Anxiety and Ironic Errors of Performance: Task Instruction Matters

Gorgulu, Recep; Cooke, Andrew; Woodman, Tim

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Abstract

We present five experiments that examined Wegner's (1994) theory of ironic processes of mental control in reactive motor performance under pressure for the first time. In Experiments 1, 2 and 4, we conducted specific examinations of the incidence of ironic error using a reactive motor task. In Experiments 3 and 5 we provided the first tests of whether task instruction moderates the incidence of ironic errors. The task required participants to react to a series of three primary color balls as they rolled down a chute under low- and high-anxiety conditions. Measures of anxiety, heart rate, heart rate variability and muscle activity confirmed the effectiveness of the anxiety manipulation. Experiments 1, 2 and 4 revealed that anxiety increased the number of ironic errors. In Experiments 3 and 5, we provided the first evidence that instructional interventions can reduce the incidence of anxiety-induced ironic performance errors in reactive motor tasks.

Keywords: Anxiety, ironic error, reactive task, instruction.

Anxiety and Ironic Errors of Performance: Task instruction matters.

The influence of anxiety on motor performance is central to performance psychology (e.g., Woodman & Hardy, 2003). An extensive body of research devoted to determining the nature of the anxiety-performance relationship has investigated theories such as the conscious processing hypothesis (Masters, 1992), attentional control theory (Eysenck, Derakshan, Santos, & Calvo, 2007), and catastrophe models (Hardy, Woodman, & Carrington, 2004). However, these theories do not offer a mechanism via which anxiety can elicit precisely *counter-intentional* errors. These errors are more severe than general errors, and represent the worse possible scenario; that is, making the mistake one least wants to make (Janelle, 1999). For example, a professional soccer player might instruct herself to avoid striking her penalty wide of the post, before proceeding to do exactly that. One can explain such counter-intentional errors through Wegner's (1994) theory of ironic processes of mental control. To date this theory has received comparatively scant attention in the anxiety and motor performance literature. This is surprising when one considers that the consequences of counter-intentional errors in the motor performance domain, especially during tasks that require rapid decisions and responses to ever-changing environmental stimuli (e.g., competitive sport, emergency services, and armed forces) can be severe. Indeed, we are aware of no study applying ironic processes theory to the anxiety and performance relationship, where the performance task is reactive in nature. We designed the experiments in this manuscript to be the first to examine Wegner's theory of ironic processes of mental control as an explanation for anxiety-induced counter-intentional errors during reactive motor performance.

Ironic Processes of Mental Control

The foundation to Wegner's (1994,) theory is that so-called *operating* and *monitoring* cognitive processes work together to produce our thoughts and actions. Specifically, an intentional *operating process* carries out effortful regulation by consciously searching for, and directing the person toward, mental contents that will yield an intended emotional state or preferred outcome. Meanwhile an ironic *monitoring process* subconsciously searches for signals of failure to achieve the desired state; the monitoring process is unconscious, autonomous, and less demanding of mental effort. If this subconscious *monitor* identifies any such failures then it reactivates the intentional *operating process,* which aims to bring about the regulation by filling the mind with mental contents that are consistent with the desired state.

Under normal circumstances, both processes work within one control system and operate together as part of a feedback loop that provides effective mental control for the individual (Wegner, 1994). However, under conditions where there is competition for resources within our limited attentional capacity, such as when anxiety increases and burdens our conscious attention with worrisome thoughts, there is limited cognitive space for the effortful operating process to work effectively. Conversely, the functionality of the monitoring process remains mainly unaffected due to its unconscious and uninterruptable feature (i.e., once they materialize, they cannot be stopped), which yields a search for components related to the failure of the intended state of mind or behavior. Due to this diminishing effectiveness of the operating process, the monitoring process becomes relatively more prevalent with increasing anxiety. More specifically, when the monitoring process carries out a sweep for information on the to-be-avoided outcome (e.g., missing a kick to the left of the post), it brings that very scenario into consciousness. If there is insufficient capacity to re-engage the effortful operating process (e.g., when cognitive load, such as anxiety, increases), this precisely counter-intentional error ensues (Wegner, 1994). Consequently, the ironic monitoring process becomes more salient, and mental control paradoxically starts working against itself by attending to those unwanted thoughts (Janelle, 1999).

Ironic Effects and Motor Performance: Existing Research

Wegner, Ansfield and Pilloff (1998) provided some seminal evidence to support Wegner's (1994) theory as an explanation for counter-intentional errors in the motor performance domain. In one study, participants were asked to avoid moving a hand-held pendulum along a particular axis (or simply to hold it steady without mention of a direction), and in a second study they were asked not to hit golf ball past the glow spot. Consistent with ironic processes of mental control theory, participants under mental (working memory) load made more counter intentional-errors than those who were under no such load.

Others have reported similar effects . For example, Dugdale and Eklund (2003) investigated the incidence of ironic effects in a well-learnt wobble board task. Skilled dancers were required to balance on a wobble board for twenty seconds. Results revealed that participants were less stable on the wobble board during trials where they were instructed "don't wobble" compared to trials where they were instructued to "hold steady". Further, in a dart throwing task, Oudejans, Binsch, and Bakker (2013) demonstrated that the combination of negatively woded instructions (''Be careful not to hit….'') and induced anxiety significantly increased the number of darts landing in the specifically to-be-avoided zone when compared to negatively worded instructions under low –anxiety conditions.

Woodman, Barlow and Gorgulu (2015) also conducted experiments using a dart board, which they divided into a central target (i.e., bull's-eye) and four equally sized quadrants that extended out from the bulls-eye to the edge of the board. Participants were instructed to aim for the bulls-eye while being particularly careful not to hit one of the the four quadrants (e.g., top-right zone). Results revealed that performance deteriorated from low- to high-anxiety conditions, and was characterized by an anxiety-induced increase in the number of darts landing in the specifically to-be-avoided zone. Extending this work, Barlow, Woodman, Gorgulu and Voyzey (2016) revealed that trait neutroticism moderates the incidence of ironic errors during high-anxiety conditions. Individuals scoring relatively high in neuroticism made more ironic errors than those who were relatively low in neutroticism during football penalty shooting and dart throwing tasks. Finally, Gray, Orn and Woodman (2017) revealed that experienced baseball pitchers displayed an anxiety-induced increase in the number of balls pitched to an ironic (avoid) zone, while the kinematics of their technique remained stable. This finding supports an ironic processes account of performance breakdown over the explanations offered by self-focus theories (e.g., conscious processing hypothesis; Masters, 1992), since self-focus theories predict that experienced performers break down under anxiety by regressing to a more novice-like technique. Taken together these findings provide encouraging support for Wegner's (1994) ironic processes theory as an explanation for counter-intentional errors, including those that occur under anxiety, in motor performance.

Two main shortcomings remain in the limited research to date. First, previous anxiety and ironic effects research has considered only self-paced aiming movements, which arguably comprise a limited portion of daily activities for the majority of people. Making decisions and responses based on ever-changing stimuli in our environment occupies an arguably larger portion of day-to-day life (Gorgulu, 2017). Moreover, time pressures inherent in reactive tasks likely present an additional load (e.g., Wegner & Erber, 1992) that is absent from self-paced tasks, and which could increase the likelihood of ironic errors in reactive situations. Accordingly, research designed to scrutinize the predictions of ironic processes theory in anxiety-laden reactive tasks is clearly warranted. Such research could encourage coaches and psychologists to carefully consider ironic effects in addition to other more well-known theories (e.g., attentional control theory; conscious processing hypothesis) when designing interventions to prevent any adverse effects of anxiety on the performance of their athletes. Currently, there is no test of ironic processes theory in reactive, externally paced contexts.

Second, while recent research has identified conditions that might promote ironic effects (e.g., Barlow, Woodman, Gorgulu, & Voyzey, 2016; Gray, Orn, & Woodman, 2017), there has been no research dedicated to interventions aimed at reducing the incidence of ironic errors. From a theoretical perspective, one method of reducing the likelihood of ironic effects could be manipulating task instructions to ensure that the monitoring process is searching for features that are more difficult to find than those sought by the operator (Wegner, 1994). This could be especially effective in time-limited reactive motor tasks, where one often faces the choice of either making a reactive movement or doing nothing. For example, a cricket batsman has to decide whether to play a shot (i.e., an action) or to leave the ball (i.e., an inaction), and against pace bowlers who deliver balls at speeds in excess of 80 mph, if this decision is not made in less than 500 ms then inaction is the default outcome (Land & McLeod, 2000). Both action and inaction options in this example could require varying levels of stimulus detection and stimulus identification stages of information processing, but playing a shot would require an additional stage of response programming in order to bring that behavior to fruition (Schmidt, 1980). Accordingly, one could argue that playing a shot (i.e., action) represents a more cognitively demanding and time-consuming process than leaving the ball (i.e., inaction). Thus, instructions tailored to burden the monitoring process with a search for features consistent with actions rather than inactions might help to reduce the likelihood of the monitor coming to the fore. Our experiments will test this theoretically-driven prediction. Importantly, if the predictions are supported, this body of research will provide the first framework for athletes, coaches and psychologists for using instructional interventions to mitigate ironic errors during reactive sports.

The Present Experiments

In the current paper; we aimed to address both of these issues. Experiment 1 and 2 provide the first examination of ironic effects theory in an externally paced task under low- and high-anxiety conditions. We hypothesized that reactive motor performance would suffer in a specifically ironic fashion when performers were anxious. Experiment 3 provides the first test of whether task instruction moderates the likelihood of ironic errors. We hypothesized fewer ironic errors under high-anxiety conditions when we tailored instructions to load the monitoring process with a more difficult action-based search compared to inaction-based search. Experiments 4 and 5 replicate Experiments 2 and 3, but with a slightly modified manipulation designed to offer an even more rigorous test of the predictions cited above.

Experiment 1

In Experiment 1, we aimed to create an approximate externally paced analog of Wegner's (1998) classic pendulum experiments. Specifically, we asked participants to react to two different colored balls as they rolled down a chute, a target (e.g., red) that was to be caught, and a non-target (e.g., blue) that was to be avoided. If Wegner's theory of ironic processes of mental control holds for externally paced tasks, we expected participants in a high-anxiety condition to catch more non-target balls (i.e., make more to-be-avoided errors) than in a low-anxiety condition.

Method

Participants. The sample comprised 53 individuals (32 men, 21 women; M_{age} = 19.62, *SD* = 2.09; 47 right handed, 6 left handed). We recruited participants on a volunteer basis through advertisement posters. All participants reported being free from illness and injury at the time of the experiment. We obtained informed consent from all participants over the course of the Experiment 1 to Experiment 5. All the experiments (Experiments 1-5) were approved by the University research ethics committee.

The GPower 3.1 (Faul, Erdfelder, Buchner, & Lang, 2013) calculation software indicated that by adopting an alpha of .05 and a sample size of 53 the experiment was powered at .80 to detect significant differences between conditions for effect sizes exceeding $f = .20$ (i.e., small-to-medium size effects), by repeated measures analysis of variance (Cohen, 1992). While there are limited previous data upon which to base these calculations, Woodman et al.'s (2015) test of ironic effects, adopting a similar design, revealed large within-subject effects (η_p^2's = .25). Accordingly, if similar effects were to emerge, the samples we recruited in each of Experiment 1 through to Experiment 5 were more than adequately powered to detect them.

Design and Task. We adopted a within-subject design; all participants completed a reactive motor task under both low- and high-anxiety conditions. Participants sat adjacent to the bottom end of a 174cm length black chute, raised 58cm above the ground at the lower end, and set at a gradient of 27 degrees (Figure 1). Their task was to react to a series of red and blue balls as each ball rolled down the chute. Specifically, using a table tennis bat held in their dominant hand, participants either stopped the ball (i.e., they held the bat firm against the end of the chute) or they allowed the ball to continue its trajectory off the end of the chute to the ground (i.e., they moved the bat away from the chute end). Before commencing each condition we told participants, "every ball you stop will go into a prize bucket, the red ball will score you plus five points and the blue ball will score you minus five points. Obviously, you should be very careful *not to stop* the blue balls! Please try to score as many points as possible."

We secured a wooden board partition to the rear end of the chute in order to prevent participants from seeing the color of the ball before it entered the chute. We concealed the top

92cm of the chute to allow for an appropriate choice response time (450ms) on seeing the ball and its color. We determined this response time via pilot testing, which indicated that this time ensured that participants had enough time to respond to ball color, but not so much as to make the task easy. This response time is consistent with response times observed in previous studies using similar choice-based tasks (Miller & Low, 2001).

Our task and instructions established a target ball and a non-target ball. In the above example, the target ball is red, and the non-target ball is blue. The instructions were modified between participants to ensure that each ball color had an equal turn at being the target and the non-target ball over the course of the experiment (i.e., fully counterbalanced). Participants responded to 30 balls (15 blue and 15 red) in both low-anxiety and high-anxiety conditions. Details of the anxiety manipulation are in the Procedure section below.

** INSERT FIGURE 1 ABOUT HERE **

Measures

Anxiety. Anxiety was measured using the Mental Readiness Form-3 (MRF-3; Krane, 1994). Participants were asked to express how they felt *right now* by responding to three 11-point Likert-type scales. From left to right the scales are anchored at extremes with *not worried* and *worried* for cognitive anxiety; and *not tense* and *tense* for somatic anxiety. Thus, high scores represent high cognitive anxiety, and high somatic anxiety, respectively. The MRF-3 is commonly used in anxiety and motor performance research (e.g., Barlow et al., 2016; Robazza, Bortoli, & Nougier, 2000; Woodman & Davis, 2008; Woodman et al., 2015).

Cardiac Activity. To increase experimental rigor we also obtained some objective psychophysiological indices of anxiety. We measured heart rate and heart rate variability via electrocardiogram (ECG). We placed disposable silver/silver chloride electrodes (Blue sensor, Ambu, St Ives, UK) on the right and left clavicals and on the lowest left rib. An amplifier (Dual BioAmp, ADInstruments, Oxford, UK) connected to a 16-bit digital-to-analog convertor (Powerlab, ADInstruments) and a computer running Chart 7 software (Chart v7.3.7, ADInstruments), were used to acquire the ECG signals. Recordings were subsequently imported into Kubios HRV version 2.2 software (Tarvainen, Niskanen, Lipponen, Ranta-aho & Karjalainen, 2014) for offline analyses. Specifically, we computed heart rate (beats per minute) as well as the root mean square of successive R-R intervals (r-MSSD), as a time-domain measure of heart rate variability. We chose these measures because increased heart rate and decreased r-MSSD have previously been associated with elevated pre-competitive anxiety (e.g., Barlow et al., 2016; Mateo et al., 2011; Murray & Raedeke, 2008).

Muscle activity. As an additional objective measure of arousal and tension associated with anxiety, we recorded muscle activity in the dominant forearm. We placed two silver/silver chloride electrodes (Neuroline 720, Ambu, St Ives, UK) 2 mm apart, over the belly of the extensor carpi radialis muscle, and a reference electrode (Blue sensor, Ambu, St Ives, UK) on the left clavicle. The signal was amplified (Dual BioAmp, ADInstruments, Oxford, UK), filtered (50-500 Hz) and then processed at a sample rate of 1000 Hz by a 16-bit PowerLab data acquisition system (ADInstruments, Oxford, UK) connected to a computer running Chart 7 software (ADInstruments, Oxford, UK). We chose the extensor carpi radialis based on pilot testing and previous research implicating this muscle in anxiety-induced increases in grip force during motor tasks (e.g., Cooke et al., 2010; Smith et al., 2000).

Performance. To measure performance we counted the number of target and non-target balls that were stopped in each condition. An electronic buzzer system was connected to the lower end of the apparatus to allow us to determine clearly whether a ball was successfully stopped. The start position for each trial required participants to hold the bat flushes to the end of the chute. This depressed the buzzer switch and ensured that the buzzer was silenced. Any subsequent movement of the bat away from the end of the chute activated the switch and caused the buzzer to sound. Participants were told that the buzzer had to remain silent for a stop to be deemed successful. This criterion prevented participants from making multiple bat movements, such as initially moving the bat away from the end of the chute, and then returning it in time to stop the ball. The range of scores was 0-15 for each ball, where the best score would be 15 for the target balls, and 0 for the non-target balls.

Procedure. Each participant individually attended a single laboratory session lasting approximately 60 minutes. Upon entry to the laboratory, we first briefed participants about the experiment, and then we used exfoliant gel (NuPrep, Weaver, Aurora, USA) and alcohol wipes (Uni-Wipe, Universal, Middlesex, UK) to prepare the electrode sites for psychophysiological recordings. Next, we affixed the electrodes and checked the signals, and then we described the task and instructions as detailed in the Design and Task section above. Participants then completed a familiarization block, comprising 10 balls (5 red, 5 blue) delivered in a random order. This allowed participants to become accustomed to the nature of the task and allowed the experimenter to verify that participants understood the instructions before the main experimental conditions.

After the familiarization block, participants were told that they would now complete the same task for two more blocks of trials, containing 30 balls each. They were then asked to complete the MRF-3, were reminded of the instructions, and then the 30-ball low-anxiety condition commenced. The balls (15 red and 15 blue) were delivered in an order that was randomized prior to the start of the experiment, and then fixed as the same random order for all participants. The instructions were repeated half way through this condition. After the final ball, participants were then given a 5-minute break.

After the break, the experimenter provided participants with additional instructions designed to increase their anxiety, ahead of the final high-anxiety block. Specifically, we told participants that their performance in this final block would be recorded as part of a competition and that we would display all scores on a television screen located in a busy indoor thoroughfare of the university. We told them that the winner of the competition (i.e., the highest number of points scored) would receive a £100 (approx. US$125) prize, and that the second and third placed participants would receive prizes of £30 and £20, respectively. Participants were then asked to complete the MRF-3, they were reminded of their instructions, and then the 30-ball high-anxiety condition commenced. Once again, the balls (15 red and 15 blue) were delivered in an order that was randomized prior to the start of the experiment, and then fixed as the same random order for all participants. Also consistent with the low-anxiety condition, we reminded participants of their instructions half way through the block. We decided that the low-anxiety condition should always precede the high-anxiety condition to minimize any anxiety carryover effect (cf. Hardy & Hutchinson, 2007; Woodman et al., 2015). On completion of the high-anxiety block, the participants were thanked for their participation and fully debriefed. They were also informed that the researcher would be in touch on completion of data collection if they had won a cash prize.

Data Reduction. The psychophysiological measures were obtained continuously throughout the experiment. For our analyses, we calculated heart rate and heart rate variability from 30 seconds before the delivery of the first ball until 30 seconds after the delivery of the final ball in each condition. Ball delivery was identified by a switch affixed to the top of the chute, which triggered each time a ball was released, and was interfaced with the data-acquisition system to place an event marker in the Chart 7 software that was acquiring the psychophysiological recordings. To analyze muscle activity, we rectified the electromyographic signal and then averaged activity across the trials for each condition during the final second prior to ball release. We focused our analyses here because this was the time when participants were in the ready position gripping the bat at the end of the chute and preparing for the ball to be released. It was expected that any anxiety-induced increases in tension would manifest as an increase in grip force (and the associated forearm muscle activity) during these final seconds of motor preparation (e.g., Smith et al., 2000). Due to excessive artifacts, the electrocardiogram and the electromyogram recordings were unscorable for twelve and six participants, respectively. Occasional missing data are reflected in the degrees of freedom reported in the results section.

Statistical Analyses. Data were screened for outliers (none were identified in Experiments 1-5) and a normal distribution was confirmed prior to analyses taking place. We conducted paired-samples *t*-tests to examine the effectiveness of our anxiety manipulation, and repeated measures ANOVA to examine the effects of anxiety on performance. The results of univariate tests are reported with the Greenhouse-Geisser correction procedure applied for analyses that violated the sphericity of variance assumption.

Results

Anxiety manipulation. Paired samples *t*-tests were conducted to analyse our self-report and psychophysiological data. The results are summarized in Table 1. They confirm the effectiveness of the anxiety manipulation. Specifically, we observed the expected increases in cognitive anxiety, somatic anxiety, muscle activity and heart rate, along with the expected decrease in r-MSSD, from the low- to the high-anxiety condition.

** INSERT TABLE 1 ABOUT HERE **

Performance. A 2 (condition: low anxiety, high anxiety) × 2 (ball: target, non-target) fully repeated measures ANOVA was employed to analyze performance. This yielded a significant Condition × Ball interaction, $F(1, 52) = 27.02$, $p < .001$, $\eta_p^2 = .34$. Subsequent paired sample *t* tests revealed that participant scores comprised fewer target balls, $t(52) = 2.45$, $p = .018$, and more non-target balls, $t(52) = 5.19$, $p < .001$, in the high-anxiety compared to the low-anxiety condition (see Figure 2).

** INSERT FIGURE 2 ABOUT HERE **

Discussion

The primary purpose of Experiment 1 was to examine Wegner's (1994) theory of ironic processes of mental control in an externally paced motor task. As hypothesized, participants caught significantly more of the forbidden non-target balls in the high-anxiety condition compared to the low-anxiety condition. This finding can be interpreted in support of Wegner's (1994) theory. The increased feelings of worry in the high-anxiety condition could have consumed some of the conscious attentional resources required by the operating process, thereby compromising its effectiveness, and allowing the normally unconscious monitoring process to come to the fore.

In addition to making more errors on the non-target balls, participants also made more errors on the target balls (i.e., caught fewer of them) when anxiety was increased. This pattern of worse performance on both target and non-target balls under anxiety represents a worst-case scenario in terms of limiting the number of points that each participant accrued. Moreover, it is compatible with previous ironic effects research. For example, Woodman and colleagues (2015) reported fewer darts hitting the target, and more darts hitting the to-be-avoided zone, under the high-anxiety condition in their dart throwing study. However, due to the increased errors on the target balls, one could argue that our findings reflect general performance deterioration rather than a uniquely ironic breakdown during the high-anxiety condition. Specifically, it is possible that attentional resources were overloaded (e.g., Eysenck et al., 2007) causing an increase in all types of errors (e.g., target and non-target), rather than specifically priming ironic errors, as would be predicted by Wegner (1994). In Experiment 2 we introduced the third ball in an attempt to examine this possibility.

Experiment 2

The aim of Experiment 2 was twofold: (a) to replicate the findings of Experiment 1 with a new sample to increase reliability and methodological rigor, and (b) to examine the relative merits of ironic processes versus an attentional overload account of performance breakdown under anxiety. In brief, attention-based models of performance (e.g., Eysenck et al., 2007) contend that we possess a limited attentional capacity, and that anxiety serves to consume attentional resources. Consequently, increasing anxiety reduces goal-driven attention, and can impair both processing efficiency and performance effectiveness (Eysenck & Calvo, 1992; Eysenck et al., 2007). While these theories have some overlap with ironic processes theory, a key distinction is that anxiety-induced performance impairments according to the former would be characterized by inefficient processing (e.g., slowed responses) and a range of general errors, while the latter would predict that impairment would be characterized by errors that are specifically ironic in nature (Wegner, 1994). Our comparison of these competing theoretical accounts of performance was permitted by the addition of a third ball, which had no instruction attached. Accordingly, we had a target ball, a to-be-avoided non-target (ironic error) ball, and a non-target (non-error) ball. Based on the view that stopping balls (i.e., inaction in the current task) represents an easier outcome than programming an action in time-limited reactive tasks (cf. Land & McLeod, 2000; Schmidt, 1980), we formulated alternate predictions about the non-target (non-error) ball. In support of an attentional overload account of our findings (e.g., Eysenck et al., 2007), one would expect that the number of non-target (non-error) balls stopped would increase from low- to high-anxiety conditions. This would reflect the high-anxiety condition combining with any confusion that may be caused by the third ball, to prompt attentional overload, slowing processing down, and making the default inaction (i.e., stopping the ball) more likely. Alternatively, in support of Wegner's (1994) ironic processes of mental control theory, we hypothesized that there would be an anxiety-induced increase in the number of non-target (ironic error) balls stopped, while the number of non-target (non-error) balls stopped would remain unchanged. Such a finding would suggest that any anxiety-induced performance impairment can be specifically attributed to an increase in ironic errors, rather than a more general slowing down and increased likelihood of inaction under pressure.

Method

Participants. The sample comprised 40 participants (21 men, 19 women; M_{age} = 22.65, *SD* = 6.3; 34 right handed, 6 left handed). We recruited participants according to the same criteria as in Experiment 1. We excluded participants who had already taken part in Experiment 1 to ensure that all participants had no previous experience with the task. Informed consent obtained from all participants.

Design and Task. We adopted the same two-condition (low-anxiety; high-anxiety) within-subject design, and the same reactive motor task as detailed in Experiment 1, but with a modification. Specifically, we introduced a third ball color (yellow) and told participants "every ball you stop will go into a prize bucket, the red ball will score you plus five points and the blue ball will score you minus five points, obviously you should be very careful not the stop blue balls! Please try to score as many points as possible." No instruction or point value was attached to the third ball color. These instructions were designed to create a target ball, a non-target (ironic error) ball, and a non-target (non-error) ball. In the above example, the target ball is red, the non-target (ironic error) ball is blue and the non-target (non-error) ball is yellow. The instructions were modified between participants to ensure that each ball color had an equal turn at being the target, the non-target (ironic error), and the non-target (non-error) over the course of the experiment (i.e., fully counterbalanced). Participants reacted to 45 balls (15 blue, 15 red and 15 yellow) in both low-anxiety and high-anxiety conditions.

Measures

Manipulation Check. We measured anxiety, cardiac activity and muscle activity using the same methods as described in Experiment 1.

Performance. To measure performance we counted the number of the target, non-target (ironic error) and non-target (non-error) balls that were stopped, in each condition. The same electronic buzzer system as described in Experiment 1 was used to determine whether a ball was successfully stopped. The range of scores was 0-15 for each ball, where the best score would be 15 for the target balls, and 0 for the non-target (ironic error) balls. The number of non-target (non-error) balls stopped had no bearing on the number of points accrued so was of little performance-related consequence to the participants.

Procedure. The procedure and anxiety manipulation were largely the same as described in Experiment 1. The only difference is that the familiarization block contained 15 balls (5 blue, 5 red, 5 yellow) instead of 10, and the anxiety conditions each contained 45 balls (15 blue, 15 red, 15 yellow) instead of 30. This increase in a number of balls reflects the addition of the third ball color in this experiment. The laboratory session lasted approximately 75 minutes.

Data Reduction and Statistical Analyses. Measures of heart rate, r-MSSD and muscle activity were computed from the continuous recordings using identical methods to those described in Experiment 1. Due to excessive artefacts, the electrocardiogram recordings were unscorable for six participants. Occasional missing data are reflected in the degrees of freedom reported in the results section. Statistical analyses were performed using the same strategy as described in Experiment 1.

Results

Anxiety manipulation. Paired samples *t*-tests were conducted to analyze the self-report and psychophysiological data. The results confirm the effectiveness of the anxiety manipulation. Specifically, we observed the expected significant increases in cognitive anxiety and somatic anxiety, and a non-significant trend for increases in muscle activity and heart rate, along with the expected significant decrease in, r-MSSD, from the low- to the high-anxiety condition (see Table 2).

** INSERT TABLE 2 ABOUT HERE **

Performance. We performed a 2 (condition: low anxiety, high anxiety) × 3 (ball: target, non-target ironic error, non-target non-error) fully repeated measures ANOVA to analyze performance. Results revealed no significant main effect for anxiety, $F(1, 39) = 1.80$, $p = .19$, $\eta_p^2 = .04$, a significant main effect for ball $F(2,78) = 34.54$, $p < .001$, $\eta_p^2 = .47$, and a significant condition × ball interaction, $F(2, 78) = 10.03$, $p < .001$, $\eta_p^2 = .20$. Follow-up paired sample t tests indicated that participant scores comprised fewer target balls, $t(39) = 2.44$, $p = .019$ and more non-target (ironic error) balls, $t(39) = 3.18$, $p < .001$, in the high-anxiety compared to low-anxiety condition. The number of non-target (non-error) balls stopped did not change $t(39) = 1.39$, $p = .17$ (see Figure 3).

** INSERT FIGURE 3 ABOUT HERE **

Discussion

The primary aim of Experiment 2 was to examine the relative merits of an ironic process versus an attentional overload account of performance breakdown under anxiety. In accord with Wegner's (1994) theory of ironic processes of mental control, we found that participants significantly stopped more non-target (ironic error) balls in the high-anxiety condition than in the low-anxiety condition, while the number of non-target (non-error) balls stopped was unchanged. These data favour an ironic processes explanation rather than an attentional overload explanation for the impaired performance under anxiety observed in Experiments 1 and 2. Specifically, participants were more likely to do the thing they were specifically instructed not to do (i.e., to stop the non-target ironic error balls). The number of non-target (non-error) balls stopped remained stable, which is important because such a pattern precludes a uniform attentional overload account of the results. That is, participants were not simply uniformly slowed under anxiety. Having established support for Wegner's theory as an explanation for anxiety-induced performance impairments in reactive tasks, a logical next applied step is to focus on methods of reducing the likelihood of such errors. Those methods are the focus of Experiment 3.

Experiment 3

Presently, there are no studies that focus on instructional interventions designed to reduce the likelihood of ironic errors during motor tasks. Instructions that burden the monitoring process with a relatively more difficult search than the operator could achieve this goal. Importantly, in Experiments 1 and 2, we instructed participants to "be particularly careful not to stop" the non-target (ironic error) ball. In this case, the operating process would have been searching for features associated with *not stopping* (i.e., an action; to move the bat out of the way before the ball reached the end of the chute), while the monitor would have been searching for features associated with stopping (i.e., an inaction; holding the bat firm). Given that action requires more programming than inaction in time-limited reactive tasks (e.g., Land & McLeod, 2000; Schmidt, 1980), we seemingly gave the monitoring process an easier search than we gave the operator in Experiments 1 and 2, maximizing the likelihood of ironic errors under anxiety. To reverse this in Experiment 3, we instructed participants to "be particularly careful not to let [the non-target (ironic error) balls] go." With this revised instruction, the operator should have a comparatively easy search for inaction (i.e., stopping) while the monitoring process has the more difficult search for features associated with an action (i.e., letting go). Accordingly, for our theoretically-driven argument to be supported, we hypothesized that the anxiety-induced increase in ironic errors observed in Experiment 1 and 2 would be absent in Experiment 3.

Method

Participants. The sample comprised 41 individuals (24 men, 17 women; M_{age}= 22.63, *SD*= 3.92; 39 right handed, 2 left handed). We recruited participants according to the same criteria as in Experiment 1. We excluded participants who had already taken part in Experiments 1 or 2 to ensure that all participants had no previous experience with the task.

Design and Task. We adopted the same two-condition (low-anxiety; high-anxiety) within-subject design, and the same reactive motor task as detailed in Experiment 2, but we changed the instruction. Specifically, we told participants "every ball you let go will go into a prize bucket, the red ball will score you plus five points and the blue ball will score you minus five points, obviously you should be very careful not to let the blue balls go! Please try to score as many points as possible." As per Experiment 2, no instruction or point value was attached to the third ball color. Participants reacted to 45 balls (15 blue, 15 red and 15 yellow) in both low-anxiety and high-anxiety conditions.

Measures

Manipulation Check. We measured anxiety, cardiac activity and muscle activity using the same methods as described in Experiments 1 and 2.

Performance. To measure performance we counted the number of target, non-target (ironic-error), and non-target (non-error) balls that were let go, in each condition. The same electronic buzzer system as described in Experiments 1 and 2 was used. However, this time participants were informed that the buzzer must sound continuously from the point at which the bat is removed, and must sound before the ball strikes the bat, for a let go to be deemed successful. Once again, the range of scores was 0-15 for each ball, where the best score would be 15 for the target balls, and 0 for the non-target (ironic error) balls.

Procedure. The procedure was identical to that reported in Experiment 2.

Data Reduction and Statistical Analyses. Heart rate, r-MSSD and muscle activity were determined in the same way as reported in Experiments 1 and 2. All files were useable in this experiment; hence, there were no missing data. Statistical analyses were performed using the same strategy as described in Experiments 1 and 2.

Results

Anxiety Manipulation. Paired samples *t*-tests were conducted to analyse our self-report and psychophysiological data. The results are summarised in Table 3. Once again, they confirm the effectiveness of our anxiety manipulation.

** INSERT TABLE 3 ABOUT HERE **

Performance. We conducted a 2 (condition: low anxiety, high anxiety) × 3 (ball: target, non-target ironic error, non-target non-error) fully repeated-measures ANOVA to analyze performance. Results revealed no significant main effect for anxiety, $F(1, 40) = 1.33$, $p = .25$, $\eta_p^2 = .03$, a significant main effect for balls, $F(2, 80) = 50.08$, $p < .001$, $\eta_p^2 = .55$, and no significant anxiety × ball interaction $F(2, 80) = 0.29$, $p = .75$, $\eta_p^2 = .01$. Participants let more target balls go than non-target (non-error) and non-target (ironic error) balls; the number of times these latter two balls were let go did not differ (see Figure 4). This reflects consistent and relatively good performance across both anxiety conditions.

** INSERT FIGURE 4 ABOUT HERE **

Discussion

Experiment 3 tested our theoretically-driven prediction that instructions which give the monitoring process a more difficult search than the operator may reduce the likelihood of ironic errors occurring. The results of Experiment 3 represent the first support for this hypothesis. Specifically, by instructing participants "not to let [the non-target (ironic error) balls] go", we provided the operating process with a comparatively easy search for inaction (i.e., stopping) while the monitoring process had the more difficult search for features associated with an action (i.e., letting go). Results confirmed that there was no deterioration in performance and no increase in ironic errors during the high-anxiety condition. This is despite the anxiety manipulation being equal in strength to those that did impair performance in Experiments 1 and 2. Accordingly, Experiment 3 provides the first evidence that instructional interventions can reduce the incidence of anxiety-induced ironic performance errors in reactive motor tasks. Although these results are encouraging, one could argue that the data in support of our hypotheses that ironic errors occur during reactive motor tasks (Experiment 2) and can be alleviated by instructional interventions (Experiment 3) would be more compelling had the non-target (non-error) ball used in these experiments been a non-target (error) ball. Specifically, we could have attached a negative consequence to the third ball, but of less severity than the negative consequence already attached to the ironic error ball. Doing so would have given participants a clear target ball and two forms of error balls, the severe “ironic error” ball, and a less severe “other error” ball. Compelling support for Wegner’s theory would be revealed if anxiety increases errors on the “ironic error” ball only in this dual error configuration. This more stringent design was adopted in Experiment 4.

Experiment 4

The aim of Experiment 4 was to replicate the findings of Experiment 2 with a new sample to increase reliability and methodological rigor. The latter aim was permitted by the addition of a point value for the third ball. The purpose in Experiment 4 was to differentiate ironic from non-ironic error by clearly establishing two error balls. To do so, we introduced a new scoring system, awarding plus and minus five points for the target ball, and the non-target (ironic error) ball, respectively, and minus two points for the non-target (other error) ball. With this revised scoring system, in support of Wegner’s (1994) ironic processes of mental control theory and in accord with Experiment 2, we hypothesized that there would be an anxiety-induced increase in the number of non-target (ironic error) balls stopped, while the number of non-target (other error) balls stopped should remain unchanged.

Method

Participants. The sample comprised 24 individuals (17 men, 7 women; M_{age}= 25.58, *SD*= 4.52; 20 right handed, 4 left handed). We excluded participants who had already taken part in previous experiments of this study to ensure that all participants had no previous experience with the task.

Design and Task. We adopted the same two-condition (low-anxiety; high-anxiety) within-subject design, and the same reactive motor task as detailed in Experiments 1, 2 and 3 but with a modification. Specifically, we told participants "every ball you stop will go into a prize bucket, the red ball will score you plus five points, the yellow ball will score you minus two points, and the blue ball will score you minus five points. Obviously you should be very careful not to stop the blue balls! Please try to score as many points as possible." These instructions were designed to create a target ball, a non-target (ironic error) ball, and a non-target (other-error) ball. In the above example, the target ball is red, the non-target (ironic error) ball is blue and the non-target (other-error) ball is yellow. The instructions were modified between participants to ensure that each ball color had an equal turn at being the target, the non-target (ironic error), and the non-target (non-error) over the course of the experiment (i.e., fully counterbalanced). Participants reacted to 45 balls (15 blue, 15 red and 15 yellow) in both low-anxiety and high-anxiety conditions.

Measures

Manipulation Check. We measured anxiety, cardiac activity and muscle activity using the same methods as described in Experiments 1, 2 and 3.

Performance. To measure performance we counted the number of target, non-target (ironic-error), and non-target (other-error) balls that were stopped, in each condition. The same electronic buzzer system as described in Experiments 1, 2 and 3 was used to determine whether a ball was successfully stopped. The range of scores was 0-15 for each ball, where the best score would be 15 for the target balls, and 0 for the non-target (ironic error) and the non-target (other error) balls.

Procedure. The procedure was identical to that reported in Experiments 1, 2 and 3.

Data Reduction and Statistical Analyses. Heart rate, r-MSSD and muscle activity were determined in the same way as reported in Experiments 1, 2 and 3. Due to excessive artifacts, the electrocardiogram and the electromyogram recordings were unscorable for four and two participants, respectively. Occasional missing data are reflected in the degrees of freedom reported in the results section. Statistical analyses were performed using the same strategy as described in Experiments 1, 2 and 3.

Results

Anxiety Manipulation. Paired samples *t*-tests were conducted to analyse our self-report and psychophysiological data. The results are summarised in Table 4. They again endorse the effectiveness of our anxiety manipulation with all variables changing in the expected direction. All the changes were statistically significant with the exception of muscle activity.

** INSERT TABLE 4 ABOUT HERE **

Performance. We conducted a 2 (condition: low anxiety, high anxiety) × 3 (ball: target, non-target ironic error, non-target other-error) fully repeated-measures ANOVA. Results revealed no significant main effect for anxiety $F(1, 23) = .44$, p= .51, $\eta_p^2 = .01$, a significant effect for balls , $F(2, 46) = 41.26$, $p < .001$, $\eta_p^2 = .64$, and a significant anxiety × ball interaction $F(2, 46) = 10.32$, $p = .001$, $\eta_p^2 = .31$, $\varepsilon = .68$. Follow-up paired sample *t* tests indicated that participant scores comprised fewer target balls, $t(23) = 2.65$, $p = .01$, and more non-target (ironic error) balls, $t(23) = 3.55$, $p < .001$, in the high-anxiety compared to low-anxiety condition. The number of non-target (other-error) balls stopped did not change $t(23) = 1.30$, $p = .20$ (see Figure 5).

** INSERT FIGURE 5 ABOUT HERE **

Discussion

The primary aim of Experiment 4 was to replicate the findings of Experiment 2 to increase the reliability of our conclusions, as the replication would give a greater confidence in the results and thus better support for Wegner's (1994) theory of ironic processes. We also sought to increase methodological rigor from Experiment 2 by revising the task instructions in order to clearly establish two error balls, and test whether anxiety elicited an increase in errors on the severe "ironic error" balls only.

Results from Experiment 4 provide support for the results of Experiment 2 and therefore Wegner's (1994) theory of ironic processes of mental control. In Experiment 4, participants significantly stopped more non-target (ironic error) balls in the high-anxiety condition compared to the low-anxiety condition. Importantly, the number of non-target (other-error) balls stopped was unchanged across anxiety conditions. Thus, Experiment 4 was able to differentiate ironic from non-ironic error and thereby add more compelling support for the conclusion that anxiety can elicit a specific increase in ironic errors during reactive motor tasks. We have already articulated that instructional interventions could reduce susceptibility to these errors in Experiment 3, but to add further confidence to this conclusion, a next logical step would be to test the effectiveness of the instructions used in Experiment 3, with the dual-error scoring system used in Experiment 4. This was our aim in Experiment 5.

Experiment 5

The purpose of our final experiment was to replicate the findings from Experiment 3 in order to support our theoretically driven argument for instructional interventions to reduce the likelihood of ironic performance errors during reactive tasks. In that experiment we argued that instructions that load the monitoring process with a relatively more difficult search than the operator should help reduce the likelihood of specifically ironic errors.

However, we concede that in Experiment 3 we only had one obvious error ball (i.e., ironic error ball, minus five points). In Experiment 4 we modified our scoring system to establish two types of error (*ironic error*, minus five points; and *other error*, minus two points). We adopted this dual-error scoring system in Experiment 5. If our instructional intervention (i.e., giving the monitor a more difficult task) really does help alleviate specifically ironic errors, we hypothesized that the anxiety-induced increase in ironic errors that we observed in Experiment 4 should be absent in Experiment 5.

Method

Participants. The sample comprised 23 individuals (16 men, 7 women; M_{age}= 23.43, *SD*= 3.62; 23 right handed). We recruited participants according to the same criteria as in Experiment 1. We excluded participants who had already taken part in Experiments 1, 2, 3 and 4 to ensure that all participants had no previous experience with the task.

Design and Task. We adopted the same two-condition (low-anxiety; high-anxiety) within-subject design, and the same reactive motor task as detailed in Experiments 1, 2, 3 and 4 but we modified the instruction. Specifically, we told participants “every ball you let go will go into a prize bucket, the red ball will score you plus five points, the yellow ball will score you minus two points, and the blue ball will score you minus five points. Obviously, you should be very careful not to let the blue balls go! Please try to score as many points as possible.” Participants reacted to 45 balls (15 blue, 15 red and 15 yellow) in both low-anxiety and high-anxiety conditions.

Measures

Manipulation Check. We measured anxiety, cardiac activity and muscle activity using the same methods as described in Experiments 1, 2, 3 and 4.

Performance. To measure performance we counted the number of target, non-target (ironic-error), and non-target (non-error) balls that were let go, in each condition. The same electronic buzzer system as described in Experiments 1, 2, 3 and 4 was used. However, this time participants were informed that the buzzer must sound continuously from the point at which the bat is removed, and must sound before the ball strikes the bat, for a let go to be deemed successful. Once again, the range of scores was 0-15 for each ball, where the best score would be 15 for the target balls, and 0 for the non-target (ironic error) and non-target (other error) balls.

Procedure. The procedure was identical to that reported in Experiment 4.

Data Reduction and Statistical Analyses. Heart rate, r-MSSD and muscle activity were determined in the same way as reported in Experiments 1, 2, 3 and 4. Due to excessive artifacts, the electrocardiogram and the electromyogram recordings were unscorable for three and two participants, respectively. Occasional missing data are reflected in the degrees of freedom reported in the results section. Statistical analyses were performed using the same strategy as described in Experiments 1, 2, 3 and 4.

Results

Anxiety Manipulation. Paired samples *t*-tests were conducted to analyse our self-report and psychophysiological data. The results are summarised in Table 5. They again endorse the effectiveness of our anxiety manipulation with all variables changing in the expected direction. All changes were significant with the exception of muscle activity.

** INSERT TABLE 5 ABOUT HERE **

Performance. We conducted a 2 (condition: low anxiety, high anxiety) × 3 (ball: target, non-target ironic error, non-target non-error) fully repeated-measures ANOVA to analyze performance. Results revealed no significant main effect for anxiety, $F(1, 22) = .12$, $p = .72$, $\eta_p^2 = .006$, a significant main effect for ball, $F(2, 44) = 38.87$, $p < .001$, $\eta_p^2 = .63$, $\varepsilon = .69$, and no significant anxiety × ball interaction $F(2, 44) = 1.71$, $p = .19$, $\eta_p^2 = .07$. Participants let more target balls go than non-target (other-error) and non-target (ironic error) balls; the number of times these latter two balls were let go did not differ (see Figure 6). This reflects consistent and relatively good performance across both anxiety conditions since the instructions were changed from Experiment 4 to Experiment 5.

** INSERT FIGURE 6 ABOUT HERE **

Discussion

The primary purpose of Experiment 5 was to replicate the Experiment 3 and thereby provide more compelling evidence that instructional interventions can mitigate against anxiety-induced increases in specifically ironic performance errors. Results confirmed no deterioration in performance and no increase in ironic errors during the high-anxiety condition. The findings of Experiments 3 and 5 thus supported our theoretically driven argument that burdening the monitor with a relatively more difficult search than the operator can prevent ironic errors. This represents the first support for instructional interventions to reduce ironic errors during reactive motor performance.

General Discussion

We conducted five experiments to address two limitations from the meagre extant literature examining Wegner's (1994) ironic processes of mental control in a performance setting. Specifically, we provide the first examination of ironic effects theory in an externally paced task under low- and high-anxiety conditions. Moreover, we report the first manipulation of task instruction designed to reduce the incidence of ironic performance errors.

In support of Wegner's (1994) theory, in Experiment 1, results demonstrate that participants made significantly more ironic errors when anxious. To our knowledge, this is the first evidence to support ironic processes theory as an explanation for performance breakdown under anxiety during reactive motor tasks. The results of Experiments 2 and 4 confirmed these findings and – by the addition of a third ball color (Experiment 2) and an additional type of error (Experiment 4) – revealed that any ironic performance errors were unlikely to be accounted for simply by an indiscriminate anxiety-induced performance decline (Woodman et al., 2015). Taken together, the results of these three experiments suggest that instructions that prime the monitoring process with an easier search than the operating process increase the prevalence of ironic errors. This is due to anxiety increasing strain on our limited attentional capacity, preventing actions being programmed fast enough to stop the forbidden error from occurring. Time-pressure concerns are particularly relevant to reactive motor tasks. For instance, in the present experiments, participants had just 450 ms for their action to be programmed in order for them to successfully get out of the non-target ironic error ball's path. With anxiety increasing the burden on the limited attentional system during the high-anxiety condition, successful operating process performance was more difficult to accomplish in the available time, and hence the monitor was more likely to come to the fore.

Crucially, the results of Experiments 3 and 5 offer a solution to the ironic performance problem. Specifically, by reframing task instruction in order to burden the monitoring process with the more time-intensive action-based search, the anxiety-induced increase in ironic errors observed in Experiments 1, 2 and 4 was eradicated in Experiments 3 and 5. Collectively, these results represent the first evidence to support Wegner's (1994) ironic processes theory in reactive motor tasks, and the first to offer a practical and theoretically-driven solution to limit the troublesome ironic error. The key applied implication of our finding is that the instructions we issue to ourselves and to others should be framed to ensure that the operating process always has an easier search than the monitor. For example, Gorgulu and Woodman (2016) argued that coaches should tell their athletes what to do (e.g., strike the soccer ball into the net) rather than what to avoid (e.g., don't hit the post). The current data support this recommendation and indicate that this is equally important for reactive tasks where movement decisions have to be made under time pressure. The current data can also be interpreted to endorse holistic process goals as a way for performers to support their operating process and promote successful motor performance. Holistic process goals encompass the key elements of a movement in a single phrase (e.g., “smooth”, when applied to a golf putt; Mullen, Jones, Oliver & Hardy, 2016) and thereby satisfy the need for an instruction of what do rather than what to avoid. Further, holistic process goals have been found to reduce anxiety (Kingston & Hardy, 1997), which should reduce the likelihood of the monitoring process coming to the fore (Woodman et al., 2015). Moreover, when used by a sample of experienced athletes, holistic process goals such as “reach” and “drive” were associated with superior performance (e.g., less errors) during high-anxiety conditions (Mullen & Hardy, 2010). Thus, we recommend that performers are issued with a clear and simple positive instruction (e.g., holistic process goals), to limit their susceptibility to ironic errors in sport. It would be interesting for future research to empirically examine this recommendation by testing the effects of holistic process goals on the incidence of specifically counter-intentional errors in the field (e.g., real-life sport).

Limitations and Future Directions

Although our results are highly consistent across studies, they should be interpreted in light of some limitations. First, we adopted a fixed condition order (i.e., low-anxiety condition; high-anxiety condition). This reduced the likelihood of anxiety carryover effects (Woodman et al., 2015), but provided an opportunity for learning effects. Specifically, participants may have been advantaged in the high-anxiety condition compared to the low-anxiety condition due to greater task familiarity / practice. Our data argue against the presence of learning effects, since performance was consistently worse in the high-anxiety condition. Nonetheless, it would be interesting for future research to re-examine our findings using well-learned tasks / expert populations to mitigate the risk of learning effects. For instance, testing the theory with expert sport performers and ecologically valid reactive sport tasks would help increase the generalizability and utility of our conclusions (Henrich, Heine, & Norenzayan, 2010).

Second, future studies examining the merits of attentional models of performance such as ironic processes theory would do well to employ techniques to measure attention. For example, probe reaction time could be assessed during performance to provide an insight into the attentional load that participants are experiencing (Lam, Masters & Maxwell, 2010). Such research has the potential to provide even more compelling evidence that anxiety-induced performance breakdown is attributable to worry consuming our limited attentional resources and leaving insufficient space for effective goal-driven (e.g., operating process) control, as predicted by Wegner's (1994) theory.

Conclusion

In conclusion, our findings provide the first support for Wegner's ironic effects theory in an externally-paced task. Moreover, we offer a practical instruction-based solution that can reduce susceptibility to ironic errors and instead help individuals to thrive under pressure. Specifically, performers and practitioners should be educated about ironic effects theory, and encouraged to frame instructions in a way that burdens the monitoring process with the more difficult task.

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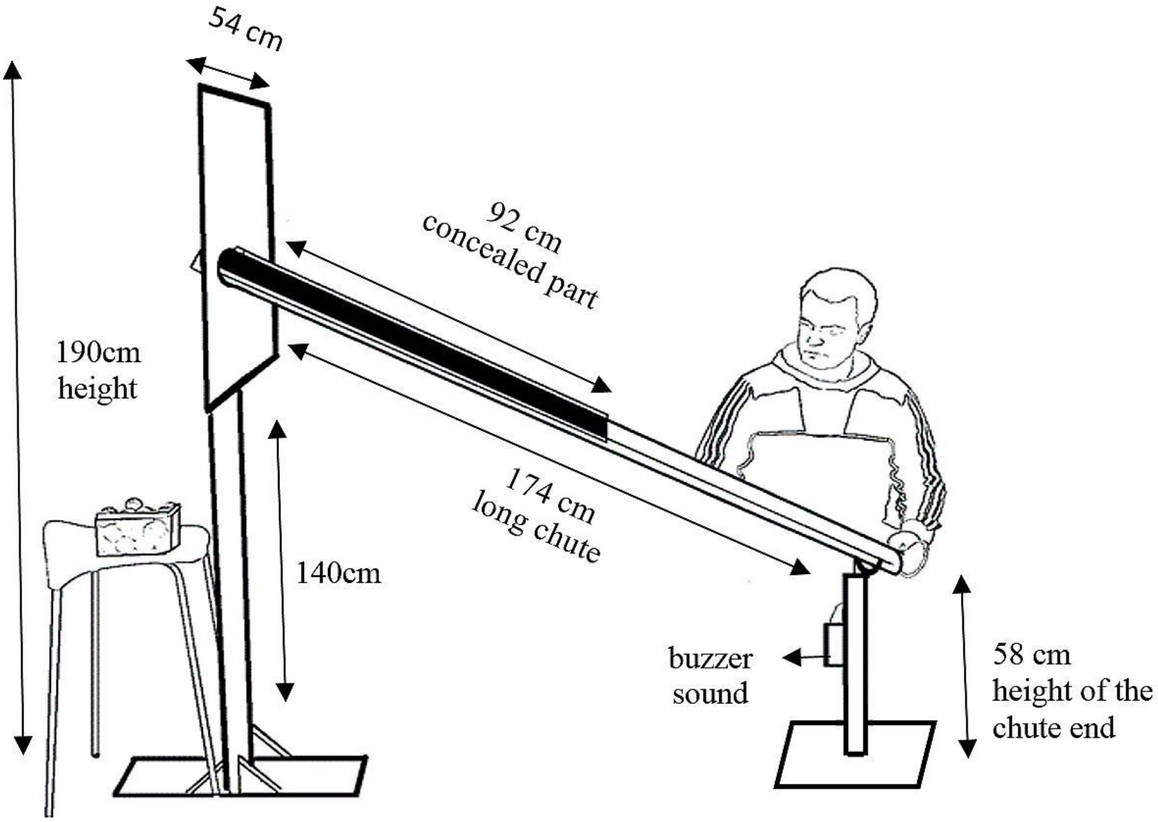

Figure 1. Illustration of the apparatus used. The buzzer system is described in the performance measures section.

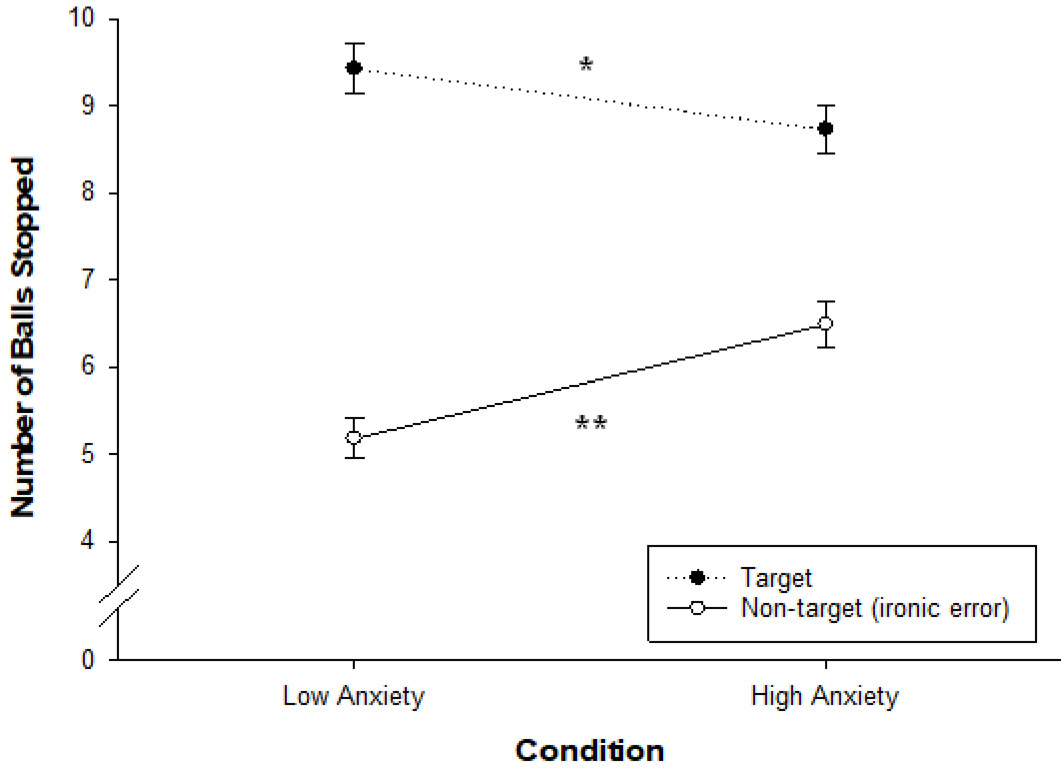

Figure 2. Mean number of target balls and non-target ironic error balls under low-anxiety and high-anxiety conditions in Experiment 1. Error bars indicate standard error of the means. * $p < .05$, ** $p < .01$.

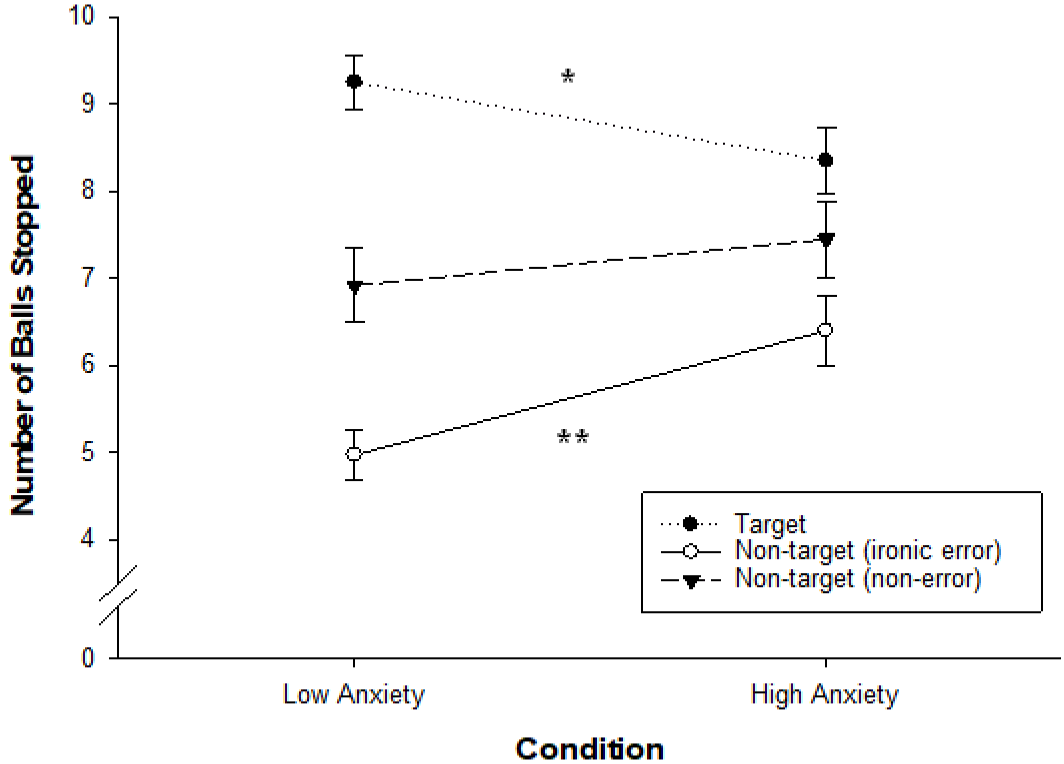

Figure 3. Mean number of target balls, non-target-non- error balls and non-target ironic error balls under low-anxiety and high-anxiety conditions for Experiment 2. Error bars indicate standard error of the means. * = $p < .05$, ** = < .01.

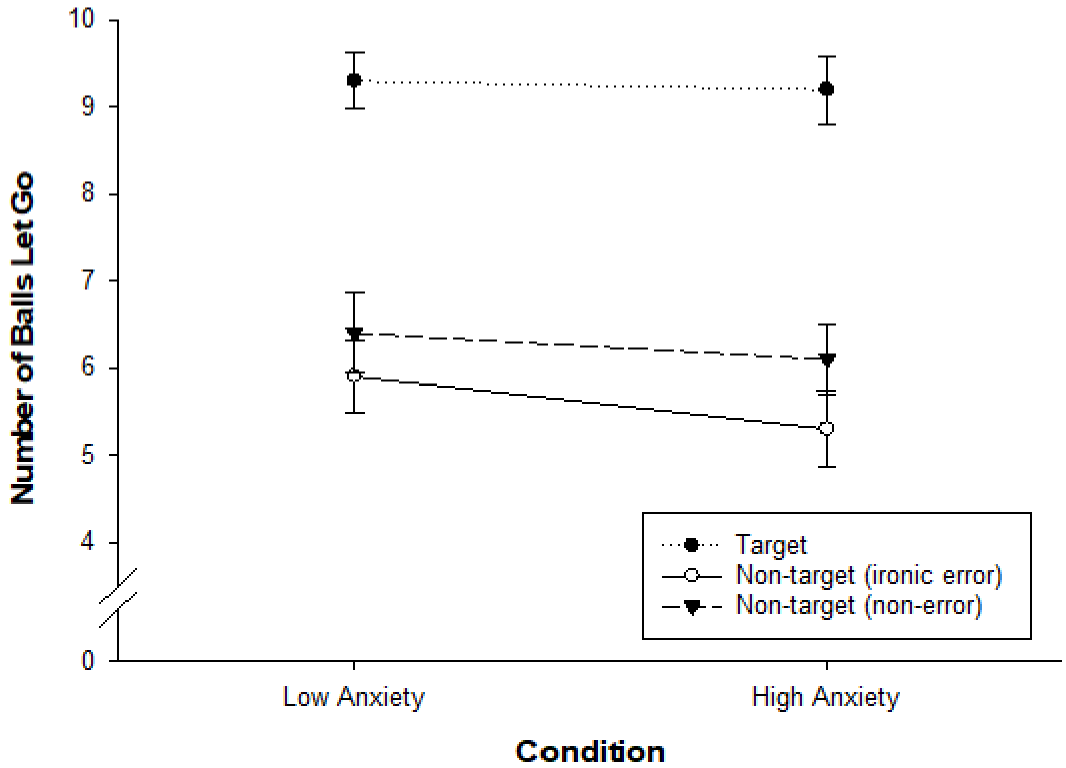

Figure 4. Mean number of target balls, non-target-non-error balls and non-target ironic error balls under low-anxiety and high-anxiety conditions for Experiment 3. Error bars indicate standard error of the means.

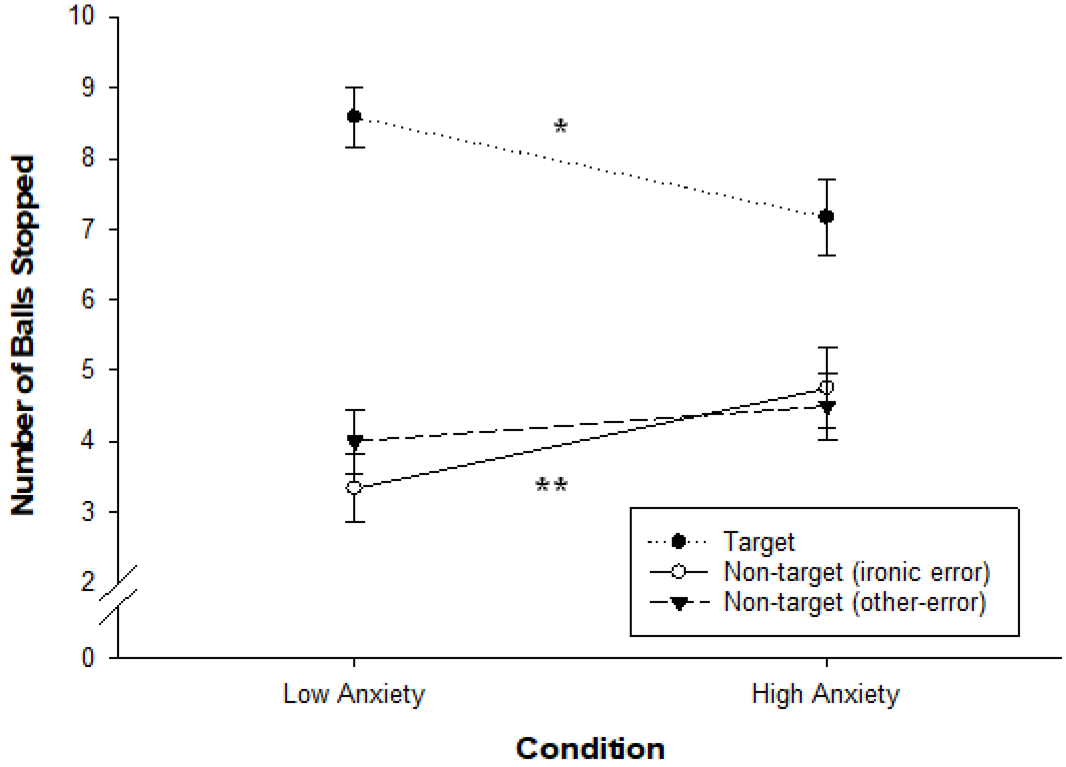

Figure 5. Mean number of target balls, non-target-other-error balls and non-target ironic error balls under low-anxiety and high-anxiety conditions for Experiment 4. Error bars indicate standard error of the means. * = $p < .05$, ** = < .01.

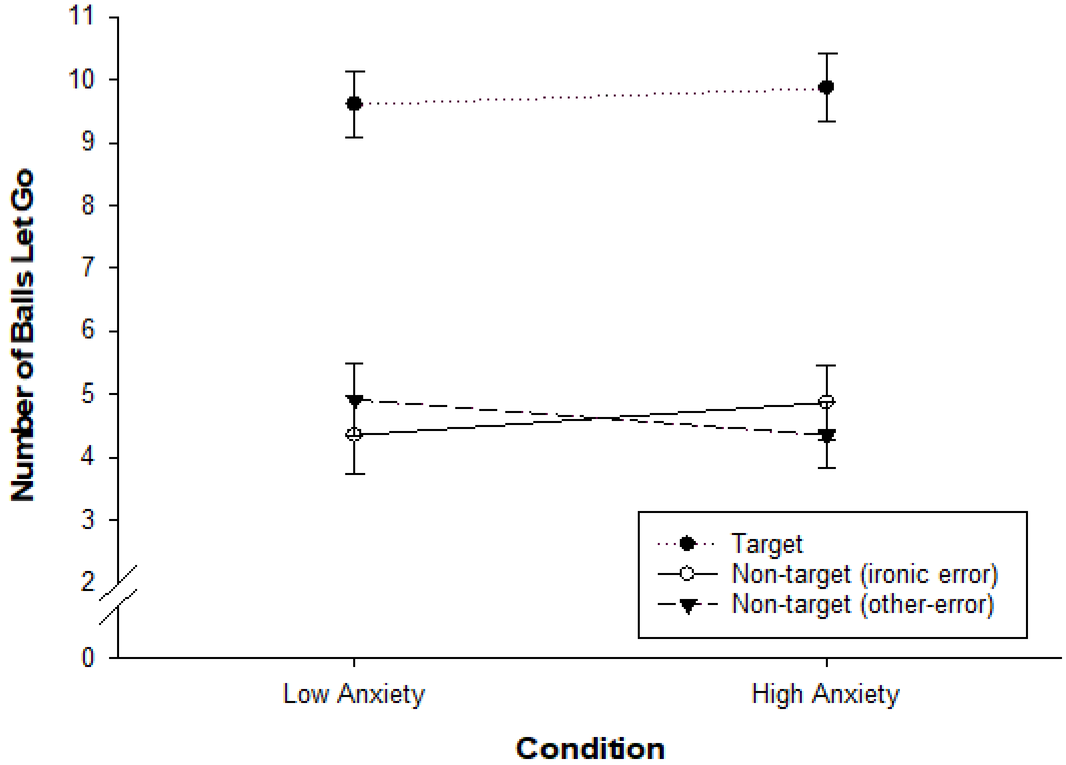

Figure 6. Mean number of target balls, non-target-other error balls and non-target ironic error balls under low-anxiety and high-anxiety conditions for Experiment 5. Error bars indicate standard error of the means.

Table 1

Descriptive statistics confirming the effectiveness of the anxiety manipulation in Experiment 1.

Measure	Condition		
	Low-Anxiety	High-Anxiety	
	Mean (SD)	Mean (SD)	*t*(52)
Cognitive anxiety	4.96 (2.69)	7.35 (2.58)	5.66***
Somatic anxiety	5.47 (2.58)	7.45 (2.18)	5.70**
			t(41)
Heart rate (bpm)	92.85 (15.28)	95.44 (14.39)	2.38*
r-MSSD (ms)	44.19 (27.51)	33.53 (17.33)	3.09**
			t(47)
Muscle activity (μV)	27.01 (11.89)	29.59 (13.81)	2.14*

Notes: *$p < .05$, ** $p < .01$, *** $p < .001$.

Table 2

Descriptive statistics confirming the effectiveness of the anxiety manipulation in Experiment 2.

Measure	Condition: Low-Anxiety	Condition: High-Anxiety	
	Mean (SD)	Mean (SD)	*t*(39)
Cognitive anxiety	4.77 (1.95)	7.40 (2.3)	6.78***
Somatic anxiety	5.25 (2.03)	7.55 (1.72)	5.90***
			t(34)
Heart rate (bpm)	90.59 (16.36)	92.81 (15.61)	1.73†
r-MSSD (ms)	59.29 (33.54)	47.84 (26.02)	3.04**
			t(39)
Muscle activity (μV)	23.31 (10.55)	25.22 (12.42)	1.73†

Notes: ** $p < .01$, *** $p < .001$, † = .09.

Table 3

Descriptive statistics confirming the effectiveness of the anxiety manipulation in Experiment 3.

Measure	Condition: Low-Anxiety	High-Anxiety	
	Mean (SD)	Mean (SD)	*t*(40)
Cognitive anxiety	4.85 (2.46)	7.29 (2.00)	6.27***
Somatic anxiety	5.14 (2.44)	7.46 (2.00)	6.49***
Heart rate (bpm)	87.36 (12.30)	91.23 (14.03)	4.02***
r-MSSD (ms)	50.35 (23.82)	41.43 (18.92)	3.63***
Muscle activity (μV)	23.45 (12.67)	25.29 (15.17)	2.68*

Notes: *$p < .05$, *** $p < .001$.

Table 4

Descriptive statistics confirming the effectiveness of the anxiety manipulation in Experiment 4.

Measure	Condition: Low-Anxiety	Condition: High-Anxiety	
	Mean (SD)	Mean (SD)	*t*(23)
Cognitive anxiety	3.70 (2.21)	6.66 (2.61)	4.67***
Somatic anxiety	4.29 (2.25)	6.33 (2.40)	3.58***
			t(19)
Heart rate (bpm)	85.69 (17.37)	90.46 (20.03)	3.51***
r-MSSD (ms)	56.30 (32.96)	47.33 (33.10)	2.84*
			t(21)
Muscle activity (μV)	21.28 (9.06)	22.09 (9.62)	-.48

Notes: *p < .05, *** p < .001.

Table 5

Descriptive statistics confirming the effectiveness of the anxiety manipulation in Experiment 5.

	Condition		
Measure	Low-Anxiety	High-Anxiety	
	Mean (SD)	Mean (SD)	$t(22)$
Cognitive anxiety	5.69 (1.91)	6.82 (2.20)	2.39*
Somatic anxiety	5.21 (1.85)	6.56 (2.27)	2.44*
			$t(19)$
Heart rate (bpm)	80.91 (11.26)	86.11 (14.88)	2.71*
r-MSSD (ms)	49.92 (24.94)	39.48 (21.75)	2.52*
			$t(20)$
Muscle activity (µV)	20.25 (7.67)	20.40 (7.47)	-.15

Notes: $*p < .05$.