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Bridging attentional control and reinvestment: A test of the interactionist hypothesis in an E-sport context

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ABSTRACT

Attentional control and reinvestment are two competing mechanisms explaining why anxiety-provoking situations may undermine performance. To date, both perspectives have received empirical support, but neither of them perfectly explain how anxiety affects performance. In the present study, we examined a novel, interactionist hypothesis, that worry during task performance (i.e., a product of low attentional control) undermines performance to a greater extent when reinvestment (i.e., attempts to consciously control actions) is high compared to low, in an E-sport context. In a test of 84 experienced players in the Brawlhalla E-sport game, neither worry during the games nor reinvestment propensity on their own predicted ranked match performance, but the interaction between the two did. Specifically, players who were more worried during the ranked games (i.e., lower attentional control) tended to lose more games, of which the effect was evident only when movement-specific reinvestment was high, not low. However, decision-specific reinvestment did not moderate the effect of low attentional control on performance, nor predict performance on its own. Unlike movement-specific reinvestment, decision-specific reinvestment does not appear detrimental to E-sport performance. Overall, the findings provide the first evidence for the interactionist hypothesis of attentional control and reinvestment (especially movement-specific propensity), of which the interaction effect may be underpinned by availability of additional cognitive resources that assure adaptive task processing.

1. Introduction

Anxiety-performance literature has offered two competing mechanisms, namely attentional control (Eysenck et al., 2007) and reinvestment (Masters & Maxwell, 2008), to explain how anxiety influences performance. Specifically, undermined attentional control occurs when an anxious performer's task processing is distracted by worrisome feelings and thoughts, which in turn reduce cognitive resources essential for the task (Eysenck et al., 2007). For comparison, reinvestment occurs when an anxious performer's task processing suffers interference by attempts to consciously control actions using declarative task knowledge (Masters & Maxwell, 2008). Although research has offered strong support for both mechanistic standpoints (Payne et al., 2019; Zhang et al., 2018), these competing mechanistic propositions have not yet been experimentally tested for possible interaction. In an E-sport context, the present investigation aimed to conduct the first formal test of the interactionist hypothesis, that the adverse influences of impaired attentional control on performance amplify as reinvestment increases (see Zhang et al., 2018).

Attentional control theory (Eysenck et al., 2007) proposes that anxiety undermines working memory capacity by creating a shift from *top-down goal-directed* attention regulation (e.g., concentration on task performance) to *bottom-up stimulus-driven* attention regulation (e.g., worry), which reduces processing efficiency and subsequently performance effectiveness. This shift from top-down to bottom-up attention regulation is a product of impaired *inhibition* (e.g., resisting worrisome distraction's disruption of task processing) and *shifting* (e.g., re-directing attention from worrisome distractions to task processing) functions of the working memory system (Miyake et al., 2000). Once anxiety and its associated worrisome thoughts consume attention to a point where there are insufficient cognitive resources available for the current task (i.e., insufficient attentional control), performance diminishes (see Wilson, 2008; Zhang et al., 2018).

Reinvestment theory (Masters & Maxwell, 2008) contends a different explanation of anxiety's effect on task performance. According to Fitts and Posner (1967), skill acquisition is a process of developing explicit

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and conscious task execution into implicit and unconscious processing. Informed by Fitts and Posner's (1967) stages of skill learning, reinvestment theory states that performance impairment under anxiety-provoking situations is due to either the application of explicit knowledge (Masters, 1992) or step-by-step monitoring (Beilock & Carr, 2001) that is intended to help maintain performance but ironically regresses skilled and automatic task processing to a novice level. Such compensation strategies via reinvestment can maladaptively influence one's behavioural movement organisation (i.e., movement-specific reinvestment; Masters et al., 2005) and cognitive decision making (i.e., decision-specific reinvestment; Kinrade et al., 2010) during task performance (see Woodman & Hardy, 2001; Zhang et al., 2018).

While a plethora of evidence supports reinvestment and attentional control theory (e.g., Cooke et al., 2015; Ducrocq et al., 2016; Gallicchio et al., 2016; Wood & Wilson, 2012), neither these two perspectives can perfectly account for anxiety's influence on performance. Empirical evidence exists to support that, even when one is anxious or under high pressure, reinvestment is not always detrimental to performance (e.g., Wilson et al., 2007), and undermined attentional control does not necessarily lead to performance diminishes (e.g., Mullen & Hardy, 2000).

Indeed, researchers have attempted to tease apart attentional control and reinvestment mechanisms when examining the impact of anxiety on performance. For example, Wilson et al. (2007) conducted a driving simulation test under low- and high threat conditions whereas participants were more worried when performing under high threat. These researchers found levels of performance were maintained under high compared to low threat condition, and reinvestment via explicit monitoring (i.e., asking participants to constantly monitor and verbally report the position of left-compared to right-hand by saying high, low, same at 2s–6s interval) did not undermine driving performance even under high threat condition. The findings, therefore, provide stronger support the attentional control mechanism of anxiety and performance. For comparison, Mullen and Hardy (2000) tested experienced but anxious golfers when putting under either dual-task distraction (i.e., generating random letters while performing; low attentional control) or conscious processing (i.e., engaging verbal individual cues while performing; high reinvestment) conditions. Results revealed that, increased mental effort under distraction conditions helped maintain performance, but effort on conscious processing led to a performance drop. The findings, in contrast to Wilson et al. (2007), offer stronger support to the reinvestment mechanism of anxiety and performance (see also Gucciardi & Dimmock, 2008, for examining and comparing the effects of attentional depletion and conscious processing on pressured performance).

Zhang et al. (2018) proposed an interactionist view to explain this paradoxical picture in the anxiety-performance literature. Specifically, both attentional control and reinvestment require cognitive resources, and the impacts of low/undermined attentional control (e.g., worry during task performance) and high/exacerbated reinvestment (e.g., step-by-step processing) on performance will depend on how much extra, remaining mental resources are available for task execution. Therefore, the extent to which reinvestment consumes cognitive resources may determine the degree of adverse effect of insufficient attention control on performance (Zhang et al., 2018). In other words, worry-related distraction would lead to greater performance impairment when reinvestment is high compared to low, because increased reinvestment adds additional strain on the capacity-limited working memory, leaving less cognitive resources for task processing.

In the present investigation, we attempted to test and establish initial evidence for Zhang et al.'s interactionist hypothesis within an E-Sport context. Brawlhalla (Blue Mammoth Games, USA), a popular, fast-paced, inter-person fighting game was employed as the testing platform for this study. This is because superior execution of decisions and movement are key to success in the Brawlhalla game, with the game providing internally valid competitive settings (i.e., 1 vs 1 ranked mode which removes confounding factors such as teammates). We employed self-report psychometric measures assessing impaired attentional control (i.e., worry during task performance; Jones et al., 2019) and reinvestment propensity (i.e., both movement- and decision-specific; Kinrade et al., 2010; Masters et al., 2005) and also adopted objective performance data extracted by the Brawlhalla game to dissolve potential concerns over common method variance (Chang et al., 2010). We hypothesised that reinvestment propensity (either movement- or decision-specific) amplifies the adverse effects of worry during task execution on performance (i.e., winning rate) in the Brawlhalla game.

2. Method

2.1. Participants

Participants were 84 active, regular Brawlhalla players (M_{age} = 21.21, SD = 2.49; N_{male} = 70) at the time of study recruitment. A priori power analysis (Faul et al., 2007) suggested that 81 was required to achieve sufficient power (0.80) in detecting a moderate regressive, interaction effect (i.e., Cohen's $f^2 = 0.10$, alpha set at 0.05) to test our hypothesis. The study sample therefore fulfilled the minimal requirements for a priori estimated sample size.

2.2. Task and performance

We used Brawlhalla, a popular free-to-play online fighting game, as the E-sport for this study. The game can be operated on various gaming-capable platforms such as console, PC, and smartphone. A within-group observational design was adopted to reduce between-person sampling error and to allow an appropriate test of interaction between worry-induced distraction and reinvestment on E-sport performance under an ecological setting, i.e., the standard random ranked matches of Brawlhalla. In a testing session, the task was to complete ten 1 vs 1 online random ranked matches. This 1 vs 1 ranked mode randomly assigned the participant a fighting character and matched them up with a real player opponent of similar rank. During the ranked match, each player had 3 lives, and the one to lose all 3 lives first lost the match. At the end of each ranked match, the player received ranking points (i.e., known as ELO in the game) generated by the gaming system based on their match performance (e.g., number of hits taken) and match winning status. The winning player gained points and increased in ranking (based on ranking points), while the losing player was deducted points and decreased in ranking. Consequently, the game's primary structure to achieve the highest possible ranking across various 'seasons' (i.e., 13-week timeframes) created performance pressure in every 1 vs 1 ranked match played. Ranking points were averaged to indicate participants skill levels, and winning status (coded 1 for winning and 0 for losing) were averaged over ten ranked matches as an estimation of winning rate for further analysis.

2.3. Measures

Worry. We used the worry subscale of the *Hierarchical Competitive Anxiety Scale* (Jones et al., 2019). This subscale comprises five items specifically describing various state worrisome feelings under competitive settings (e.g., "I am worried that I may make mistakes"); it has demonstrated good to very good internal consistency (i.e., Cronbach's alpha ranged .78-.87; Jones et al., 2019). Participants gave ratings on a 5-point Likert scale after the test session to recall their worrisome feelings during task performance from 1 – "totally disagree" to 5 – "totally agree". Ratings were averaged for each participant, with higher scores indicating greater worry-induced distractions during task performance.

Movement-specific reinvestment. We used the 10-item *Movement-Specific Reinvestment Scale* (i.e., MSRS; Masters & Maxwell, 2008) to assess participants' overall propensity of movement self-consciousness (e.g., "I am concerned about my style of moving") and conscious motor processing (e.g., "I reflect my movement a lot"). MSRS has demonstrated acceptable to good internal consistency (i.e., Cronbach's alpha ranged .71 to .78; Masters et al., 2005). The scale operates on a 6-point Likert scale going from 1 – "strongly disagree" to 6 – "strongly agree". Scores were averaged across all items, with higher scores indicating greater propensity of movement-specific reinvestment.

Decision-specific reinvestment. We used the 13-item *Decision-Specific Reinvestment Scale* (i.e., DSRS; Kinrade et al., 2010) to assess participants' overall propensity to engage in conscious monitoring when making decisions (e.g., "I'm always trying to figure out how I make decisions") and decision-related rumination (e.g., "I remember poor decisions I make for a long time afterwards"). DSRS has demonstrated superior internal consistency (i.e., Cronbach's alpha ranged .89 to .91; Kinrade et al., 2010). Participants responded to the scale on a 5-point Likert scale from 0 – "extremely uncharacteristic" to 4 – "extremely characteristic". Scores were averaged across all items, with higher scores indicating greater decision-specific reinvestment.

2.4. Procedures

With institutional ethics approval, a research assistant contacted active Brawlhalla players (i.e., who were playing the Brawlhall ranked matches at the time of recruitment) through the game's official forum, other online gaming forums, and social media: providing detailed information about the study prior to requesting participation consent. Only those who aged 18 or above were eligible for partaking in this study. After receiving the completed consent, the research assistant discussed test details with each participant. The participation was voluntary, and no monetary or other forms of incentives was offered. Each participant had a 2.5-h window on a testing day, which the participant selected, to complete the ranked matches. On the testing day, the participant received a digital study pack which contained standard instructions, a performance log, and a questionnaire containing the study measures. Each participant was briefed via an online virtual meeting and then independently played as many warm-up games as they wanted prior to starting the testing session, using their own, familiar gaming devices. After that, the participant completed ten ranked matches as required and logged the ranking points and winning status for each match provided by the game (see *Task and performance*). On completion of the ten ranked matches, the participant filled the questionnaire containing the study measures (see *Measures*) and sent the completed questionnaire with performance log back to the research assistant within the agreed 2.5-h testing window. The research assistant then thanked, debriefed the participant, and checked to ensure all parts of study measures were completed.

2.5. Data analyses

For preliminary analyses, we used the IBM SPSS Version 27 to check for missing data and outliers that were more than three standard deviations from the mean for each study variable (Jaccard & Turrisi, 2003). We then generated descriptive statistics and assessed the zero-order correlation among study variables. For main analyses, we performed moderated regressions using the PROCESS macro for SPSS (Hayes, 2013) with 5000 bootstraps to test the interaction between worry and movement- or decision-specific reinvestment on winning rate. Bootstrapping is desirable in the proposed analysis because it provides more accurate standard errors and alleviates the impact of potential data non-normality and sampling error (Kulesa et al., 2015). We entered winning rate as a dependent variable, worry during ranked matches as an independent variable, and movement- and decision-specific reinvestment as the moderating variables in separate regression models. We treated any correlated demographic factors and participants' ranking points as covariates and controlled movement- and decision-specific reinvestment for each other in the analyses.

To assist interpretation and mitigate potential collinearity issue, we applied z-score transformations to study predictor variables prior to the moderated regression analysis (see Jaccard & Turrisi, 2003). We probed any significant interaction using the simple slope approach (or the "pick-a-point" method (Cohen et al., 2003); and the *Johnson-Neyman* (J-N) technique (Bauer & Curran, 2005). Such approaches allowed not only a conventional test of effect of worry on performance at high (e.g., 1SD above mean) vs low (e.g., 1SD below mean) level of reinvestment, but also an estimation of the *regions of significance* at which effect of the predictor variable was significant. We report correlation coefficients (r), standardised coefficients (β), precise p-value, and lower and upper bound 95% confidence intervals (CI) when appropriate. Alpha was set at 0.05 for all analyses.

3. Results

3.1. Preliminary analyses

There were no missing data, and all individual scores on study variables were within three standard deviations of the mean. Correlation analysis revealed that players' age was negatively related to winning rate ($r = -0.51$, $p = .00$) and ranking points ($r = -0.57$, $p = .00$), and male players achieved higher winning rate ($r = 0.40$, $p = .00$) and ranking points ($r = 0.37$, $p = .00$) than female players. Worry, movement- and decision-specific reinvestment were correlated positive with each other ($r = 0.22$-0.48, all $Ps < .05$) but not associated with neither demographic variables ($r = -0.10$–0.21, all $Ps > .05$) nor performance metrics ($r = -0.06$–0.18, all $Ps > .05$). Table 1 displays the descriptive statistics and zero-order correlations.

3.2. Main analyses

Worry × movement-specific reinvestment interaction. The regression model accounted for 80.71% of the variance in winning rate, with ranking points being the strongest predictor ($\beta = 0.84$, $p < .01$, 95% CI [0.71, 0.97]). After controlling for individual ranking points, participants who were male ($\beta = 0.34$, $p = .03$, 95% CI [0.04, 0.64]) and higher in their propensity for decision-specific reinvestment ($\beta = 0.16$, $p = .01$, 95% CI [0.03, 0.29]) achieved higher winning rate, while age ($\beta = 0.01$, $p = .67$, 95% CI [-0.04, 0.06]), worry during the games ($\beta = 0.01$, $p = .83$, 95% CI [-0.11, 0.13]), and movement-specific reinvestment ($\beta = -0.06$, $p = .28$, 95% CI [-0.19, 0.06]) alone did not predict winning rate. More importantly, effect of the hypothesised worry × movement-specific reinvestment interaction was significant, i.e., $\triangle R^2 = 0.03$, F (1, 76) = 8.98; $\beta = -0.15$, $p < .01$, 95% CI [-0.24, −0.05]. Simple slopes indicated that worrisome feelings during the games was negatively related to winning rate only when movement-specific reinvestment was high ($\beta = -0.13$, $p = .02$, 95% CI [-0.24, −0.02]) not low ($\beta = 0.16$ $p = .10$, 95% CI [-0.03, 0.35]). Region of significance revealed that the conditional effect of state worrisome feelings on winning rate was significant and negative only when movement-specific reinvestment was equal to or greater than 0.85 standard deviation above the mean. Fig. 1 illustrates the nature of the interaction. Table 2 displays all regression statistics.

Worry × decision-specific reinvestment interaction. The regression model accounted for 78.46% of the variance in winning rate, with ranking points being the strongest predicter ($\beta = 0.84$, $p < .01$, 95% CI [0.70, 0.98]). After controlling for ranking points, no significant effect on winning rate was demonstrated by age ($\beta = -0.01$, $p = .99$, 95% CI [-0.06, 0.05]), gender ($\beta = 0.28$, $p = .08$ 95% CI [-0.03, 0.59]), worry during the games ($\beta = -0.07$, $p = .22$, 95% CI [-0.19, 0.04]), decision- ($\beta = 0.12$, $p = .10$, 95% CI [-0.02, 0.26]), and movement-specific reinvestment ($\beta = -0.05$, $p = .49$, 95% CI [-0.19, 0.09]). The hypothesised worry × decision-specific reinvestment interaction was not significant, i.e., $\triangle R^2 < 0.01$, F (1, 76) = 0.10; $\beta = -0.15$, $p = .74$, 95% CI [-0.15, 0.11]. Table 2 displays all regression statistics.

Table 1
Descriptive statistics and zero-order correslations between study variables.

Measure	1	2	3	4	5	6	7
(1) Age (in years)	–	−.20	−.51**	−.57**	.19	−.10	.13
(2) Sex (1-male, 0-female)		–	.40**	.37**	−.03	.21	−.04
(3) Winning rate			–	.88**	−.06	.15	.09
(4) Ranking points				–	.01	.18	.04
(5) Worry-induced distraction					(.74)	.22*	.32**
(6) Movement-specific reinvestment						(.72)	.48**
(7) Decision-specific reinvestment							(.84)
Mean	21.31	.83	.43	1203.24	3.42	3.13	3.10
SD	2.49	.38	.15	189.57	.70	.43	.58

Note. The range of score is 0–1 for winning rate, 0 to infinite for ranking points, 1–5 for worry-induced distraction, 1–6 for movement-specific reinvestment, 0–4 for decision-specific reinvestment. Cronbach's alphas are presented in parentheses when appropriate.
**p* < .05; ***p* < .01.

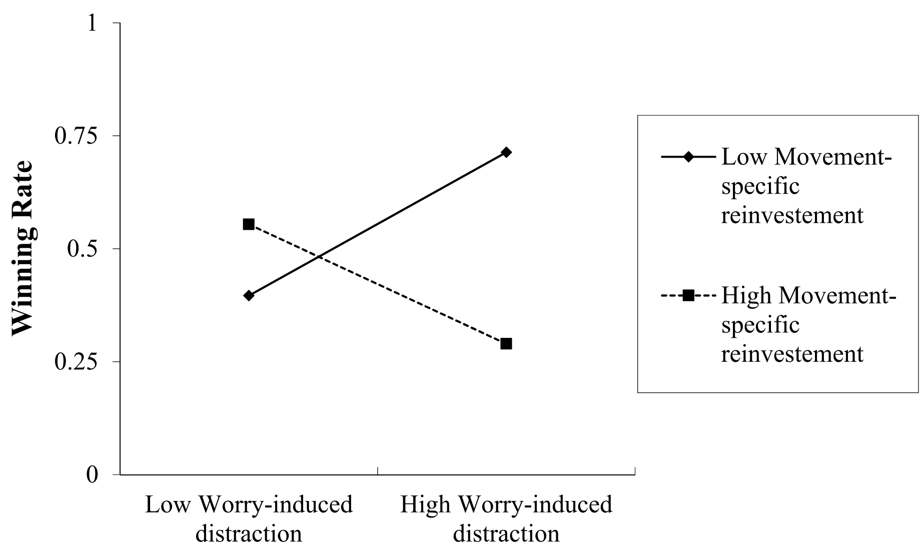

Fig. 1. The nature of interaction between worry-induced distractions and movement-specific reinvestment on Brawlhalla players' winning rate in the ranked games. Slopes were derived from regression equations with hypothetical individuals who are one standard deviation below or above the mean.

Table 2
Regression statistics of the worry × reinvestment interaction on Brawlhalla winning rate.

	R^2	*β*	*se*	*p*	95% CI
Model 1	**.81**				
Age		.01	.03	.67	[-.04, .06]
Gender (1 – male, 0 - female)		.34	.15	.03	[.04, .64]
Ranking points		.84	.07	.00	[.71, .97]
Decision-specific reinvestment		.16	.06	.01	[.03, .29]
Worry		.01	.06	.83	[-.11, .13]
Movement-specific reinvestment		−.06	.06	.28	[-.19, .06]
Worry × movement-specific reinvestment		−.15	.04	.00	[-.24, −.05]
Model 2	**.78**				
Age		−.01	.03	.99	[-.06, .05]
Gender (1 – male, 0 - female)		.28	.16	.08	[-.03, .59]
Ranking points		.84	.07	.00	[.70, .98]
Movement -specific reinvestment		−.05	.07	.49	[-.19, .09]
Worry		−.07	.06	.22	[-.19, .04]
Decision-specific reinvestment		.12	.07	.10	[-.02, .26]
Worry × decision-specific reinvestment		−.15	.07	.74	[-.15, .11]

Note. R^2 = proportion of variance in winning rate accounted by the model; β = standardised regression coefficient; *se* = standard error; CI = confidence interval.

4. Discussions

4.1. Summary of findings

Anxiety-performance research to date is remiss not to consider the interaction between attentional control and reinvestment mechanisms. Although calls to unify these mechanistic standpoints have been made (Payne et al., 2019; Zhang et al., 2018), to our knowledge the present investigation is the first to formally test the interactionist hypothesis which contends that the adverse impact of low attentional control (e.g., worrying during task processing) on performance becomes greater as the level of reinvestment increases. In a sample of experienced Brawlhalla players, worrisome feelings during the ranked E-sport match predicted reduced winning rate only when movement-specific reinvestment was high not low. However, decision-specific reinvestment did not moderate the effect of low attentional control on performance, neither predicting performance on its own.

4.2. Research highlights

The current study highlights how neither attentional control nor reinvestment on their own perfectly explain performance under pressure, at least in the E-sport setting of the Brawlhalla game. Based on attentional control theory (Eysenck et al., 2007), one would anticipate individuals experience impaired performance under anxiety, due to reductions in attentional control associated with anxiety resulting in cognitive resources being diverted away from task-relevant factors, towards task-irrelevant threats and worries. In contrast, based on reinvestment theory (Masters & Maxwell, 2008) one would anticipate that individuals experience impaired performance under anxiety due to attempts to apply explicit monitoring or conscious processing (i.e., reinvestment) to ensure high-level performance, ironically regressing task execution to a novice level (e.g., via step-by-step processing).

However, in the present study, we found that neither worry during performance (i.e., low attentional control) nor movement-specific reinvestment (i.e., high reinvestment) independently predicted performance in the ranked Brawlhalla game. Instead, the findings establish evidence for the interactionist hypothesis, demonstrating the negative effects of worry during the E-sport ranked games on performance magnified as reinvestment propensity increased. Alternatively, one could interpret the findings as an increase in movement-specific reinvestment impairs performance in the Brawlhalla game only when worry during the ranked games was high, not low.

Although a large body of research has provided robust evidence that low attentional control (Eysenck et al., 2007) and high reinvestment (Masters & Maxwell, 2008) under a pressured, anxiety-provoking situation can inhibit performance independently (see also Payne et al., 2019; Zhang et al., 2018), it is noteworthy that existing anxiety-performance studies have predominately relied on anxiety manipulation strategies (i.e., creating anxious feelings via task instructions and consequences etc.) rather than introducing anxious feelings via a nature, ecological performance task (e.g., ranked matches in an E-sport). Also, most anxiety-performance studies also employed a dichotomous classification (i.e., applying a mean split, allocating/grouping participants into different experimental conditions) rather assessing worry and reinvestment on a continuum. These differences in study design may provide an explanation to the non-effect of worry and reinvestment in the current E-sport study.

To supplement our argument and the interpretation of results, findings from our data do not reject the debilitative effects of low attentional control (e.g., worry) and reinvestment on performance, and a main effect could be misleading and meaningless when there is an interaction effect emerging (see Hayes, 2013; Jaccard & Turrisi, 2003). Instead, results from the present study supported the detrimental effects of both low attentional control (e.g., worry) and high reinvestment (e.g., movement-specific reinvestment) on performance and further revealed an interactive, or more precisely an “aggravation effect” of the two fundamental anxiety-performance mechanisms (i.e., the impairment of worry on ranked Brawlhalla performance was greater as movement-specific reinvestment increased, or vice versa). The findings, therefore, suggest that the interaction between attentional control and reinvestment mechanisms, rather than their main effects, provides a superior explanation for anxiety’s influence on performance, at least in the specific E-sport context.

4.3. Theoretical advancement

To further explain the observed interaction effect and offer a theoretical account to unify the two competing perspectives (i.e., attentional control *vs.* reinvestment), we embraced the position that availability of additional cognitive resources for task processing underpins the effects of attentional control and reinvestment and their interaction on performance. Since both the worrisome feelings during task execution and reinvestment consume cognitive resources (Zhang et al., 2018), the reason Brawlhalla players who were worried during the ranked match managed to maintain high-level performance was perhaps due to having sufficient cognitive resources for task processing thanks to low reinvestment propensity (thus less likely to consciously process or explicitly monitor how they performed the game).

Such a viewpoint received support from Gucciardi and Dimmock’s (2008) test of attention depletion and conscious processing among experienced golfers. Specifically, these researchers examined putting performance repeatedly under low and high anxiety across an explicit knowledge group (i.e., participants concentrated on technique cues such as arm, weight, and head during putting; thus high reinvestment and cognitive demand), a swing thought condition (i.e., participants formulated and concentrated on a swing thought such as ‘easy’ and ‘smooth’ whilst performing the putts; thus high reinvestment but low cognitive demand as no need to monitor the step-by-step task processing), and a task-irrelevant group (i.e., participants generated task-irrelevant cue words such as red, blue, green during task performance; thus high distraction or low attentional control but relatively low cognitive demand). Results of the study suggested that deteriorated putting performance was only evident in the explicit knowledge group but not the rest two experimental group. While Gucciardi and Dimmock (2008) argued the findings supported more the conscious processing or reinvestment perspective of anxiety and performance, they did not reject that the amount of cognitive resources required for the various experimental groups may play a role in the putting performance. It is possible that performance deteriorates only when cognitive demands for reinvestment reaches to a point that pre-empts the essential cognitive resources for a smooth task processing. In other words, when reinvestment does not consume the required cognitive resources for successful task execution, low attentional control such as worry may not undermine performance because performers can allocate additional effort to compensate task processing and main performance effectiveness (see also Zhang et al., 2018).

4.4. Practical implications

From an attentional control perspective, in practice, investing greater effort should compensate for the effect of worry or poor attentional control on performance, despite costing performance efficiency (e.g., longer processing time, more mental or physical effort) (Eysenck & Calvo, 1992). However, Masters (1992) argued that any additional effort engaging explicit knowledge of the performance task undermines performance. Evidence for this paradox (i.e., compensatory effort to maintain attentional control *vs.* compensatory effort comprising reinvestment) has been documented in literature.

For example, Mullen and Hardy (2000) tested experienced but anxious golfers when putting under either dual-task distraction (i.e., generating random letters while performing; low attentional control) or conscious processing (i.e., engaging verbal individual cues while performing; high reinvestment) conditions. Results revealed that, increased mental effort under distraction conditions helped maintain performance, but effort on conscious processing led to a performance drop. In a follow-up test of pressured performance in three different sport tasks (i.e., long jump, basketball shot, putting), Mullen and Hardy (2010) demonstrated that anxious performers engaging in a holistic process goal (i.e., a global movement focus) outperformed those engaging in a process goal (i.e., step-by-step movement focus). It is possible that engaging simple dual-task and adopting a holistic process require less attentional or cognitive resources compared to conscious processing or concentrating on a step-by-step process of the performance task.

These literature remarks and explanations support the notion that availability of additional cognitive resources underpin the interaction between attentional control and reinvestment on performance under pressure; anxious performers can maintain or achieve higher-level performance when having sufficient mental resources or superior cognitive capacity for task performance, which is more likely to happen when reinvestment is low not high. As such, practice that facilitates emotional regulation in anxiety-provoking settings for more adaptive task processing, such as mindfulness (see Bondár et al., 2021), self-distancing (see Kross & Ayduk, 2017), and compassionate mind training (see Neff, 2023), may be useful for preventing performers from being distracted by worrisome feelings or interfered by maladaptive reinvestment which pre-empts essential cognitive resources for task performance.

Additionally, the findings suggest movement-specific reinvestment is more detrimental to E-sport performance than decision-specific reinvestment. Although decision-specific reinvestment was found debilitative to decision-making in sport (Kinrade et al., 2010, 2015), it is the first time decision-specific reinvestment was assessed against objective performance (i.e., winning rate of ranked games), rather than decision making quality or accuracy. While the finding on decision-specific reinvestment's non-influence on E-sport performance was to some extent surprising, it is possible that such a cognitive-level reinvestment (e.g., thinking about poor decisions) consumed some cognitive resources required by movement-specific reinvestment and thus reduces one's capacity or likelihood of engaging in the more maladaptive form of reinvestment (i.e., movement-specific). Whilst calling for more research efforts to examine and compare the performance effects of movement- and decision-specific reinvestment, we suggest practitioners working with E-sports players place greater emphasis on managing movement-specific (e.g., step-by-step movement processing) rather decision-specific reinvestment (e.g., conscious decision monitoring).

4.5. Limitations and future directions

We admit the current study is not without limitations. One major concern is the employment of the widely used movement- and decision-specific reinvestment scales (Kinrade et al., 2010; Masters et al., 2005) which measure one's reinvestment propensity in general (more trait-like characteristic) rather than state reinvestment during the task performance. As such, the interaction effect between worry during the ranked game and reinvestment propensity, that were obtained from this study, do not provide the strongest evidence for interactionist hypothesis bridging attentional control and reinvestment mechanisms. This is because one's reinvestment 'propensity' does not precisely reflect the extent to which one actually reinvests during the task performance. However, considering the absence of a validated, performance-specific state reinvestment scale and the advancement of the study in assessing reinvestment on a continuum instead of dichotomous classification (either via experimental manipulation or mean split), the present research still offers valuable insights into the interactionist hypothesis that bridges attentional control and reinvestment to explain how anxiety influences performance. Future research should develop and validate a state measure for reinvestment to better assess levels of reinvestment during task performance. Anxiety-performance researchers would also do well to apply more complex design (e.g., manipulating attentional control and reinvestment simultaneously) to test the interaction between attentional control and reinvestment in predicting performance under pressure. These research efforts will contribute to further unifying the attentional control and reinvestment theories and offering insights into practices on optimising performance under pressure.

Another potential measurement-related concern of the study is the absence of an effort measure. Indeed, the attention control theory embraces the position from its preceding theory, namely the processing efficiency theory, that an increase effort will be observed among anxious performers, indicating undermined processing efficiency before the impaired performance effectiveness occurs (Eysenck et al., 2007). However, an increase in effort can be an indicator of both attentional control and reinvestment (see Zhang et al., 2018, for review), and various studies have consistently demonstrated that a performer's effort is not necessarily distinguishable between distraction (i.e., low attentional control) and self-focus (i.e., high reinvestment) conditions when performing under pressure (e.g., Mullen & Hardy, 2000; Wilson et al., 2007). As such, we did not use an effort measure when examining the hypothesis that attentional control and reinvestment mechanisms interactively influence pressured performance but focused on measures that exclusively indicate either attentional control (e.g., worry) and reinvestment (e.g., movement- and decision-specific reinvestment).

Moreover, whilst employing a ranked E-sport match via Brawlhalla as the performance task, the nature of this study was more observational rather experimental. That is, we did not apply any additional pressure or anxiety manipulations to the participating Brawlhalla players. Instead, we believed that the ranked matches in Brawlhalla provided a nature, anxiety-provoking performance condition, because each ranked game contributed to a player's overall ranking over a 13-week match season. In the current study, participants scored considerably high in worry (an average of 3.42 out of 5), and in movement- (an average of 3.13 out of 4) and decision-specific (an average of 3.10 out of 4) reinvestment during the ranked Brawlhalla games, indicating a meaningful rise in anxiety levels compared to a "null" condition whereas participants' worry and reinvestment level should be closer to the low end (i.e., reporting a low not high score). However, one could argue such an ecological approach we took in this study did not allow precise capture of changes in worrisome feelings and reinvestment propensities throughout the performance tasks, and thus it was difficult to determine the extent to which the level of anxiety the ranked games added to participants. Nevertheless, the current study provided insights into how naturally evolved anxiety (i.e., via competing in ranked games) and its associated worry and reinvestment propensities exert influences on E-sport performance. Researchers would do well to employ various anxiety manipulation strategies and test the replicability of findings from this study.

Additionally, we acknowledge that our study is not optimal in controlling variables that may influence performance. Due to the remote testing nature (i.e., individuals played the ranked game in their own environment instead of a researcher-led laboratory setting), variations in PC/gaming devices and physical environments (e.g., device setting, internet connection, other distractions during testing) were not controlled. Also, despite adjusting for players' ranking points in data analysis (i.e., 1203.24 on average within a possible range of ranked tier including Tin – "0–909", Bronze – "910–1129", Silver – "1130–1389", Gold – "1390–1679", Platinum – "1680–1999", Diamond – "2000+" ranking points), we did not know the average play time each players spent in the game on daily or weekly basis at the time of data collection. Most of the players we recruited were mid-ranged in the global ranking (7.1% Tin, 28.6% Bronze, 52.4% Silver, 12% Gold, 2.4% Platinum and Diamond), and thus our findings may not be generalisable to the highest-level players in the Brawlhalla game. Future research should apply more rigorous control of the testing environments and examine the interactionist hypothesis among elite players.

5. Conclusion

The current study provided the first evidence to support the interactionist hypothesis of attentional control and reinvestment on anxiety and performance, using an E-sport context. The results suggested that reinvestment magnifies the negative effects of anxiety-induced distraction (e.g., worry) on performance under pressure or anxiety-provoking situations. Findings of the study imply that availability of additional resources for task processing underpins the interaction of attentional control and reinvestment mechanisms. Practitioners should pay attention to strategies that help release cognitive resources for task execution and promote more appropriate use of effort for achieving high-level performance. We also call for research to replicate this study and apply different experimental designs to further test the interactionist hypothesis for attentional control and reinvestment.

Credit authorship statement

Conceptualisation, Methodology, & Investigation: SZ, RO; Analysis & Writing - Original Draft: SZ; Writing – Review & Editing: RO & SZ; Project Administration: SZ.

Data availability

Data will be made available on request.

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