact) on the open-goal space compared to the no-ironic participants; (17) Shooting performance was unaccompanied by shorter final fixation on the open-goal space in the AI condition compared to the PI and NI conditions for no-ironic participants; (18) Focused on comparing the results with those of Wegner et al. (1998, study 1); (19) The effect size *d* value computed descriptively for performance under high CL and AI compared to low CL; (20) Performance under high CL and AI compared to PI; (21) The nonsignificant *p* value showed that authors' assumption of performance under high CL was unsupported; (22) Groups showed declined performance; (23) Groups improved their performance considerably; (24) The single significant interaction effect reported involving gender; (25) Poor performance in the test block compared to in baseline block; (26) A marginally significant *p* value for sex difference; (27) Participants exhibited extra movement errors when they tried to avoid the to-be-avoided direction under 'load' compared to without 'load'; (28) Participants committed more movement errors under 'load' when given AI compared to under 'load' when given PI; (29) The nonsignificant main or interaction effect on CL and physical load indicated that the incidence of ironic movements errors were not specifically relied on either CL or physical load; (30) Abbreviations used as follows: T*P* = target performance; IPE = ironic performance error; NIPE = non-ironic performance error; POI = precision of irony: Woodman et al. (2015) conceptualized it as measuring arc-length from the closest non-ironic error zone and radial error, i.e., the radial distance from the target zone. PR*P* = pre-pressure; *P* = pressure; PO*P* = post-pressure; LFL*P* = leading foot landing position; EFA = elbow flexion angle; PAAD = pitch-body axis angular deviation; BB = baseline block; TB = trial/test block; IR = ironic; NIR = no-ironic; OS = 'open-space' condition (as PI); NI = neutral instruction; AI = avoidant instruction; TB3 = 'no-load' block in de la Pena et al. (2008, Study 1); SI = stability index; CL = cognitive load; nCL = no-CL; M = male; F = female; MSE = mean standard error; L = 'load'; nL = 'no-load'; VM = visual monitoring load; nVM = no-visual monitoring load; *Attention, CL, gender, and order were used as a between-subject factor, whereas phase (BB and TB) used as a within-subject factor in the repeated measure ANOVA analyses.

oriented instructional interventions to reduce ironic errors (Gorgulu et al., 2019, Studies 3 and 5). They found that participants showed stable and satisfactory performance when the avoidant goals were tailored to 'not let the ironic color balls go' across anxiety conditions. Except for Study 1, which did not incorporate the non-ironic error measures, all four studies found that action- and inaction-oriented goals had no effect on participants' reactions to non-ironic error stimuli across anxiety conditions.

### *Direction outcome-based motor task*

Woodman and Davis (2008) investigated how anxiety and specific anxiety coping styles influence the likelihood of ironic errors, particularly in repressors, who reported low cognitive anxiety but had high heart rates under high-anxiety conditions. They found that when instructed 'don't overshoot', novice repressor golfers significantly put the ball further under high-anxiety compared to low-anxiety conditions.

## *Dual-task-based techniques*

Of the reported dual-task-based manipulation techniques ($k = 8$), four included memory and arithmetic tasks, three studies used visual attention tasks, and one implemented a cue rehearsal task.

### *Memory and arithmetic tasks*

Wegner et al. (1998) reported that novice golfers significantly put the ball longer when given 'don't overshoot' instructions under 'load' compared to without 'load' conditions (Study 1). However, de la Peña et al. (2008) reported that trained golfers significantly put the ball in the direction opposite to the 'don't put the ball short' instructions under 'load' compared to 'no-load' conditions (Study 1). This is because, as predicted by de la Peñ a and colleagues' implicit overcompensation hypothesis[4], instructions like 'don't putt it short' may unintentionally lead golfers to putt the ball longer—a phenomenon known as *overcompensating errors*. Additionally, Dugdale and Eklund (2003) found that highly trained dancers committed more movement errors and showed less stability when given 'don't wobble' instructions under a high-cognitive load (i.e., counting a digit-number backward mentally) compared to when given 'hold steady' instructions under the same high-cognitive load condition. Wegner and colleagues' (1998) study constituted the only concurrent task manipulation involving physical load—holding a load in one's nondominant hand (Study 2). They found that participants demonstrated an enhanced movement towards the to-be-avoided direction when given 'don't shake' instructions under both cognitive (i.e., counting a digit-number backward mentally) and physical 'load' compared to the 'no-load' conditions.

### *Visual attention tasks*

Under time pressure and visual distractions, Bakker et al. (2006) found that highly trained football players' performance and their initial gaze-fixations were significantly more directed toward the to-be-avoided ('not-keeper', 'not-next to the goal') and positive ('hit the open space') instructions than the neutral instruction condition (Study 2). Furthermore, Binsch et al. (2010a) found that ironic players kicked their penalties closer to the to-be-avoided target (i.e., keeper) under both 'not-keeper' and 'pass-keeper' instructions to a similar degree than under the neutral instruction condition. Notably, ironic players fixated significantly longer on the keeper when given 'not-keeper' instructions than both 'pass-keeper' and neutral instruction conditions, increasing the likelihood of ironic errors. Binsch et al. (2010b) found that players (44%) who demonstrated ironic errors had shorter final fixations on the open goal space under 'not-keeper' instructions than under 'open-space' and neutral instruction conditions.

### Cue rehearsal task

A study conducted by Liu et al. (2015) reported that the low-cognitive load (no-time constraint) and 'don't shake' rehearsal groups performed worse in the test block than the baseline block, committing more unsteady movement errors. Particularly, male participants' performance deteriorated in the test block compared to the baseline block, but female participants' performance remained similar across both blocks.

## Theoretical perspectives of the reviewed studies

While this review uncovered the underlying nature of the ironic processes-performance relationship when given avoidant instructions under conditions of cognitive load, the majority of the reviewed studies' findings ($k = 22$; 92%) align with Wegner's theory. Two studies ($k = 2$; 8%) provided inconclusive findings: de la Peña et al. (2008, Study 1) supported the implicit overcompensation hypothesis, whereas Gorgulu and Gokcek (2021) did not support Wegner's theory but did provide significant insight into Woodman et al.'s (2015) assumption. That is, distinguishing between ironic and non-ironic performances is critical when testing ironic errors in motor performance.

Furthermore, the review highlights that few studies tailored their examinations on the likelihood of ironic errors toward their predictions, and hence their measurements. For instance, ironic errors were partially mediated by gaze fixation (Binsch et al., 2010a), and moderated by specific dispositions, such as neuroticism[5] and anxiety coping styles (Barlow et al., 2016, Studies 1–2; Woodman & Davis, 2008). Exceptionally, Gray and colleagues' (2017) kinematics findings substantiated Wegner's assumption of how precisely participants' specific movement patterns broke down when anxious. Two studies, in particular (Liu et al., 2015; Oudejans et al., 2013), suggested that ironic errors can be a contributing factor to choking under pressure. However, Liu et al. partially supported Wegner's theory under low-cognitive load but not under high-cognitive load conditions.

In the studies that incorporated both avoidant and positive instructions, Bakker et al. (2006, Study 2) and Binsch et al. (2010a) suggested that ironic errors can also occur when given positive instructions—including words related to the forbidden target. Furthermore, Gorgulu et al.'s (2019) interventional studies support theoretically driven assumptions. Their studies (Studies 3 and 5), for example, reveal that ironic errors were less likely when the operator had an advantage over the monitor when given inaction-oriented goals, which are easy and energy-saving to process.

# Discussion

This systematic review evaluated current evidence on the incidence of ironic errors of motor performance. A considerable amount of literature has investigated the likelihood of ironic errors in motor actions, despite some scholars have expressed doubts about Wegner's theory (Hall et al., 1999; Janelle, 1999). We reviewed twenty-four separate studies that investigated the likelihood of ironic errors using thirteen motor tasks. Of the twenty-four studies, more than half (*k* = 15) were published between 2015 and 2021. The most common cognitive load manipulation techniques were anxiety-based (k = 16; 67%) and dual-task-based (*k* = 8; 33%). Furthermore, cognitive load manipulation techniques were integrated with avoidant instructions and implemented experimentally (*k* = 5) and quasi-experimentally (*k* = 19) using within- and between-subject designs. Despite two studies' inconclusive findings, most of the reviewed studies support Wegner's theory. However, given the significant heterogeneity in the samples, motor tasks, designs, methods, manipulation, and measurement techniques used, comparing findings between and within the included studies is problematic. As a result, caution is necessary when interpreting the evidence. In the following sections, we will address these concerns as well as the efficacy of the manipulation and measurement techniques.

### Sample and study characteristics

While analyzing study characteristics, we identified that novice volunteer participants made up exactly half of the participants in the reviewed studies, whereas some were highly trained participants with small sample sizes. Although empirical evidence on elite performers is limited in relation to Wegner's theory (see Gorgulu, 2019a), there is also a general lack of investigations on the likelihood of ironic errors among national, international, and professional athletes. As predicted, it is not surprising that the effect of cognitive load on ironic errors is more prominent for novice participants when given avoidant instructions (Wegner et al., 1998). However, Gorgulu (2019a) showed that elite participants are not immune to ironic errors when given avoidant instructions under high-anxiety conditions.

Furthermore, seventeen studies conducted their experimental manipulations in lab settings. While lab-based experimentation is critical, the generalizability of research findings in highly structured and controlled scenarios compared to 'real-world[6]' and 'ecologically valid (see endnote 6)' professional sports competitions is somewhat problematic. To address the main question of this review, namely, how cognitive loads induce ironic errors when given avoidant instructions, the reviewed studies used experimental and quasi-experimental designs, albeit disproportionately. While assessing the quality of the reviewed studies using MMAT (Hong et al., 2018), we identified two major issues for quasi-experimental studies: failure to address potential confounding factors and selection bias. Therefore, caution should be used when interpreting the findings associated with small sample sizes, limited data on the likelihood of ironic errors among highly trained and elite participants, and questionable experimental methodologies.

### The effectiveness of cognitive load manipulation and measurement approaches

When analyzing cognitive load manipulation techniques, we noted three key issues: first, twenty studies in the review induced cognitive loads with ecologically valid competitive stressors[7] that mimicked pressure in real-world scenarios. Conversely, four dual-task-based studies induced cognitive loads to tax participants' working memory (rehearsing and counting a digit-number). However, researchers have expressed concerns about using memory and arithmetic manipulation techniques; specifically, their viability in sports performance contexts is limited in terms of inducing competitive anxiety (Woodman et al., 2015; Woodman & Davis, 2008). An exception to this concern is the study by Wegner et al. (1998), which incorporated the physical load (Study 2).

Second, it is worth noting how the reviewed studies measured cognitive load. Anxiety-based studies were successful in monitoring participants' level of anxiety by integrating direct (e.g., heart rate, heart rate variability, and muscle activity) and indirect (e.g., MRF-3) measurements of anxiety. Furthermore, Gorgulu (2019a) used a rating scale of mental effort to track how much resources elite athletes used to deal with the anxiety manipulations, despite the nonsignificant main or interaction effects across anxiety conditions (see Table 4). Evidence from mainstream psychology research suggests that measuring mental effort coupled with task performance represents the most reliable estimator of cognitive load (Paas et al., 1994). Of the dual-task-based studies, four studies monitored the effectiveness of the outcomes of cognitive load manipulations, such as visual attention using eye-tracking devices (Bakker et al., 2006, Study 2; Binsch et al., 2010a, 2010b) and using post-test pressure rating (Liu et al., 2015). On the other hand, three studies that manipulated cognitive load through memory and arithmetic tasks were unsuccessful in reporting participants' rehearsal accuracy of a digit-number. Furthermore, they failed to explain whether the rehearsal methods are linked to measuring participants' mental effort or testing the strengths of cognitive load manipulations. The study by Dugdale and Eklund (2003) is an exception in that they noted each participant's rehearsal report and provided verbal feedback on its accuracy. Although de la Peña et al. (2008) monitored the memory manipulations by having participants rehearse the digit-sequence aloud, they failed to monitor the effectiveness of their other 'load' manipulations (Study 1). On the other hand, Wegner et al. (1998) did not disclose how they controlled participants' physical exhaustion when holding a common brick with their nondominant hand, as well as their mental effort when counting a digit-number backward mentally (Study 2). Consequently, inducing either a cognitive or physical load without any 'load' manipulation check may raise questions about its effectiveness.

Last, while analyzing the instructional manipulations, we noted that all studies in the review used avoidant instructions as pressure-inducing elements in combination with cognitive load-inducing stressors, such as financial incentives, rewards, time pressure, videotaping, and performing at height. The most frequently used avoidant instructions that aim to manipulate anxiety using multiple ecologically valid stressors are ego-threatening and social evaluative instructions. Instructing participants that they will be penalized for every action they perform in the forbidden zones or in response to the to-be-avoided stimuli as well as informing them that their videotaped performance or score will be evaluated by a coach are examples of ego-threatening and social evaluative instructions. Two studies, for instance, found that the effects of ego-threatening and social evaluative instructions, and financial incentives on ironic errors were moderated by personality traits such as neuroticism and repression (Barlow et al., 2016, Studies 1–2; Woodman & Davis, 2008). In contrast, Gorgulu and Gokcek (2021) found that participants did not show ironic errors using award, ego-threatening, and social evaluative instructions. This implies that using multiple ecologically valid stressors to induce cognitive load such as anxiety may have different effects on anxiety responses depending on the individual and the context.

**Table 4.** Summary of cognitive load measurements and outcome reporting (Mean, SD, [1]*p* values, effect size[2]).

| Reference | Condition | Anxiety (MRF-3) | | | HR (bpm) | HRV | | MA (μV) | ME |
|---|---|---|---|---|---|---|---|---|---|
| | | CA | SA | SC | | SDNN (ms) | r-MSSD (ms) | | |
| *i. Anxiety-based* | | | | | | | | | |
| Barlow et al. (2016, Study 1) | LA | 9.07 (1.82) | 8.69 (2.05) | 4.16 (2.09) | | | | | |
| | HA | 7.30 (2.19) | 7.33 (2.17) | 5.25 (2.49) | | | | | |
| | | ***[1] | *** | *** | | | | | |
| Barlow et al. (2016, Study 2) | LA | 8.10 (2.48) | 7.63 (2.60) | 5.46 (2.06) | 85.83 (12.72) | 75.34 (18.93) | 40.63 (15.48) | | |
| | HA | 6.37 (2.86) | 6.09 (2.57) | 6.17 (2.22) | 96.03 (14.20) | 64.34 (18.93) | 35.05 (15.27) | | |
| | | *** | *** | *p* = .004 | *** | *** | *** | | |
| Gorgulu (2019a) | LA | 6.56 (2.48) | 6.18 (2.27) | 6.23 (1.93) | 81.75 (18.15) | 65.13 (21.75) | 46.38 (25.41) | | 82.65 (19.40) |
| | HA | 8.24 (2.25) | 7.83 (2.64) | 5.20 (1.97) | 94.58 (16.40) | 53.47 (22.63) | 31.33 (18.47) | | 98.43 (20.35) |
| | | *** | ** | ** | * | ** | ** | | [3]*ns.* |
| Gorgulu (2019b) | LA | 4.75 (2.29) | 5.43 (2.37) | 6.70 (1.59) | | | | | |
| | HA | 7.86 (2.09) | 8.18 (1.82) | 4.48 (1.72) | | | | | |
| | | *** | *** | *** | | | | | |
| Gorgulu (2019c) | LA | 5.00 (1.54) | 4.81 (1.92) | 7.43 (1.74) | | | | | |
| | HA | 7.87 (1.97) | 8.21 (1.71) | 4.25 (1.52) | | | | | |
| | | *** | *** | *** | | | | | |
| Gorgulu et al. (2019, Study 1) | LA | 4.96 (2.69) | 5.47 (2.58) | | 92.85 (15.28) | | 44.19 (27.51) | 27.01 (11.89) | |
| | HA | 7.35 (2.58) | 7.45 (2.18) | | 95.44 (14.39) | | 33.53 (17.33) | 29.59 (13.81) | |
| | | *** | ** | | * | | ** | * | |
| Gorgulu et al. (2019, Study 2) | LA | 4.77 (1.95) | 5.25 (2.03) | | 90.59 (16.36) | | 59.29 (33.54) | 23.31 (10.55) | |
| | HA | 7.40 (2.3) | 7.55 (1.72) | | 92.81 (15.61) | | 47.84 (26.02) | 25.22 (12.42) | |
| | | *** | *** | | ns. | | ** | *ns.* | |
| Gorgulu et al. (2019, Study 3) | LA | 4.85 (2.4) | 5.14 (2.44) | | 87.36 (12.30) | | 50.35 (23.82) | 23.45 (12.67) | |
| | HA | 7.29 (2.00) | 7.46 (2.00) | | 91.23 (14.03) | | 41.43 (18.92) | 25.29 (15.17) | |
| | | *** | *** | | *** | | *** | * | |
| Gorgulu et al. (2019, Study 4) | LA | 3.70 (2.21) | 4.29 (2.25) | | 85.69 (17.37) | | 56.30 (32.96) | 47.33 (33.10) | |
| | HA | 6.66 (2.61) | 6.33 (2.40) | | 90.46 (20.03) | | 21.28 (9.06) | 22.09 (9.62) | |
| | | *** | *** | | *** | | * | *ns.* | |
| Gorgulu et al. (2019, Study 5) | LA | 5.69 (1.91) | 5.21 (1.85) | | 80.91 (11.26) | | 49.92 (24.94) | 20.25 (7.67) | |
| | HA | 6.82 (2.20) | 6.56 (2.27) | | 86.11 (14.88) | | 39.48 (21.75) | 20.40 (7.47) | |
| | | * | * | | * | | * | *ns.* | |
| Gorgulu and Gokcek (2021) | LA | 4.96 (2.69) | 5.47 (2.58) | 6.03 (1.95) | 133.14 (29.71) | 63.99 (26.87) | 27.01 (11.89) | | |
| | HA | 7.35 (2.58) | 7.45 (2.18) | 5.00 (2.23) | 137.80 (27.13) | 57.40 (22.23) | 29.59 (13.81) | | |
| | | * | ** | [4]*ns.* | [5]* | [5]*ns.* | [5]*ns.* | | |
| [6]Gray et al. (2017) | Pre-test | 1.9 (.7) | | | 83.6 (5.2) | | | | |
| | Pressure | 3.0 (.7) | | | 88.7 (5.9) | | | | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | Post-test | 2.1 (.3) | | | 84.4 (5.5) | | |
| | | ***, $\eta_p^2 = .48$[2] | | | ***, $\eta_p^2 = .29$[2] | | |
| [7]Oudejans et al. (2013) | LP | 1.90 (1.26) | | | 109.25 (16.31) | | |
| | HP | 3.84 (1.75) | | | 111.98 (18.52) | | |
| | | | | | *, $f = .33$[2] | | |
| [8]Woodman and Davis (2008) | [9]Baseline | 7.91 (1.97) | 7.27 (1.79) | 7.45 (2.62) | 83.09 (9.46) | | |
| | £50 putt | 8.82 (1.78) | 7.82 (2.72) | 8.73 (2.15) | 96.91 (12.34) | | |
| | | *ns.* | *ns.* | *ns.* | *** | | |
| Woodman et al. (2015, Study 1) | LA | 6.83 (2.46) | 6.38 (2.49) | 6.80 (2.09) | | | |
| | HA | 8.50 (1.90) | 7.83 (2.30) | 5.23 (2.02) | | | |
| | | *** | *** | *** | | | |
| Woodman et al. (2015, Study 2) | LA | 6.37 (2.86) | 6.09 (2.57) | 6.17 (2.22) | 85.49 (12.96) | [10]726.52 126.55) | |
| | HA | 8.10 (2.48) | 7.63 (2.60) | 5.46 (2.06) | 97.79 (16.15) | 641.46 (99.22) | |
| | | *** | *** | ** | *** | *** | |
| *ii. DT-based* | | | | | | | |
| | Phase | PP | | | Mean | | Cohen's *d* |
| Liu et al. (2015) | Baseline Test | $p < .03$, $\eta_p^2 = .06$ (CL × TB) | | | [11]1.05 for HCL | 50[2] | |
| | | | | | .30 for LCL | | |
| | | $p = .26$, $\eta_p^2 = .02$ (Phase × CL using SCL) | | | | | |

Notes: (1) *p* values: ****p* < .001; ***p* < .01; **p* < .05; *ns.* = nonsignificant; (2) Effect sizes as reported by the studies; (3) The nonsignificant *p* value signifies that ME did not correlate to any of the physiological indices; (4) Participants' self-confidence did not change across anxiety conditions; (5) The association between HR and HRV is contradictory; (6) CA was measured using the IAMS; (7) CA was measured using STAI; (8) Authors used MRF-3 and HR scores to classify participants' coping style; (9) For repressors; (10) R-R interval mean values; (11) HCL group perceived high pressure compared to LCL group, indicating the effectiveness of the CL manipulation; (12) Abbreviations used as follows: MRF = mental readiness form; CA = cognitive anxiety; SA = somatic anxiety; SC = self-confidence; IAMS = immediate anxiety measure scale; STAI = state-trait anxiety inventory; HR = heart rate; HRV = heart rate variability; MA = muscle activity; μV = microvolts; ME = mental effort; r-MSSD = root mean square of the successive differences; SDNN = standard deviation of NN intervals; ms = milliseconds; bpm = beat per minute; L*P* = low position (as low anxiety); H*P* = high position (as high anxiety); TB = trial/test block; CL = cognitive load; HCL = high cognitive load; LCL = low cognitive load P*P* = perceived pressure; SCL = skin conductance level

On the other hand, thirteen studies failed to report whether participants followed the given instructions. Twenty-three studies, for example, did not monitor participants' responses to instructional manipulations (see Table S5). One study that did offer such an example is that of Liu et al. (2015), in which they assessed participants' attentional focus on the given instructions using a post-experimental survey that was reported to be effective.

## Effectiveness of performance measures

This review highlights that measuring motor performances in a controlled environment raises concerns over ecological validity while testing Wegner's theory. For example, measuring a single trial's performance, like the single putts used by Wegner et al. (1998, Study 1) and Woodman and Davis (2008), appears 'ecologically valid'. However, most studies show that ironic errors are also likely to occur after repeated participant performances across trial blocks. Another concern related to ecological validity when measuring performance is giving opportunities to re-attempt the task (Barlow et al., 2016, Studies 1–2) and the specificity of the tasks, such as the use of virtual goalkeepers and goals (Bakker et al., 2006, Study 2; Binsch et al., 2010a, 2010b), a virtual batter (Gray et al., 2017), wobble board tasks for dancers (Dugdale & Eklund, 2003), dart throwing at height (Oudejans et al., 2013), the absence of real goalkeepers (Barlow et al., 2016, Study 1; Woodman et al., 2015, Study 1), and absence of opponents in ball servings tasks (Gorgulu, 2019c; Gorgulu & Gokcek, 2021).

Furthermore, nine studies in the review measured participants' performance using the 'one-dimensional' approach, such as asking participants to perform a desired action or not to perform an undesired action. For example, asking participants to stay stable is a desirable behavior in a balance performance, whereas asking them not to shake and if they shake, it is an undesirable behavior. Consequently, participants' undesirable actions were conceptualized as ironic errors. However, it is unclear whether participants' undesired behaviors are the result of ironic errors or simply poor performances under conditions of cognitive load when given avoidant instructions. In contrast, thirteen anxiety-based studies offered promising examples of measuring participants' motor task performances using the 'two-dimensional' approach: the specific ironic errors and the generic non-ironic errors. Given everything discussed so far, the generalizability of the findings and the efficacy of the experimental manipulations in the reviewed studies are contentious.

## Theoretical stance inconsistencies

This section discusses contradictory results and theoretical support positions. Gorgulu and Gokcek (2021), for instance, did not support Wegner's theory since they found a generic serve error rather than a specific ironic serve error. The most striking finding from the data is that players performed effectively while being exposed to competitive stressors (see Tables 4 and S4). Two possible explanations exist for these findings: first, for the sake of winning the present, players might be conscious of the need to avoid serving into the ironic zone, which was allocated adjacent to the target zone. Furthermore, they recognized that the task is being performed in the absence of an opponent.

Second, the players might not pay attention to the ego-threatening and social evaluative instructions during the trials. Consequently, they might not find the anxiety manipulations or task meaningful. Concerns like these could be addressed by looking at different behavioral measures, such as gaze-behavior, using manipulation checks to see how participants respond to instructions, and modifying instructional manipulations by adding more ecologically valid stressors that can increase their level of anxiety.

The paradox of testing Wegner's theory is shown by the results of the likelihood of ironic errors (Wegner et al., 1998, Study 1) and the likelihood of overcompensating errors (de la Peña et al., 2008, Study 1). This inconsistency might be the result of differences in approach at the conceptual level; for example, the implicit overcompensation hypothesis is not rooted in a theory; at the very least, its assumption is not based on a dual-process system, as Wegner's theory is. As such, its potential to explain ironic processes is questionable. Furthermore, Wegner's theory emphasizes the importance of cognitive load when given avoidant instructions, whereas the implicit overcompensation hypothesis emphasizes the impact of negative self-instruction on the efficiency of attentional resources, although de la Peña et al. did offer support for the implicit overcompensation hypothesis under four different 'load' conditions when given negative instructions. However, some of the 'loads' used by de la Peña and colleagues lack ecological validity in taxing participants' attentional resources.

Methodological concerns in relation to the direction of the avoidant instructions might be another potential cause. Neither study, for example, attempted to simultaneously manipulate 'don't overshoot' and 'don't undershoot' instructions. As well, the study by Wegner et al. included novice golfers, whereas de la Peña et al. included trained golfers. Furthermore, de la Peña et al. found that a small percentage of golfers (37.5%) showed ironic errors, implying that both the likelihood of overcompensating and ironic errors might coexist when given avoidant instructions under 'load' conditions in the golf-putting tasks. Recently, a study that was not included in this review attempted to explain their co-occurrence using an attentional imbalance paradigm in golf-putting task performances (Liu et al., 2019). It is interesting to note whether the predisposition to overcompensating errors is exclusive to the golf sport or ubiquitous in the performance of other professional sports. However, questions remain unanswered at present, including the mechanism of the co-occurrence of ironic and overcompensating errors when given avoidant instructions under cognitive load, and whether the implicit overcompensation hypothesis and Wegner's theory may interact in the dual-process system.

## *Methodological critique*

This review highlights some methodological concerns that stemmed from the experimental manipulations, measurements, and analyses. As an ecologically valid stressor, time constraints made it hard for participants to control their attention during visual attention tasks, which ironically diverted their gazes to the to-be-avoided locations (Bakker et al., 2006, Study 2; Binsch et al., 2010a; Binsch et al., 2010b). In these studies, however, time as a cognitive load was not retained as a factor and the findings were also analyzed at the group level. More importantly, time pressure is a significant feature of competitive sports (Janelle, 1999), which applies to penalty kickers who tend to kick the ball quickly under pressure conditions (Jordet, 2009). Similarly, Gorgulu et al. (2019, Studies 1–5) did not include time in their analysis, even though time pressure is an integral part of reactive motor tasks, which may enhance ironic errors (Wegner, 1994).

Counterbalancing experimental conditions is fundamental to experimental research (Shaughnessy et al., 2000). As noted, quasi-experimental studies ($k = 8$) used fixed presentations of anxiety conditions to lessen the anxiety burden on novices. Despite the studies monitored the anxiety carryover effect in participants, this strategy has at least two major drawbacks, First, it may suggest that there is only a single linear link between cognitive load and ironic performance errors. It may also infer that investigating the phenomenon of ironic error in the realm of sports performance is straightforward.

Another point worth mentioning is the instructional manipulations. We noted that most studies used negative priming phrases while giving both short and long avoidant instructions. It is questionable, however, which of the two factors—the participants' attempts to suppress the avoidant instructions or the negative priming phrases—contributed more to an increased likelihood of ironic errors (Woodman et al., 2015). Furthermore, from a practical standpoint, it is uncommon for professional athletes and coaches to make use of extensive instructions combined with negative priming statements. As a result of this, the findings of the reviewed studies showed a discernible bias on the part of the researchers when they manipulated just a limited set of ecologically valid instructions about how the participants should act.

### *Conceptual issues*

Understanding theoretical work and providing conceptual definitions of constructs rigorously are prerequisites for good measurement and manipulation strategies, which increase the development of effective experimental manipulation (Breakwell et al., 2006; Chester & Lasko, 2021). The concept of cognitive load[8], as discussed in the introduction section, is central to Wegner's theory. Researchers often mix cognitive load with the construct of mental load, but none of the reviewed studies provided operational definitions of the constructs. While manipulating the same arithmetic task, for example, Dugdale and Eklund (2003) used the term cognitive load, whereas Wegner et al. (1998) used the term mental load (Study 2). Further, we identified that the reviewed studies used different variants of avoidant instructions, including avoiding instructions (Gorgulu & Gokcek, 2021), negative self-instructions (de la Peña et al., 2008, Study 1), negative instructions (Oudejans et al., 2013), and suppressive self-talk cues (Liu et al., 2015). It is surprising that the reviewed studies used the various terminologies without explicating the constructs in sport-specific contexts using Wegner's theory.

Furthermore, within the context of Wegner's theory, ironic processes are the operators' and monitors' pathways through which mental control are traced. Ironic effects and ironic errors, on the other hand, are both examples of behavior (performance) outcomes. When describing performance outcomes, the reviewed studies often used terminologies like 'ironic processing incidences', 'ironic movement errors', 'ironic effects', and ironic errors', which may confuse researchers and sport psychologists. In particular, two studies revealed that benefiting the operator with inaction-oriented goals, such as simple positive instructions can reduce the incidence of ironic errors (Gorgulu et al., 2019, Studies 3 and 5). However, sport- and cognitive-psychology literature have criticized the use of dual-process approaches for oversimplifying the types of instructions employed (Fritsch et al., 2022; Melnikoff & Bargh, 2018). This raises questions concerning the reliability with which researchers may interpret thefindings from the dual (cognitive) pathways approach, as was done in the studies conducted by Gorgulu et al. (2019, Studies 3 and 5). Methodological and conceptual flaws in the existing evidence on the ironic effects of motor performance casts doubt. Therefore, the findings of the reviewed studies and any general inferences regarding the efficacy of the experimental manipulations should be approached with caution.

### Strengths and limitations

The review's strengths include its critical evaluation of empirical studies, which aimed to spark future interest in Wegner's theory in motor performances, and its call for more transparency and less author bias. However, it does have certain drawbacks. Because the review's scope is confined to Wegner's theory, further insights might have been missed due to the exclusion of research that tested Wegner's theory alongside alternative paradigms in motor task performances. Also, the review only includes studies that examined motor tasks in sports settings: the incidence of ironic effects influences individuals in sporting contexts similarly across different psychological performance contexts because it is a disposition (Wegner, 1997b).

Due to sizable heterogeneity in the reviewed studies, our attempt to categorize studies and synthesize the results using both statistical and narrative approaches could be seen as a limitation. This is because combining both approaches may imply that true-experimental studies are equally important as quasi-experimental studies in explaining the direction of the manipulation effects reported. Furthermore, our approach to grouping studies merges those that use ecologically valid cognitive load stressors with those that do not. This is particularly true in dual-task-based studies. However, we do not think these limitations affect the conclusions of the current review because its primary goal was to explain what ironic effects are, how the cognitive load manipulation techniques work, how effective the manipulations are, and whether they can be used in sporting contexts.

### Future directions

Based on this review, future studies should consider the following to further advance Wegner's theory. Sample classification frameworks (McKay et al., 2022; Swann et al., 2015) may be used to address the gaps in the explanatory power of the reviewed studies on categorizing participants' skill levels, especially highly trained and elite participants. Due to the paucity of data, expert and professional elite athletes should be tested using ecologically valid performance stressors in various contexts.

The present review recommends using rigorous methodologies, such as randomized controlled trials, to understand the causal effects of distinct stressors on ironic errors. In addition, intervention trials are important to reduce the likelihood of ironic errors. Gorgulu et al. (2019) recommended providing simple positive instructions (i.e., process goals) to mitigate the likelihood of ironic errors (Studies 3 and 5). To determine the viability of their suggestions, future research should experimentally test holistic process goals in ecologically valid professional sports. This is because training toward process goals may help performers overcome high-anxiety circumstances and focus on the most crucial aspects of their performances (Kingston & Hardy, 1997). Furthermore, inner and outer distractions and emotional loading such as anger and anxiety, might increase the likelihood of ironic effects (Wegner, 1994). Consequently, future research should develop cognitive strategies to help athletes reduce internal and external distractions while suppressing unwanted thoughts in competitive scenarios or when applying negative self-instructions. Another practical strategy to reduce the likelihood of ironic errors is to teach athletes and coaches about the phenomenon and why it is important to stay present-centered and nonjudgmental about their internal and external thoughts and feelings, which are transient incidences that come and go in the conscious mind (Gardner & Moore, 2004; Josefsson et al., 2019).

The presentation of cognitive load manipulations varies significantly in terms of intensity and frequency in the reviewed studies. Adopting the idea from Mellalieu et al. (2021), future research should be explicit about the dimensions of the cognitive load construct when testing ironic errors in motor performance. These dimensions include the type of stressors (ecologically valid or limited ecologically valid stressors), the intensity of stressors (single or multiple stressors), the duration of the stressors (longer or shorter), and the frequency of the stressors (more or less frequent).

Although, as previously discussed, the present review provides promising examples in terms of cognitive load and performance measurements, future research should incorporate other cognitive load measurements, like mental effort, with more objective neuroimaging tools (EEG and fMRI) as used in sports (Tan et al., 2019). Furthermore, EEG and fMRI may foster future research to determine whether brain processes and determinants of thoughts influence the likelihood of ironic errors under conditions of cognitive load. In the absence of such objective measures, however, researchers can use post-experimental manipulation checks and Likert scale surveys to identify the mediating variables (Hauser et al., 2018).

The overriding strengths of the reviewed studies were that few studies examined potential individual variables that might moderate the cognitive load and ironic processes relationships (Barlow et al., 2016, Studies 1–2; Woodman & Davis, 2008). Working memory capacity is crucial in determining the link between the attained mental control and the ironic effects on the dual-process system (Wegner, 1994). As such, future research should look at how one's attention span (working memory capacity) influences their propensity to ironic errors, particularly when performing cognitively demanding motor tasks.

The reviewed studies lack a compelling theoretical rationale for using a dual-process approach for instructional manipulation. The provision of rationales safeguards the need for the research method employed, which is important for theory development and practice (Javernick-Will, 2018). As such, future research should focus on developing a sport-specific model to explain how the neural bases of avoidant instructions affect motor control. One approach again is to use neuroimaging technologies to investigate whether avoidant instructions on their own can tax participants' cognitive resources, increasing the likelihood of ironic errors.

If Wegner's theory gains prominence, further consideration will need to give more thought to the operational definitions of terms like cognitive load, avoidant instructions, and the term 'load,' as used by de la Peña et al. (2008) and Wegner et al. (1998). While investigating Wegner's theory in sports context, we suggest that future studies may consider the definition of cognitive load proposed by Russell et al. (2020). Furthermore, researchers should minimize their preference for manipulating lengthy instructions that may hardly have real-world applications, as this may improve the efficacy of the experimental manipulations.

## Conclusion

Based on a review of twenty-four studies presented in seventeen published articles about ironic effects on motor task performance, it is apparent that further research is necessary. Future investigations of ironic processes should not be limited solely to athletes and motor performance in sports, but should also consider surgeons, healthcare professionals, and members of the armed forces. These professions may benefit from knowledge about the consequences of ironic effects on motor performance during tasks that require snap decisions and responses to ever-changing environmental stimuli. By pursuing these directions, experts working in this area can better understand how best to develop interventions aimed at reducing susceptibility to ironic effects and helping individuals and athletes thrive under high-pressure conditions in sports and other areas of life.

## Notes

1. The term is used in this review to refer to the phenomenon of ironic effect in sports performance contexts as conceptualized in Wegner (1994) and Woodman et al. (2015).
2. Any action that requires motor skills, such as kicking, throwing, catching, hitting, serving, balancing, running, jumping, and so on in the context of sports performance.
3. Further subcategorized into closed ($k = 16$) and open ($k = 8$) motor tasks.
4. The assumption is explained in the context of a golf-putting task as 'negatively worded instructions trigger an implicit (unconscious) command that exaggerates the negative meaning (e.g., "don't putt it short"), causing a compensatory interpretation of target location and/or distance' (de la Peña et al., 2008, p. 1324).
5. The tendency to feel unpleasant, painful feelings, anxiety, and lack of emotional stability (Widiger & Oltmanns, 2017). A neurotic is someone who often experiences worry and anxiety (Bolger & Schilling, 1991).
6. These terms have specific uses in mainstream psychology (Holleman et al., 2020; Kihlstrom, 2021), but this paper uses the terms to denote scenarios that closely resemble competitive stressors and environments.
7. These may include 'scant physical, mental, technical, or tactical preparations, external expectations, self-presentation, and opponents' (Mellalieu et al., 2009, p. 731).
8. For a detailed explanation of the cognitive load construct, we refer to Paas et al. (1994) work.

## Data repository

*Primary data.*
https://osf.io/n24gv/?view_only=197bf08e8d1841a68c98b3b0afee3f3b.

## Disclosure statement

No potential conflict of interest was reported by the author(s).

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