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1 The relationship between challenge and threat states and performance: A systematic review

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Abstract

The biopsychosocial model of challenge and threat states specifies that these states engender different physiological and behavioural responses in potentially stressful situations. This model has received growing interest in the sport and performance psychology literature. The present systematic review examined whether a challenge state is associated with superior performance than a threat state. Across 38 published studies that conceptualised challenge and threat states in a manner congruent with the biopsychosocial model, support emerged for the performance benefits of a challenge state. There was, however, significant variation in the reviewed studies in terms of the measures of challenge and threat states, tasks, and research designs. The benefits of a challenge state on performance were largely consistent across studies using cognitive, physiological, and dichotomous challenge and threat measures, cognitive and behavioural tasks, and direct experimental, indirect experimental, correlational, and quasi-experimental designs. The results imply that sports coaches, company directors, and teachers might benefit from trying to promote a challenge state in their athletes, employees, and students, respectively. Future research could benefit from a greater consensus on how best to measure challenge and threat states to help synthesise the evidence across studies. Specifically, we recommend that researchers use both cognitive and physiological measures and develop stronger manipulations for experimental studies. Finally, future research should report sufficient information to enable risk of bias assessment.

Keywords: Motivated performance situation; biopsychosocial model; stress; cardiovascular reactivity; demand resource evaluations

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48 The relationship between challenge and threat states and performance: A systematic review
49 Understanding individuals' responses to stress is key for optimising performance in contexts
50 including business, medicine, education, and sport. Although some models explain individuals'
51 successes and failures in terms of psychology or physiology, one increasingly popular theory
52 combines these perspectives. The biopsychosocial model (BPSM; Blascovich & Mendes, 2000) of
53 challenge and threat (CAT) states built on Lazarus and Folkman's (1984) transactional theory of
54 stress and Dienstbier's (1989) theory of physiological toughness, and has been applied to contexts
55 as diverse as sport, education, and medicine (Moore, Wilson, Vine, Coussens, & Freeman, 2013;
56 Roberts, Gale, McGrath, & Wilson, 2015; Seery, Weisbuch, Hetenyi, & Blascovich, 2010). Across
57 these contexts, CAT states have been associated with different performance outcomes (e.g., Allen &
58 Blascovich, 1994; Blascovich, Seery, Mugridge, Norris, & Weisbuch, 2004), although some studies
59 have found non-significant or contradictory results (e.g., Feinberg & Aiello, 2010; Laborde,
60 Lautenbach, & Allen, 2015), and there is notable diversity in how CAT states have been measured
61 and the research designs employed. To advance our understanding of the impact of CAT states on
62 performance, the consistency of findings across different methods, and to highlight important
63 directions for future research, the current article reports a systematic review of the published
64 literature that utilised the BPSM as a theoretical framework.

65 Central to the BPSM is the assumption that CAT states only occur in motivated performance
66 situations. Motivated performance situations are goal-relevant, evaluative, and potentially stressful,
67 requiring adequate active performance in order to ensure wellbeing and personal growth
68 (Blascovich & Mendes, 2000). Sport competitions, academic exams, and job interviews are typical
69 examples of such situations. Importantly, according to the BPSM, CAT states represent opposite
70 ends of a unidimensional continuum rather than two dichotomous states, allowing researchers to
71 examine relative (rather than absolute) differences in challenge and threat (i.e., greater vs. lesser
72 challenge or threat; Blascovich, 2008). This contrasts the earlier views of Lazarus and Folkman
73 (1984), and other researchers (e.g., Skinner & Brewer, 2004), who considered CAT as independent

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74 cognitive appraisals that can occur simultaneously. Although these other frameworks offer useful
75 insights, this review focused only on publications that examined CAT states in the unidimensional
76 manner hypothesised in the BPSM.

77 CAT states differ in terms of underlying cognitive evaluations and resulting physiological
78 responses, which are predicted to be linked (Blascovich & Mendes, 2000). According to the
79 BPSM, challenge states are characterised by the largely subconscious evaluation that one's personal
80 coping resources match or exceed situational demands. Physiologically, challenge states are
81 marked by increases in heart rate (HR) and cardiac output (CO), and decreases in total peripheral
82 resistance (TPR). This cardiovascular pattern is due to sympathetic adrenal medullary activation,
83 which causes epinephrine release, and dilation of the blood vessels. In contrast, threat states are
84 characterised by an evaluation that coping resources fall short of situational demands. Threat states
85 are indexed by little change or small increases in HR, little change or minor decreases in CO, and
86 little change or small increases in TPR (Tomaka, Blascovich, Kelsey, & Leitten, 1993). This
87 physiological response is due to additional activation of the pituitary-adrenocortical pathway, which
88 constricts blood vessels, causes cortisol release, and inhibits the effects of sympathetic-
89 adrenomedullary activation (Blascovich & Mendes, 2000). Importantly, validation studies showed
90 that: a) cognitive CAT evaluations and physiological CAT responses were significantly correlated,
91 and b) cognitive CAT evaluations triggered physiological responses, not vice versa (Blascovich,
92 2008). These divergent CAT states are predicted to influence performance, with challenge states
93 being related to superior performance than threat states.

94 The relevance of the BPSM to a range of contexts has led to considerable variation in the
95 tasks and performance outcomes examined across the literature. For example, studies have
96 examined the relationship between CAT states and cognitive performance in academic (Seery et al.,
97 2010), GRE word problem (Chalabaev, Major, Cury, & Sarrazin, 2009), and mental arithmetic
98 (Kelsey et al., 2000) tasks. Further, Blascovich et al. (2004) found that a cardiovascular CAT
99 index, measured during a pre-season speech about athletes' sports, predicted batting performance

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100 during the season, with a challenge state linked to better performance than a threat state (i.e., more
101 runs). This initial evidence provided impetus for subsequent research involving behavioural tasks
102 as varied as simulated surgery (Vine et al., 2013) and cricket batting (Turner et al., 2013).

103 This early research also led to the development of new theories that extended the predictions
104 of the BPSM (i.e., Theory of Challenge and Threat States in Athletes [TCTSA]; Jones, Meijen,
105 McCarthy, & Sheffield, 2009; integrated framework of stress, attention, and visuomotor
106 performance; Vine, Moore, & Wilson, 2016). These theories suggest that CAT states could
107 influence performance through various mechanisms. For example, the TCTSA predicts that a threat
108 state may lead to more negative emotions, unfavourable interpretations of emotions, impaired
109 cognitive functioning, decision-making and anaerobic power, greater self-regulation, increased
110 reinvestment and avoidance coping, and less effective attention, which may in turn impair
111 performance (Jones et al., 2009). Further, Vine et al. (2016) argue that a threat state might deter
112 performance by disrupting attentional and visuomotor control, causing individuals to become
113 distracted by less relevant (and potentially negative) stimuli at the expense of more important task-
114 relevant cues. This is in keeping with the original mechanism proposed by Blascovich et al. (2004),
115 who speculated that attentional resources might be diverted from the task at hand towards the
116 environment or themselves during a threat state. However, to date, relatively little research has
117 tested these potential mechanisms (e.g., Moore, Vine, Wilson, & Freeman, 2012).

118 With increasing interest in the BPSM, there has been greater diversity in the
119 conceptualisation and measurement of CAT states. Indeed, while some authors have used self-
120 report measures of demand and resource evaluations (e.g., Gildea, Schneider, & Shebilske, 2007),
121 others have used physiological indices computed from CO and TPR reactivity (i.e., change in CO
122 and TPR from baseline to post-instruction/task exposure; e.g., Blascovich et al., 2004). Although
123 both the cognitive evaluations and physiological responses accompanying CAT states are predicted
124 to influence performance, it is not known which has the strongest effect. Even within these
125 approaches, little consensus exists regarding standardised measurements. For example, both single-

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126 and multi-item self-report measures of cognitive evaluations have been used to calculate either a
127 ratio (e.g., demands divided by resources), or a difference score (e.g., resources minus demands).
128 Researchers have also differed in the timing and duration of baseline and post-instruction/task
129 exposure periods when recording cardiovascular data, and have used different methods to calculate
130 a single CAT index from CO and TPR reactivity (e.g., difference vs. residualised change scores).

131 In addition to the diversity in the measurement of CAT states and the tasks employed,
132 studies have adopted different research designs. Some studies have employed experimental
133 designs, directly manipulating individuals into CAT states and observing performance. For
134 example, Moore and colleagues (2013) used verbal instructions to elicit CAT states before a golf
135 putting task, and found that the golfers in the challenge group outperformed those in the threat
136 group (Moore, Wilson et al., 2013). Other experimental studies have indirectly manipulated CAT
137 states via an antecedent and then measured performance (e.g., resource appraisals; Turner, Jones,
138 Sheffield, Barker, & Coffee, 2014). Correlational studies have also been employed, with CAT
139 states observed before a task and subsequently related to performance (e.g., Turner et al., 2013).
140 Finally, studies have used quasi-experimental designs, recording CAT states with continuous
141 measures, and then splitting the sample into CAT groups before examining between-group
142 differences in performance (e.g., via median split; Gildea et al., 2007).

143 Given the increasing adoption of the BPSM for understanding performance variation during
144 stressful tasks, aligned with notable diversity in the conceptualisation of CAT states, performance
145 outcomes, and research designs employed, the primary aim of this systematic review was to
146 examine the pattern of associations between CAT states and performance outcomes. The secondary
147 aim was to examine the consistency of this pattern across different conceptualisations of CAT states
148 (i.e., cognitive evaluations vs. physiological responses vs. dichotomous groups), performance
149 outcomes (i.e., cognitive vs. behavioural tasks), and research designs (i.e., direct experimental vs.
150 indirect experimental vs. correlational vs. quasi-experimental designs). Synthesising the current
151 evidence will provide crucial insight into the utility of the BPSM to explain performance variation

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152 under stress, the impact of employing different methods, and highlight important directions and
153 methodological considerations for future research.

154 **Method**

155 This systematic review was conducted in accordance with the Preferred Reporting Items for
156 Systematic reviews and Meta-Analyses guidelines (Moher, Liberati, Tetzlaff, & Altman, 2009). It
157 involved four steps: (1) initial literature search (including selection of search terms, electronic
158 databases, and inclusion criteria), (2) screening based on title, (3) screening based on abstract, and
159 (4) screening based on full text. Two independent assessors completed each step, compared their
160 records and discussed any disagreements. The assessors searched for relevant articles using the
161 following databases: MedLine, PsycINFO, and SPORTDiscus (combined in one search) and Web
162 of Science (in a separate search). The search terms were (“challenge and threat” AND
163 “performance”). To be included, studies had to fulfil five inclusion criteria: (1) published in
164 English in a peer-reviewed academic journal, (2) report at least one empirical study, (3) conducted
165 with healthy human participants, (4) conceptualise CAT in terms of a unidimensional continuum,
166 and (5) report at least one performance outcome and its association with at least one CAT measure,
167 or dichotomous CAT groups that were compared on a CAT measure in a manipulation check.

168 To examine the consistency of the pattern of associations between CAT states and
169 performance within different conceptualisations of CAT states, performance outcomes and research
170 designs, we used Sallis, Prochaska, and Taylor’s (2000) sum code classification. This classification
171 focuses on the percentage of studies that demonstrate a statistically significant effect. Further, to
172 assess the quality and risk of bias in experimental and non-experimental studies, respectively, the
173 Cochrane Collaboration’s tool for assessing risk of bias (Higgins & Altman, 2008) and the Risk of
174 Bias Assessment Tool for Nonrandomised Studies (Kim et al., 2013) were used. For experimental
175 studies, two independent assessors examined random sequence generation (were experimental
176 conditions assigned randomly?), allocation concealment (could condition allocations have been
177 foreseen before/during enrolment?), blinding of participants and personnel (were participants and

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178 researchers blind to the participants' allocated experimental condition?), blinding of outcome
179 assessment (were outcome assessors blind to experimental condition?), incomplete outcome data
180 (were attrition/exclusion rates and reasons reported?), selective reporting (was there a possibility of
181 selective reporting?), and other sources of bias (Higgins & Altman, 2008). For non-experimental
182 studies, two independent assessors examined blinding of outcome assessment, incomplete outcome
183 data, selective reporting, selection of participants (how adequate was the selection of participants?),
184 confounding variables (was there adequate consideration of confounders?), and intervention
185 (exposure) measurement (was there performance bias caused by inadequate measurement of
186 exposure?; Kim et al., 2013).

187 **Results**

188 The initial search (conducted in December 2017) yielded 1107 unique results. After
189 reviewing titles, 155 records remained. After reading abstracts, 59 records remained. After
190 reviewing full-texts, 30 articles reporting 38 studies with a total of 3257 participants were identified
191 and included in the review. Figure 1 illustrates the search and screening process. Inter-rater
192 agreements in the second, third, and fourth step were 96.6%, 84.4%, and 84.7%. Disagreements
193 were resolved through discussion between the assessors and a third member of the research team.

194 **General Study Characteristics**

195 Table 1 presents the characteristics and main outcomes of the included studies. Sample
196 sizes ranged from 16 to 238 with a mean sample size of 85.7 participants ($SD = 54.4$). Most
197 samples contained both genders, but four samples were all male (Gildea et al., 2007; Laborde et al.,
198 2015; Turner et al., 2013), and five samples were all female (Chalabaev et al., 2009; Chalabaev,
199 Major, Sarrazin, & Cury, 2012; Mendes, Blascovich, Hunter, Lickel, & Jost, 2007; Study 2,
200 Scheepers, 2017; Turner, Jones, Sheffield, & Cross, 2012). The average age in the 28 studies that
201 reported this statistic ranged from 11.0 to 36.3 years with an average mean of 22.5 years ($SD = 4.9$).
202 The remaining studies reported a mode age of 18 years (Quigley, Barrett, & Weinstein, 2002), a
203 median of 28 years (Roberts et al., 2015), or no age statistic (Blascovich et al., 2004; Chalabaev et

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204 al., 2009; Chalabaev et al., 2012; Feinberg & Aiello, 2010; Kelsey et al., 2000; Seery et al., 2010).
205 Most studies sampled university students, but others incorporated athletes, doctors, adolescents,
206 academic staff, and non-specified adults.

207 **Risk of Bias in Individual Studies**

208 Table 2 presents the risk of bias results. Interrater agreements were 84.1% and 85.8% for
209 experimental and non-experimental studies, respectively. The assessors resolved disagreements in
210 discussions with a third member of the research team. In experimental studies, the lowest risk of
211 bias ratings emerged for “random sequence generation”, “incomplete outcome data”, and “other
212 sources of bias”, as 88.9%, 77.8%, and 100% of studies received a “low risk of bias” rating,
213 respectively. Unclear risk of bias was more apparent for “allocation concealment”, “blinding of
214 participants and personnel”, “blinding of outcome assessment”, and “selective reporting”, with
215 88.9%, 88.9%, 55.6%, and 100% of studies rated as “unclear risk of bias” respectively. The
216 assessors rated one study (5.6%) in the “incomplete outcome data” category as “high risk of bias”.

217 In non-experimental studies, a low risk of bias ratings emerged for “blinding of outcome
218 assessment”, “incomplete outcome data”, “confounding variables”, and “intervention (exposure)
219 measurement”, as 55.0%, 75.0%, 100%, and 100% of studies in these categories received a “low
220 risk of bias” rating, respectively. “Selective reporting” and “selection of participants” received
221 mostly “unclear risk of bias” ratings (100% and 90.0%, respectively). The assessors rated two
222 studies (10.0%) in the “incomplete outcome data” category as “high risk of bias”.

223 **Association between CAT States and Performance**

224 Of the 38 included studies, 28 (74%) found an effect on performance favouring a challenge
225 state, although three of the observed effects were contingent on an interaction with another variable.
226 The three interaction effects depended on solo status (performing alone or not; Study 1, White,
227 2008), performance goals (performance-avoidance or approach goal; Chalabaev et al., 2012), and
228 integrative task structure (whether concessions on less important aspects of a negotiation tasks led
229 to gains on more important aspects or not; Study 2, O’Connor, Arnold, & Maurizio, 2010). Of the

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230 remaining 10 studies, one found an effect favouring a threat state (Study 1, Feinberg & Aiello,
231 2010), and nine found no significant effects (Chalabaev et al., 2009; Study 4, Feinberg & Aiello,
232 2010; Study 2, Gildea et al., 2007; Laborde et al., 2015; Mendes et al., 2007; Quigley et al., 2002;
233 Rith-Najarian et al., 2014; Sammy et al., 2017; Turner et al., 2014). At least one effect size was
234 reported in 24 studies, yielding 29 in total: 12 Cohen's d values ranging from 0.29 to 1.09, 15 R^2
235 values ranging from .06 to .61, one sr^2 of .04, and one η_p^2 of .12 (see Table 1). These reflected 11
236 small, 14 medium, and four large effect sizes (Cohen, 1992).

237 **Effects of cognitive, physiological, and dichotomous CAT measures on performance.**

238 Table 3 lists the associations between CAT states and performance based on whether CAT was
239 analysed as a continuous cognitive, continuous physiological, or dichotomous variable. The
240 dichotomous category included studies that compared challenge and threat groups in the analysis,
241 regardless of whether the groups were created by an experimental manipulation or by a median split
242 of a continuous CAT measure. Studies that reported an association with performance of more than
243 one CAT measure are included in each relevant category; thus, the number of effects is 43.

244 Sixteen studies reported 17 analyses that examined the association between a cognitive CAT
245 measure and performance. Thirteen analyses (76%) found a statistically significant effect favouring
246 a challenge state, with two effects contingent on interactions (Study 1, White, 2008; Chalabaev et
247 al., 2012). Four analyses found no significant effect (Chalabaev et al., 2009; Laborde et al., 2015;
248 Quigley et al., 2002; Rith-Najarian et al., 2014). Of the six effect sizes reported, three were small
249 (Chalabaev et al., 2012; Moore, Young, Freeman, & Sarkar, 2017; Study 1, Moore, Wilson et al.,
250 2013), two were medium (Study 1, O'Connor et al., 2010; Schneider, 2004), and one was large
251 (Vine et al., 2015). The majority of the cognitive CAT indices used self-report items from Tomaka
252 and colleagues' (1993) cognitive appraisal ratio or Schneider's (2008) stressor appraisal scale to
253 create demand and resource evaluation scores. These scores were combined into a ratio (i.e.,
254 demands divided by resources; e.g., Quigley et al., 2002) or a difference score (i.e., resources minus

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255 demands; e.g., Chalabaev et al., 2012). However, some studies used single-item measures that
256 assessed the degree to which participants felt challenged or threatened (e.g., Turner et al., 2012).

257 Eleven studies reported 12 analyses that examined the association between a physiological
258 CAT measure and performance. Eight (67%) found that a challenge cardiovascular response was
259 associated with better performance than the threat response (Blascovich et al., 2004; Moore et al.,
260 2017; Scheepers, 2017; Scholl, Moeller, Scheepers, Nuerk, & Sassenberg, 2015; Seery et al., 2010;
261 Turner et al., 2013; Studies 1 and 2, Turner et al., 2012). Four analyses found no significant effect
262 (Mendes et al., 2007; Rith-Najarian et al., 2014; Seery et al., 2010; Vine, Freeman, Moore,
263 Chandra-Ramanan, & Wilson, 2013). Of the 10 effect sizes reported, five were small (Blascovich
264 et al., 2004; Moore et al., 2017; Scheepers, 2017; Scholl et al., 2015; Seery et al., 2010), and five
265 were medium (Scholl et al., 2015; Studies 1 and 2, Turner et al., 2012). The physiological CAT
266 index comprised a sum score of the changes in CO and TPR from baseline to a post-instruction (or
267 manipulation) period. These changes were determined by using difference scores in all studies in
268 the “Physiological” group. However, two studies in the “Dichotomous” group used residualised
269 change scores (i.e., standardised residuals of a regression of post-instruction on baseline values, to
270 control for differences in baseline values) to create the index (e.g., Moore et al., 2015; Moore, Vine,
271 Wilson, & Freeman, 2014). Both approaches typically weighted TPR reactivity negatively, so that
272 a greater value on the summed CAT index was more reflective of a challenge state. Finally, the
273 timing and duration of physiological data differed between studies. For example, some studies
274 recorded five minutes of baseline data and one minute after giving task instructions, although they
275 often only used the final minute of the baseline period in the analyses (e.g., Moore et al., 2014).
276 Other studies measured five minutes of baseline data and two minutes of reactivity data during the
277 task, using mean values of the entire time periods (e.g., Blascovich et al., 2004).

278 Only 11 studies included both physiological and cognitive CAT indices, and only three of
279 these studies reported associations with performance for both indices¹ (Moore et al., 2017; Rith-

¹ Chalabaev et al.’s (2009) study is not listed here despite reporting performance analyses for the cognitive and physiological variables (i.e., CO and TPR reactivity). This is because the physiological CAT variables were not

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280 Najarian et al., 2014; Vine et al., 2013). Moore and colleagues (2017) found that both the cognitive
281 and physiological CAT measures were related to performance. Rith-Najarian and colleagues (2014)
282 found that neither measure was related to performance. Vine and colleagues (2013) found that only
283 the cognitive CAT measure was related to performance, with a challenge state linked with better
284 performance. Further, only three of the studies that computed both cognitive and physiological
285 CAT measures provided a correlation between the two indices² (Moore et al., 2017; Turner et al.,
286 2013; Vine et al., 2013). Moore et al. (2017; $r = .19$) and Turner et al. (2013; $r = .21$) found no
287 significant correlation, whereas Vine et al. (2013) found a significant correlation during the baseline
288 test ($r = .32$), but not the pressurised test ($r = -.11$).

289 Fifteen studies created dichotomous groups, which were confirmed with a manipulation
290 check using a cognitive and/or physiological CAT measure. Ten (67%) studies found that the
291 challenge group significantly outperformed the threat group (Study 2, Feinberg & Aiello, 2010;
292 Studies 1 and 3, Gildea et al., 2007; Moore et al., 2012; Moore et al., 2014; Moore et al., 2015;
293 Study 2, Moore, Wilson et al., 2013; Study 2, O'Connor et al., 2010; Scheepers, 2017), with one
294 effect contingent on an interaction (O'Connor et al., 2010). Furthermore, Feinberg and Aiello
295 (2010) reported three significant interaction effects between CAT instructions and experimenter
296 presence. However, they did not report whether challenge was related to better performance than
297 threat in any of the two experimenter presence conditions, comparing challenge with challenge, and
298 threat with threat across the two conditions instead. Four studies found no significant effect (Study
299 4, Feinberg & Aiello, 2010; Study 2, Gildea et al., 2007; Sammy et al., 2017; Turner et al., 2014),
300 and one study found that participants in the threat condition outperformed those in the challenge
301 condition, although it should be noted that the manipulation check in this study was only marginally
302 significant (Study 1, Feinberg & Aiello, 2010). Of the 16 effect sizes reported, six were small

combined into a single CAT index, which violated the inclusion criteria. However, it is noteworthy that this analysis did find challenge reactivity to be associated with better performance, supporting the contentions of the BPSM.

² Two other studies provided associations between cognitive and physiological variables, but did not use a single physiological CAT index (Turner et al., 2012; Quigley et al., 2002). Turner et al. (2012) did not find any significant correlations, although the coefficients were consistent with the BPSM in terms of direction. Quigley et al. (2002) found a marginally significant association between cognitive CAT and CO, but not between cognitive CAT and TPR.

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303 (Study 2, Gildea et al., 2007; Moore et al., 2014; Moore et al., 2017; Study 2, O'Connor et al.,
304 2010; Scheepers, 2017), seven were medium (Study 3, Gildea et al., 2007; Moore et al., 2012;
305 Study 2, Moore, Wilson et al., 2013; Schneider, 2004; Turner et al., 2014), and three were large
306 (Study 1, Feinberg & Aiello, 2010; Study 1, Gildea et al., 2007; Moore et al., 2015).

307 **Effects of CAT states on cognitive and behavioural task performance.** The performance
308 tasks varied across studies, but could be placed into two main categories: Cognitive and
309 behavioural. Table 4 lists the studies in each category and their corresponding results.

310 Twenty studies reported 23 effects involving cognitive performance outcomes, of which
311 eight were mathematical (e.g., serial subtraction task; Kelsey et al., 2000). Examples of other tasks
312 included Stroop (Study 1, Turner et al., 2012), and word-finding (Mendes et al., 2007) tasks.
313 Fifteen (65%) analyses found that a challenge state was associated with superior performance,
314 although two of these effects were contingent on an interaction with another variable (Chalabaev et
315 al., 2012; Study 1, White, 2008). Seven effects were not significant, and one analysis found that
316 participants performed significantly better in the threat condition (Study 1, Feinberg & Aiello,
317 2010). Of the 15 effect sizes, four were small (Chalabaev et al., 2012; Scholl et al., 2015; Seery et
318 al., 2010), nine were medium (Study 3, Gildea et al., 2007; Schneider, 2004; Scholl et al., 2015;
319 Studies 1 and 2, Turner et al., 2012), and two were large (Study 1, Feinberg & Aiello, 2010; Study
320 1, Gildea et al., 2007).

321 Nineteen effects involved behavioural tasks such as golf putting (Moore et al., 2012; Moore
322 et al., 2015; Study 2, Moore, Wilson et al., 2013), cricket batting (Turner et al., 2013), flight
323 simulation (Vine et al., 2015), and a medical selection practical (Roberts et al., 2015). Sixteen
324 (84%) effects favoured a challenge state, with one effect qualified by an interaction with another
325 variable (Study 2, O'Connor et al., 2010). Three effects were not significant (Rith-Najarian et al.,
326 2014; Sammy et al., 2017; Turner et al., 2014). Of the 15 effect sizes reported, six were small
327 (Blascovich et al., 2004; Moore et al., 2014; Study 1, Moore, Wilson et al., 2013; Moore et al.,
328 2017; Study 2, O'Connor et al., 2010), seven were medium (Moore et al., 2012; Study 2, Moore,

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329 Wilson et al., 2013; Study 1, O'Connor et al., 2010; Turner et al., 2014; Studies 1 and 2, Turner et
330 al., 2012), and two were large (Moore et al., 2015; Vine et al., 2015).

331 **Effects of CAT states on performance within different research designs.** Four types of
332 research designs were used: (1) experiments that directly manipulated CAT states (explicitly
333 targeting CAT states), (2) experiments that indirectly manipulated CAT states (targeting another
334 variable, including putative CAT antecedents), (3) correlational studies, and (4) quasi-experiments.
335 Table 5 lists the studies grouped by research design. Although the “dichotomous” group in Table 3
336 shares some studies with the “experimental (direct)” and “quasi-experimental” groups, the research
337 questions pertaining to Table 3 and Table 5 are different. Table 3 is about the type of CAT measure
338 and analysis, whereas Table 5 is about the type of research design.

339 Six studies reported experiments that directly manipulated participants into CAT states by
340 framing the task instructions consistent with either a challenge or threat state (i.e., perceptions of
341 task demands and personal coping resources). Four (67%) studies found that participants in the
342 challenge group performed significantly better than those in the threat group (Study 2, Feinberg &
343 Aiello, 2010; Moore et al., 2012; Study 2, Moore, Wilson et al., 2013), although one effect was
344 qualified by an interaction (Study 2, O'Connor et al., 2010). One study found no significant effect
345 (Study 4, Feinberg & Aiello, 2010), and one study found that the threat group outperformed the
346 challenge group (Study 1, Feinberg & Aiello, 2010). Of the five effect sizes, one was small (Study
347 2, O'Connor et al., 2010), three were medium (Moore et al., 2012; Study 2, Moore, Wilson et al.,
348 2013), and one was large (Study 1, Feinberg & Aiello, 2010).

349 Twelve studies reported experiments that indirectly manipulated CAT states by
350 manipulating another variable such as resource appraisals (Turner et al., 2014), perceived effort and
351 support (Moore et al., 2014), or interpretations of physiological arousal (Moore et al., 2015), and
352 obtained different CAT responses between groups. Eight (67%) studies found that a challenge state
353 was associated with superior performance, although one effect was contingent on an interaction
354 (O'Connor et al., 2010). Four studies found no significant effect (Chalabaev et al., 2009; Mendes et

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355 al., 2007; Sammy et al., 2017; Turner et al., 2014). Of the six effect sizes reported, three were small
356 (Chalabaev et al., 2012; Moore et al., 2014; Scheepers, 2017), two were medium (Study 1,
357 O'Connor et al., 2010; Turner et al., 2014), and one was large (Moore et al., 2015).

358 Sixteen studies used a correlational design, correlating either a cognitive or physiological
359 CAT measure with performance. Of the 18 effects in this group, 14 (78%) showed a significant
360 association between CAT and performance, with a challenge state related to better performance.
361 Four analyses found no significant association (Laborde et al., 2015; Quigley et al., 2002; Rith-
362 Najarian et al., 2014; Seery et al., 2010). Of the 12 effect sizes reported, five were small
363 (Blascovich et al., 2004; Moore et al., 2017; Scholl et al., 2015; Seery et al., 2010), six were
364 medium (Study 2, Moore, Wilson et al., 2013; Scholl et al., 2015; Studies 1 and 2, Turner et al.,
365 2012), and one was large (Vine et al., 2015).

366 Finally, four studies used a quasi-experimental approach by dividing the sample into CAT
367 groups based on scores on a cognitive CAT measure. All four (100%) studies found that
368 participants in the challenge group performed significantly better than those in the threat group
369 (Gildea et al., 2007; Schneider, 2004). Of the six effect sizes reported, one was small (Study 2,
370 Gildea et al., 2007), four were medium (Study 3, Gildea et al., 2007; Schneider, 2004), and one was
371 large (Study 1, Gildea et al., 2007).

372 **Discussion**

373 For over two decades, the BPSM of CAT states has been used as a framework to understand
374 variations in cognitive, physiological, and behavioural responses in motivated performance
375 situations (Blascovich & Mendes, 2000). The aim of this systematic review was to examine the
376 relationship between CAT states and performance, and the consistency of this relationship across
377 different CAT measures, performance tasks, and research designs. In 28 (74%) of the 38 studies, a
378 challenge state was related to better performance. Based on statistical significance, the relationship
379 between CAT states and performance was relatively consistent across different measures of CAT
380 states (cognitive vs. physiological vs. dichotomous), performance outcomes (cognitive vs.

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381 behavioural), and research designs (direct experimental vs. indirect experimental vs. correlational
382 vs. quasi-experimental), although there were few studies in the direct experimental group. The
383 common finding that individuals who exhibited a challenge state outperformed individuals who
384 displayed a threat state, supports the predictions of the BPSM and holds relevance for sports
385 psychologists, coaches, business managers, educators, and other professionals interested in
386 optimising human performance.

387 The beneficial effect of a challenge state was generally consistent across different CAT
388 measures (i.e., cognitive vs. physiological vs. dichotomous). As such, the findings support the
389 prediction of the BPSM that CAT states occur on both a cognitive (i.e., underlying demand/resource
390 evaluations) and physiological (i.e., accompanying cardiovascular responses) level, and influence
391 performance. However, it is noteworthy that studies including the relationships between both CAT
392 measures and performance found an inconsistent pattern (e.g., Moore et al., 2017; Rith-Najarian et
393 al., 2014; Turner et al., 2013), implying that more research is needed to compare the two measures
394 as predictors of performance. In addition, although the BPSM predicts that different demand and
395 resource evaluations lead to distinct physiological responses (Blascovich, 2008), only three studies
396 included both cognitive and physiological CAT measures and reported correlations among these
397 variables (Moore et al., 2017; Turner et al., 2013; Vine et al., 2013). Weak to moderate correlations
398 were reported in these studies, raising questions about whether demand and resource evaluations
399 trigger distinct cardiovascular responses, as proposed by the BPSM (Blascovich, 2008). Indeed, the
400 wider BPSM literature has also demonstrated weak to moderate links between cognitive and
401 physiological markers of CAT (e.g., Zanstra, Johnston, & Rasbash, 2010).

402 Studies that used a single cognitive measure of CAT states to dichotomise individuals into
403 CAT groups (e.g., via a median split) also tended to support the superiority of a challenge state
404 (e.g., Gildea et al., 2007). However, dichotomising CAT states is incongruent with the notion that
405 they represent opposite ends of a single bipolar continuum (Blascovich & Mendes, 2000). Further,
406 dichotomising a sample with a median split could lead to problems like loss of statistical power and

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407 difficulty in comparing results between studies due to the different cut-off points employed (Altman
408 & Royston, 2006). Researchers should therefore consider whether it is appropriate to dichotomise
409 CAT measures and, if so, ensure that the study has sufficient power.

410 This review revealed notable diversity in the recording and calculation of cognitive and
411 physiological CAT measures. For instance, both single and multiple self-report items assessed
412 demand and resource evaluations (Schneider, 2008; Tomaka et al., 1993; Turner et al., 2013). In
413 addition, responses to these items were used to calculate a ratio (i.e., demands divided by resources;
414 e.g., Moore et al., 2012), or difference (i.e., resources minus demands; e.g., Moore et al., 2013)
415 score. Moreover, CO and TPR were reported as reactivity (e.g., Blascovich et al., 2004) or
416 residualised change scores (e.g., Moore et al., 2012). These values were often calculated by
417 averaging across different durations and time periods (e.g., final minute of baseline and first minute
418 after receipt of task instructions, Moore et al., 2014; or final two minutes of baseline and first two
419 minutes of the task itself, Blascovich et al., 2004). The justifications for these variations were not
420 always clearly articulated and should be made more explicit in future research.

421 Although these variations did not appear to impact the findings, future research would
422 benefit from adopting a more consistent approach in CAT measurement to facilitate the synthesis of
423 evidence across studies. If studies adopt different methods to measure CAT states, it is unclear
424 whether the observed relationships are due to CAT states themselves or the idiosyncratic
425 measurement processes (e.g., because self-report was employed rather than cardiovascular indices
426 or a ratio vs. a difference score). Although we encourage future research to contrast the different
427 ways of measuring CAT states to empirically identify the optimal approach, we make the following
428 recommendations based on the justifications provided in the current literature. Researchers should
429 use both cognitive evaluations and cardiovascular responses to measure CAT states, and further
430 examine their relationship and respective effects on performance. Given the limitations associated
431 with single-item scales (e.g., lower relative precision than multi-item scales; McHorney, Ware,
432 Rogers, Raczek, & Lu, 1992), multi-item measures of demand and resource evaluations should be

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433 employed (e.g., Schneider, 2008). The scores from these items should then be used to calculate a
434 difference score, as ratio scores have been discouraged due to their highly nonlinear distribution
435 (Vine et al., 2013). When measuring the physiological indices of CAT states (i.e., CO and TPR
436 reactivity), researchers should use comparable time periods and indices. To ensure true resting
437 values are obtained, researchers should use the final minute of the baseline period (Sherwood,
438 Allen, Kelsey, Lovallo, & van Doornen, 1990). Further, given the dynamic nature of CAT states
439 (i.e., reappraisal; Blascovich, 2008), researchers should utilise the first minute after task instructions
440 or of task exposure. While most research has employed difference scores rather than residualised
441 change scores, we recommend that researchers consult guidelines and use the approach most
442 suitable for their data (e.g., Burt & Obradovic, 2013). Finally, CO and TPR reactivity should be
443 combined into a single CAT index, which is more in keeping with the unidimensional nature of
444 CAT states, increases reliability, and simplifies analyses (Seery et al., 2010).

445 The risk of bias assessment showed that random sequence generation, incomplete outcome
446 data, other sources of bias, blinding of outcome assessment, incomplete outcome data, confounding
447 variables, and intervention (exposure) measurement exhibited a low risk of bias across most studies.
448 Allocation concealment, blinding of participants and personnel, blinding of outcome assessment,
449 selection of participants, and selective reporting often exhibited an unclear risk of bias. As only
450 three studies were rated as high risk of bias, the body of evidence appears to be of adequate quality
451 overall, but the findings highlight the importance of considering and reporting potential risks in
452 future studies. For example, researchers should minimise missing physiological and outcome data,
453 ensure that performance assessors are naive to CAT data, and provide information about allocation
454 concealment, blinding of participants, personnel and outcome assessment, and selective reporting.

455 Based on statistical significance, there was a relatively consistent relationship between CAT
456 states and performance on behavioural and cognitive tasks. The notable difference in support for
457 cognitive vs. behavioural tasks (see Table 4) could have been influenced by the included and
458 excluded studies. First, although Chalabaev et al. (2009) found that greater CO reactivity and lower

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459 TPR reactivity were associated with better cognitive performance separately, the review excluded
460 this study as no single physiological CAT index was reported. Second, Feinberg and Aiello's
461 (2010) three studies that manipulated participants into CAT groups using verbal instructions, found
462 inconsistent effects for CAT states on performance, one of which involved an only marginally
463 significant manipulation check. As well as being inconsistent with the notion that CAT states are a
464 continuum (Blascovich & Mendes, 2000), this approach averages data across CAT groups and
465 individuals who were not successfully manipulated into the required state might have attenuated the
466 results (i.e., individuals in the challenge group displaying a threat state, and vice versa; Turner et al.,
467 2013). As such, the weaker effect on cognitive outcomes might have been caused by other
468 confounding statistical and methodological issues.

469 Studies that directly manipulated CAT states provided support for the superiority of a
470 challenge state, although only six studies utilised such a design. Four studies found that the
471 challenge group outperformed the threat group (Study 2, Feinberg & Aiello, 2010; Moore et al.,
472 2012; Moore, Wilson et al., 2013; O'Connor et al., 2010), and two studies reported null or
473 contradictory results (Studies 1 and 4, Feinberg & Aiello, 2010). Issues such as the strength and
474 effectiveness of the CAT manipulation instructions (as well as the limitations noted above) might
475 explain the heterogeneous results among Feinberg and Aiello's (2010) studies. For example,
476 Feinberg and Aiello read instructions aloud to participants, whereas Moore et al. (2012, 2013)
477 delivered standardised instructions from memory more directly to participants. Researchers
478 employing experimental designs should report the methods used to manipulate participants into
479 CAT states and use both cognitive and physiological CAT measures as manipulation checks, as the
480 two measures could yield divergent results.

481 Although two theoretical models (Jones et al., 2009; Vine et al., 2016) have proposed
482 several potential mechanisms through which CAT states might influence performance, only three
483 studies included in the review explicitly tested mediation (Moore et al., 2012; Moore, Wilson et al.,
484 2013 study 2; Vine et al., 2013). Of these studies, only one study reported statistically significant

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485 mediation (Moore et al., 2012), with the findings suggesting that CAT states influenced golf-putting
486 performance primarily via kinematic variables and not through emotional, attentional, or
487 physiological pathways. Despite this limited evidence for significant mediating processes, studies
488 have reported that CAT states are associated with different emotional, attentional, and physiological
489 responses, with a challenge state linked with less cognitive anxiety, more optimal visual attention,
490 and less muscle activity (Moore et al., 2012; Moore, Wilson et al., 2013 study 2; Vine et al., 2013).
491 It is vital for research to continue exploring these and other potential underlying mechanisms to
492 better understand how a challenge state facilitates performance. In particular, research should test
493 the attentional mechanisms outlined by Vine et al. (2016), and examine whether a threat state
494 increases the influence of the stimulus-driven system and draws attention away from task-relevant
495 to less relevant (and potentially negative) stimuli, resulting in suboptimal performance.

496 Several issues emerged as limitations to the present review. First, a meta-analysis may have
497 provided additional information about the strength of the relationship between CAT states and
498 performance. However, this was not feasible due to the substantial variability in methodologies
499 adopted across studies. The variability across studies also hindered the ability to clearly delineate
500 how strongly the effects were influenced by the CAT measure, task, or research design. Second, as
501 this review only included published studies, publication bias might have influenced its results.
502 Third, the sum codes used in Tables 3, 4, and 5 (adopted from Sallis et al., 2000) use arbitrary cut-
503 off points and refer to patterns of statistical significance, which do not take into account effect sizes.
504 Finally, while the research team categorised tasks as either cognitive or behavioural, many tasks
505 required both cognitive input and behavioural execution. For example, golf putting requires
506 cognition to determine the optimal direction and behavioural control to execute the motor skill.

507 This review highlights key directions for future research. Given that a challenge state
508 facilitates performance, it is important to identify factors that elicit a challenge state to aid the
509 development of theory and effective interventions. While some antecedents proposed by the BPSM
510 (e.g., required effort and support; Moore et al., 2014) and TCTSA (e.g., control, self-efficacy, and

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511 achievement goals, Turner et al., 2014) have been investigated, research should examine other
512 possible antecedents (e.g., danger, uncertainty, familiarity, knowledge, skills, abilities; Blascovich,
513 2008). Further, although some interventions have received attention (e.g., arousal reappraisal,
514 Moore et al., 2015), research should examine other interventions aimed at promoting a challenge
515 state. Finally, the longitudinal (and likely reciprocal) relationship between CAT states and
516 performance should be explored.

517 **Conclusion**

518 To conclude, a challenge state was related to better performance than a threat state in 74%
519 of studies. The quality of the included studies was generally good, although the risk of bias
520 assessment identified some areas for improvement (e.g., minimise data loss). This association
521 between CAT states and performance was relatively consistent across cognitive, physiological, and
522 dichotomous CAT variables; cognitive and behavioural tasks; and direct experimental, indirect
523 experimental, correlational, and quasi-experimental designs. Future research would benefit from a
524 more consistent approach to CAT measurement (e.g., multi-item self-report measures of cognitive
525 evaluations), to reduce ambiguity and aid the synthesis of results across studies. Furthermore,
526 researchers should develop challenge-promoting interventions to optimise the performance of
527 individuals across a range of domains (e.g., sport, academia, business, and medicine).

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References

- 530 Allen, K. M., & Blascovich, J. (1994). Effects of music on cardiovascular reactivity among
531 surgeons. *Journal of American Medical Association*, 272, 882-884. doi:
532 10.1001/jama.1994.03520110062030.
- 533 Altman, D. G., & Royston, P. (2006). The cost of dichotomising continuous variables. *BMJ*
534 (*Clinical Research Ed.*), 332, 1080. doi: 10.1136/bmj.332.7549.1080.
- 535 Blascovich, J. (2008). Challenge and threat. In A.J. Elliot (Ed.), *Handbook of approach and*
536 *avoidance motivation* (pp. 431-445). New York: Psychology Press.
- 537 Blascovich, J., & Mendes, W. B. (2000). Challenge and threat appraisals: The role of affective cues.
538 In J. P. Forgas, J. P. Forgas (Eds.) , *Feeling and thinking: The role of affect in social*
539 *cognition* (pp. 59-82). New York: Cambridge University Press.
- 540 Blascovich, J., Seery, M. D., Mugridge, C. A., Norris, R. K., & Weisbuch, M. (2004). Predicting
541 athletic performance from cardiovascular indexes of challenge and threat. *Journal of*
542 *Experimental Social Psychology*, 40, 683-688. doi: 10.1016/j.jesp.2003.10.007.
- 543 Burt, K. B., & Obradović, J. (2013). The construct of psychophysiological reactivity: Statistical and
544 psychometric issues. *Developmental Review*, 33, 29-57. doi:10.1016/j.dr.2012.10.002
- 545 Chalabaev, A., Major, B., Cury, F., & Sarrazin, P. (2009). Physiological markers of challenge and
546 threat mediate the effects of performance-based goals on performance. *Journal of*
547 *Experimental Social Psychology*, 45, 991-994. doi: 10.1016/j.jesp.2009.04.009.
- 548 Chalabaev, A., Major, B., Sarrazin, P., & Cury, F. (2012). When avoiding failure improves
549 performance: Stereotype threat and the impact of performance goals. *Motivation and*
550 *Emotion*, 36, 130-142. doi: 10.1007/s11031-011-9241-x.
- 551 Cohen, J. (1992). A power primer. *Psychological Bulletin*, 112, 155-159. doi: 10.1037/0033-
552 2909.112.1.155.
- 553 Cronbach, L. J., & Furby, L. (1970). How should we measure “change”— or should we?
554 *Psychological Bulletin*, 74, 68-80. doi: 10.1037/h0029382.

CHALLENGE/THREAT STATES AND PERFORMANCE

- 555 Dienstbier, R. A. (1989). Arousal of physiological toughness: Implications for physical and mental
556 health. *Psychological Review*, *96*, 84-100. doi: 10.1037/0033-295X.96.1.84.
- 557 Feinberg, J. M., & Aiello, J. R. (2010). The effect of challenge and threat appraisals under
558 evaluative presence. *Journal of Applied Social Psychology*, *40*, 2071-2104. doi:
559 10.1111/j.1559-1816.2010.00651.x.
- 560 Gildea, K. M., Schneider, T. R., & Shebilske, W. L. (2007). Stress appraisals and training
561 performance on a complex laboratory task. *Human Factors*, *49*, 745-758. doi:
562 10.1518/001872007X215818.
- 563 Higgins, J. P., & Altman, D. G. (2008). Assessing risk of bias in included studies. In J. P. Higgins
564 & S. Green (Ed.), *Cochrane Handbook for Systematic Reviews of Interventions: Cochrane*
565 *Book Series*. Retrieved from <http://handbook-5-1.cochrane.org>.
- 566 Jones, M., Meijen, C., McCarthy, P. J., & Sheffield, D. (2009). A theory of challenge and threat
567 states in athletes. *International Review of Sport and Exercise Psychology*, *2*, 161-180.
568 doi:10.1080/17509840902829331.
- 569 Kelsey, R. M., Blascovich, J., Leitten, C. L., Schneider, T. R., Tomaka, J., & Wiens, S. (2000).
570 Cardiovascular reactivity and adaptation to recurrent psychological stress: The moderating
571 effects of evaluative observation. *Psychophysiology*, *37*, 748-756. doi: 10.1111/1469-
572 8986.3760748.
- 573 Kim, S. Y., Park, J. E., Lee, Y. J., Seo, H., Sheen, S., Hahn, S., & ... Son, H. (2013). Testing a tool
574 for assessing the risk of bias for nonrandomized studies showed moderate reliability and
575 promising validity. *Journal of Clinical Epidemiology*, *66*, 408-414.
576 doi:10.1016/j.jclinepi.2012.09.016
- 577 Laborde, S., Lautenbach, F., & Allen, M. S. (2015). The contribution of coping-related variables
578 and heart rate variability to visual search performance under pressure. *Physiology &*
579 *Behavior*, *139*, 532-540. doi: 10.1016/j.physbeh.2014.12.003.
- 580 Lazarus, R. S., & Folkman, S. (1984). *Stress, appraisal, and coping*. New York: Springer.

CHALLENGE/THREAT STATES AND PERFORMANCE

- 581 McHorney, C. A., Ware, J. E., Rogers, W., Raczek, A. E., & Lu, J. R. (1992). The validity and
582 relative precision of MOS short- and long-form health status scales and Dartmouth COOP
583 Charts: Results from the medical outcomes study. *Medical Care*, *30*, 253-265.
584 doi:10.1097/00005650-199205001-00025
- 585 Mendes, W. B., Blascovich, J., Hunter, S. B., Lickel, B., & Jost, J. T. (2007). Threatened by the
586 unexpected: physiological responses during social interactions with expectancy-violating
587 partners. *Journal of Personality and Social Psychology*, *92*, 698-716. doi: 10.1037/0022-
588 3514.92.4.698.
- 589 Moher, D., Liberati, A., Tetzlaff, J., & Altman, D. G. (2009). Preferred reporting items for
590 systematic reviews and meta-analyses: the PRISMA statement. *Plos Medicine*, *6*, e1000097.
591 doi: 10.1016/j.jclinepi.2009.06.005.
- 592 Moore, L. J., Vine, S. J., Freeman, P., & Wilson, M. R. (2013). Quiet eye training promotes
593 challenge appraisals and aids performance under elevated anxiety. *International Journal of*
594 *Sport and Exercise Psychology*, *11*, 169-183. doi: 10.1080/1612197X.2013.773688.
- 595 Moore, L. J., Vine, S. J., Wilson, M. R., & Freeman, P. (2015). Reappraising threat: How to
596 optimize performance under pressure. *Journal of Sport & Exercise Psychology*, *37*, 339-343.
597 doi: 10.1123/jsep.2014-0186.
- 598 Moore, L. J., Vine, S. J., Wilson, M. R., & Freeman, P. (2012). The effect of challenge and threat
599 states on performance: An examination of potential mechanisms. *Psychophysiology*, *49*,
600 1417-1425. doi: 10.1111/j.1469-8986.2012.01449.x.
- 601 Moore, L. J., Vine, S. J., Wilson, M. R., & Freeman, P. (2014). Examining the antecedents of
602 challenge and threat states: the influence of perceived required effort and support
603 availability. *International Journal of Psychophysiology*, *93*, 267-273. doi:
604 10.1016/j.ijpsycho.2014.05.009.

CHALLENGE/THREAT STATES AND PERFORMANCE

- 605 Moore, L. J., Wilson, M. R., Vine, S. J., Coussens, A. H., & Freeman, P. (2013). Champ or chump?
606 Challenge and threat states during pressurized competition. *Journal of Sport & Exercise*
607 *Psychology, 35*, 551-562. doi: 10.1123/jsep.35.6.551.
- 608 Moore, L. J., Young, T., Freeman, P., & Sarkar, M. (2018). Adverse life events, cardiovascular
609 responses, and sports performance under pressure. *Scandinavian Journal of Medicine &*
610 *Science in Sports, 28*, 340-347. doi:10.1111/sms.12928
- 611 O'Connor, K. M., Arnold, J. A., & Maurizio, A. M. (2010). The prospect of negotiating: Stress,
612 cognitive appraisal, and performance. *Journal of Experimental Social Psychology, 46*, 729-
613 735. doi:10.1016/j.jesp.2010.04.007.
- 614 Quigley, K. S., Barrett, L. F., & Weinstein, S. (2002). Cardiovascular patterns associated with threat
615 and challenge appraisals: a within-subjects analysis. *Psychophysiology, 39*, 292-302. doi:
616 10.1017/S0048577201393046.
- 617 Rith-Najarian, L. R., McLaughlin, K. A., Sheridan, M. A., & Nock, M. K. (2014). The
618 biopsychosocial model of stress in adolescence: Self-awareness of performance versus stress
619 reactivity. *Stress: The International Journal on the Biology of Stress, 17*, 193-203. doi:
620 10.3109/10253890.2014.891102.
- 621 Roberts, M. J., Gale, T. E., McGrath, J. S., & Wilson, M. R. (2015). Rising to the challenge: Acute
622 stress appraisals and selection centre performance in applicants to postgraduate specialty
623 training in anaesthesia. *Advances in Health Sciences Education, 21*, 323-339. doi:
624 10.1007/s10459-015-9629-6.
- 625 Sallis, J. F., Prochaska, J. J., & Taylor, W. C. (2000). A review of correlates of physical activity of
626 children and adolescents. *Medicine and Science in Sports and Exercise, 32*, 963-975. doi:
627 10.1097/00005768-200005000-00014.
- 628 Sammy, N., Anstiss, P. A., Moore, L. J., Freeman, P., Wilson, M. R., & Vine, S. J. (2017). The
629 effects of arousal reappraisal on stress responses, performance and attention. *Anxiety, Stress,*
630 *& Coping, 30*, 619-629. doi:10.1080/10615806.2017.1330952

CHALLENGE/THREAT STATES AND PERFORMANCE

- 631 Scheepers, D. (2017). Intergroup status differences as challenge or threat: The role of legitimacy.
632 *Group Processes & Intergroup Relations*, 20, 75-90. doi: 10.1177/1368430215595108
- 633 Schneider, T. R. (2004). The role of neuroticism on psychological and physiological stress
634 responses. *Journal of Experimental Social Psychology*, 40, 795-804. doi:
635 10.1016/j.jesp.2004.04.005.
- 636 Schneider, T. R. (2008). Evaluations of stressful transactions: what's in an appraisal? *Stress and*
637 *Health*, 24, 151-158. doi: 10.1002/smi.1176.
- 638 Schneider, T. R., Rench, T. A., Lyons, J. B., & Riffle, R. R. (2012). The influence of neuroticism,
639 extraversion and openness on stress responses. *Stress and Health*, 28, 102-110. doi:
640 10.1002/smi.1409.
- 641 Scholl, A., Moeller, K., Scheepers, D., Nuerk, H., & Sassenberg, K. (2015). Physiological threat
642 responses predict number processing. *Psychological Research*, 81, 278-288. doi:
643 10.1007/s00426-015-0719-0.
- 644 Seery, M. D., Weisbuch, M., Hetenyi, M. A., & Blascovich, J. (2010). Cardiovascular measures
645 independently predict performance in a university course. *Psychophysiology*, 47, 535-539.
646 doi: 10.1111/j.1469-8986.2009.00945.x.
- 647 Sherwood, A., Allen, M.T., Kelsey, R.M., Lovallo, W.R., & van Doornen, L.J.P. (1990).
648 Methodological guidelines for impedance cardiography. *Psychophysiology*, 27, 1-23.
649 doi:10.1111/j.1469-8986.1990.tb02171.x.
- 650 Skinner, N., & Brewer, N. (2004). Adaptive approaches to competition: Challenge appraisals and
651 positive emotion. *Journal of Sport & Exercise Psychology*, 26, 283-305. doi:
652 10.1123/jsep.26.2.283.
- 653 Tomaka, J., Blascovich, J., Kelsey, R., & Leitten, C. (1993). Subjective, physiological, and
654 behavioral effects of threat and challenge appraisal. *Journal of Personality and Social*
655 *Psychology*, 65, 248-260. doi: 10.1037/0022-3514.65.2.248.

CHALLENGE/THREAT STATES AND PERFORMANCE

- 656 Turner, M. J., Jones, M. V., Sheffield, D., Barker, J. B., & Coffee, P. (2014). Manipulating
657 cardiovascular indices of challenge and threat using resource appraisals. *International*
658 *Journal of Psychophysiology*, *94*, 9-18. doi: 10.1016/j.ijpsycho.2014.07.004.
- 659 Turner, M. J., Jones, M. V., Sheffield, D., Slater, M. J., Barker, J. B., & Bell, J. J. (2013). Who
660 thrives under pressure? Predicting the performance of elite academy cricketers using the
661 cardiovascular indicators of challenge and threat states. *Journal of Sport & Exercise*
662 *Psychology*, *35*, 387-397. doi: 10.1123/jsep.35.4.387.
- 663 Turner, M. J., Jones, M. V., Sheffield, D., & Cross, S. L. (2012). Cardiovascular indices of
664 challenge and threat states predict competitive performance. *International Journal of*
665 *Psychophysiology*, *86*, 48-57. doi: 10.1016/j.ijpsycho.2012.08.004.
- 666 Vine, S. J., Freeman, P., Moore, L. J., Chandra-Ramanan, R., & Wilson, M. R. (2013). Evaluating
667 stress as a challenge is associated with superior attentional control and motor skill
668 performance: Testing the predictions of the biopsychosocial model of challenge and threat.
669 *Journal of Experimental Psychology: Applied*, *19*, 185-194. doi: 10.1037/a0034106.
- 670 Vine, S. J., Moore, L. J., & Wilson, M. R. (2016). An integrative framework of stress, attention, and
671 visuomotor performance. *Frontiers in Psychology*, *7*. doi: 10.3389/fpsyg.2016.01671.
- 672 Vine, S. J., Uiga, L., Lavric, A., Moore, L. J., Tsaneva-Atanasova, K., & Wilson, M. R. (2015).
673 Individual reactions to stress predict performance during a critical aviation incident. *Anxiety,*
674 *Stress, & Coping*, *28*, 467-477. doi: 10.1080/10615806.2014.986722.
- 675 White, J. B. (2008). Fail or flourish? Cognitive appraisal moderates the effect of solo status on
676 performance. *Personality and Social Psychology Bulletin*, *34*, 1171-1184. doi:
677 10.1177/0146167208318404.
- 678 Zanza, Y. J., Johnston, D. W., & Rasbash, J. (2010). Appraisal predicts hemodynamic reactivity in
679 a naturalistic stressor. *International Journal of Psychophysiology*, *77*, 35-42. doi:
680 10.1016/j.ijpsycho.2010.04.00.

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Table 1

Summary of Included Studies

Reference Number	Authors, Year	N	Design	Population	Mean age (years)	CAT	Main Performance Measures	Results	Effect Sizes
1	Blascovich, Seery, Mugridge, Norris & Weisbuch, 2004	27	CR	Baseball and softball student athletes	N/A	P	Baseball and softball season performance (runs created)	CAT index related to runs created during season; (challenge > threat)	$R^2 = .11$
2	Chalabaev, Major, Cury & Sarrazin, 2009	27	EX - performance goal	Female undergraduates	N/A	P, C	Multiple-choice score on GRE word problems	Self-reported challenge was unrelated to performance CO and TPR were related to performance, but only examined separately (no CAT index)	N/A
3	Chalabaev, Major, Sarrazin & Cury, 2012	58	EX - Performance goal (approach, avoidance, control)	Female psychology undergraduates	N/A	C	Score on math word problems from GRE practice book	For those participants who received a performance avoidance goal, challenge was associated with better performance than threat	$R^2 = .06$
4	Feinberg & Aiello, 2010 ³	91	EX - CAT appraisal	Undergraduates	N/A	C, DC	Mental arithmetic score	Threat group outperformed challenge group	$d = 0.85$
		238	EX - CAT appraisal		N/A	C, DC	Mental arithmetic score	Challenge group outperformed threat group	N/A
		54	EX - CAT appraisal		N/A	C, DC	Anagram task score	No significant difference between groups	N/A
5	Gildea, Schneider & Shebilske, 2007	54	QE	Adults and	22.5	C, DC	Space Fortress (total	Challenge associated with higher scores	$d = 1.09$
		154	QE	adolescents (all male	19.9	C, DC	scores; used in all	than threat across three experiments (not	$d = 0.29$
		48	QE	in studies 1 and 3)	24.1	C, DC	studies)	significant in experiment 2)	$d = 0.65$

³ Studies 1, 2, and 4 from this publication were included in the systematic review. Study 3 was not included because it did not report the results of the main effect comparison between the CAT conditions.

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6	Kelsey et al., 2000	162	CR	Psychology undergraduates	N/A	C	Three arithmetic tasks (number of responses, arithmetic errors)	Number of responses inversely correlated with pre-task evaluations (challenge > threat) Arithmetic errors positively correlated with pre-task evaluations	N/A N/A
7	Laborde, Lautenbach & Allen, 2015	96	CR	Male sport science students	24.8	C	Concentration grid exercise (consecutive numbers clicked in two minutes)	CAT not significantly related to visual search task performance	N/A
8	Mendes, Blascovich, Hunter, Lickel & Jost, 2007	47	EX - 2x2 (confederate ethnicity x confederate accent)	Female students	19.6	P	Word-finding task (number and accuracy of responses)	No significant effect of CAT index on performance in a mediation model (marginally significant trend was found)	N/A
9	Moore, Vine, Freeman & Wilson, 2013	30	EX - training (quiet eye, technical)	Undergraduates without golf putting experience	19.7	C	Golf putting (mean radial error)	Evaluations mediated the relationship between group and mean radial error (challenge associated with smaller radial error than threat)	N/A
10	Moore, Vine, Wilson & Freeman, 2012	127	EX – CAT appraisal	Undergraduates without golf putting experience	19.5	P, C, DC	Golf putting (mean radial error)	Lower mean radial error in challenge group	$d = 0.69$
11	Moore, Vine, Wilson & Freeman, 2014	120	EX - 2x2 (effort x support)	Undergraduates	21.6	P, C, DC	Laparoscopic surgery completion time	Low effort group (challenged) outperformed high effort group (threatened)	$\eta^2_p = .12$
12	Moore, Vine, Wilson & Freeman, 2015	50	EX - Arousal reappraisal	Participants without golf putting experience	20.2	P, DC	Golf putting (mean radial error)	Arousal reappraisal group was more challenged and performed more accurately (lower error)	$d = 0.93$
13	Moore, Wilson, Vine, Coussens & Freeman, 2013	199	CR	Competitive golfers	36.3	C	Golf competition performance	Challenge evaluations were associated with superior competition performance than threat evaluations	$R^2 = .09$
		60	EX – CAT appraisal	Experienced golfers	22.9			Challenge group holed higher percentage	$d = 0.63$

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						P, C, DC	Golf putting (putts holed, performance error)	of putts than threat group Challenge group had lower error than threat group	$d = 0.70$
14	Moore, Young, Freeman & Sarkar, 2017	100	CR	Participants engaging in club or university level sports	21.9	P, C	Dart-throwing task	Physiological CAT index and cognitive CAT evaluations related to dart throwing performance (challenge > threat)	$R^2 = 0.08$ $R^2 = 0.11$
15	O'Connor, Arnold & Maurizio, 2010	138	EX - academic focus	Undergraduates	24.8	C	Negotiation task score	Threat associated with lower negotiation outcomes than challenge	$R^2 = .16$
		196	EX - 2x2 (CAT appraisal x task structure)	Undergraduates	22.2	C, DC	Negotiation task score	Challenge group scored better negotiation outcome than threat group in the integrative task structure condition only – no main effect	$d = 0.32$
16	Quigley, Barrett & Weinstein, 2002	74	CR	Psychology undergraduates	18 (mode)	P, C	Four verbal mental arithmetic tasks (attempts, number correct)	No relation between cognitive evaluations and performance (number of attempts made, percentage correct responses) No analysis reported for physiological data	N/A
17	Rith-Najarian, McLaughlin, Sheridan & Nock, 2014	79	CR	Adolescents	14.70	P, C	Independently rated speech performance	No relation between physiological and cognitive measures of CAT and performance before task	N/A
18	Roberts, Gale, McGrath & Wilson, 2015	94	CR	Doctors	28 (median)	C	Overall station performance score	CAT predicted station performance (threat < challenge)	N/A
19	Sammy et al., 2017	54	EX – Arousal reappraisal	Undergraduates	21.7	P, C, DC	Dart throwing task	Arousal reappraisal group more challenged on physiological index and evaluations, but not better on dart throwing task	N/A
20	Scheepers, 2017	103	EX – 2x2 (Group status x group legitimacy)	Female undergraduates	21	P, DC	Pattern recognition task	CAT index negatively correlated with performance (higher challenge – lower response times)	$R^2 = 0.07$
									N/A

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21	Schneider, 2004	59	QE	Undergraduates	21	C, DC	Mental arithmetic performance (responses, errors)	High status group was more challenged and outperformed low status group Threat group gave fewer responses Threat group made more errors CAT predicted percent correct (threat < challenge)	$d = -0.78$ $d = 0.53$ $r = -.33$
22	Schneider, Rench, Lyons & Riffle, 2012	152	CR	Psychology undergraduates	20.3	C	Mental arithmetic score (responses and accuracy)	Cognitive evaluations were negatively related with performance (threat < challenge)	N/A
23	Scholl, Moeller, Scheepers, Nuerk & Sassenberg, 2015	50	CR	Undergraduates	20.0	P	Number bisection task ⁴ errors made	Physiological CAT index was negatively related with number of errors made in all task conditions (challenge associated with less errors than threat)	$R^2 = .21$ $R^2 = .20$ $R^2 = .11$ $R^2 = .16$
24	Seery, Weisbuch, Hetenyi & Blascovich, 2010	95	CR	Undergraduates	N/A	P	University course grades	Cardiovascular CAT (academic interests speech) predicted course grades (challenge > threat) No association found for general test taking speech	$sr^2 = .04$ N/A
25	Turner, Jones, Sheffield, Barker & Coffee, 2014	46	EX - resource appraisals	Undergraduates and academic staff	21.7	P, DC	Bean bag throwing score	Performance not significantly higher in challenge group	$d = 0.50$
26	Turner, Jones, Sheffield & Cross, 2012	25	CR	Academic staff members	34.0	P, C	Modified Stroop accuracy and latency	Cardiovascular challenge responses predicted superior performance over threat responses in both studies	$R^2 = .16$
		21	CR	Female netball players	21.1	P, C	Netball shooting score		$R^2 = .14$
27	Turner et al., 2013	42	CR	Male elite-level cricketers	16.5	P, C	Cricket batting task (runs awarded by coaching staff)	Physiological CAT associated with batting performance (challenge > threat) Cognitive evaluations not associated with performance	N/A N/A

⁴ Analyses were only provided for each of the four sub-conditions of the number bisection task. The authors did not report on a total performance score. Thus, four values are reported in the “Effect Sizes” column.

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28	Vine, Freeman, Moore, Chandra-Ramanan & Wilson, 2013	52	CR	Final-year medical students	20.5	P, C	Laparoscopic surgery task completion time	Cognitive evaluations associated with performance under pressure (challenge > threat) Relationship not mediated by physiological CAT index	N/A N/A
29	Vine et al., 2015	16	CR	Active pilots	34.8	C	Flight simulator metrics	Challenge evaluation associated with better performance than threat	$R^2 = .61$
30	White, 2008	128	EX - Solo status manipulation	Undergraduates	19.1	C	Math test scores	Challenge associated with higher math test scores than threat	N/A
		90	EX - Solo status manipulation		19.5	C	Recall task score	Challenge was only associated with better performance than threat under solo status.	N/A
							Math test score	Challenge associated with higher math test scores than threat	N/A

Note. CAT = Challenge and threat variables recorded, CR = Correlational, DC = Dichotomous (challenge group vs. threat group), EX = Experimental, QE = Quasi-experimental, C = Cognitive, P = Physiological.

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Table 2

Risk of Bias Assessment Results

<i>Experimental Studies</i>								
Reference Number		Random Sequence Generation	Allocation Concealment	Blinding of Participants and Personnel	Blinding of Outcome Assessment	Incomplete Outcome Data	Selective Reporting	Other Sources of Bias
2		Low	Unclear	Unclear	Unclear	Low	Unclear	Low
3		Low	Unclear	Unclear	Unclear	Low	Unclear	Low
4	Study 1	Low	Unclear	Unclear	Low	Low	Unclear	Low
	Study 2	Low	Unclear	Unclear	Low	Low	Unclear	Low
	Study 3	Unclear	Unclear	Unclear	Low	Low	Unclear	Low
8		Low	Low	Low	Unclear	Unclear	Unclear	Low
9		Low	Unclear	Unclear	Unclear	Low	Unclear	Low
10		Low	Unclear	Unclear	Unclear	Low	Unclear	Low
11		Low	Unclear	Unclear	Unclear	Low	Unclear	Low
12		Low	Unclear	Unclear	Unclear	Unclear	Unclear	Low
13	Study 2	Low	Unclear	Unclear	Unclear	Low	Unclear	Low
15	Study 1	Low	Unclear	Unclear	Low	Low	Unclear	Low
	Study 2	Low	Unclear	Unclear	Low	Low	Unclear	Low
19		Low	Unclear	Unclear	Unclear	Low	Unclear	Low
20		Low	Low	Low	Low	Unclear	Unclear	Low
25		Low	Unclear	Unclear	Unclear	High	Unclear	Low
30	Study 1	Unclear	Unclear	Unclear	Low	Low	Unclear	Low
	Study 2	Low	Unclear	Unclear	Low	Low	Unclear	Low
<i>Non-experimental Studies</i>								
		Blinding of Outcome Assessment	Incomplete Outcome Data	Selective Reporting	Selection of Participants	Confounding Variables	Intervention (Exposure) Measurement	
1		Low	Unclear	Unclear	Unclear	Low	Low	
5	Study 1	Low	Low	Unclear	Unclear	Low	Low	
	Study 2	Low	Low	Unclear	Unclear	Low	Low	
	Study 3	Low	Low	Unclear	Unclear	Low	Low	
6		Unclear	Low	Unclear	Unclear	Low	Low	
7		Low	Low	Unclear	Unclear	Low	Low	
13	Study 1	Low	Low	Unclear	Unclear	Low	Low	
14		Low	Low	Unclear	Unclear	Low	Low	
16		Unclear	Low	Unclear	Unclear	Low	Low	
17		Unclear	Low	Unclear	Unclear	Low	Low	
18		Low	Low	Unclear	Low	Low	Low	
21		Unclear	High	Unclear	Unclear	Low	Low	
22		Unclear	Low	Unclear	Unclear	Low	Low	
23		Low	Unclear	Unclear	Unclear	Low	Low	
24		Unclear	High	Unclear	Unclear	Low	Low	
26	Study 1	Low	Low	Unclear	Unclear	Low	Low	
	Study 2	Unclear	Low	Unclear	Unclear	Low	Low	
27		Unclear	Unclear	Unclear	Unclear	Low	Low	
28		Unclear	Low	Unclear	Unclear	Low	Low	
29		Low	Low	Unclear	Low	Low	Low	

Note. For the “Reference Number” column coding, please consult the corresponding column in Table 1.

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Table 3

Effects on Performance of Cognitive, Physiological, and Dichotomous CAT Variables

CAT Variable	Reference Number	Number of Effects	Percentage of Effects Supporting the Association			Sum Code
			Positive	Negative	None	
Cognitive	- 2, 3, 6, 7, 9, 13, 14, 15, 16, 17, 18, 22, 27, 28, 29, 30	17	76	0	24	++
Physiological	- 1, 8, 14, 17, 20, 23, 24, 26, 27, 28	12	67	0	33	++
Dichotomous	- 4, 5, 10, 11, 12, 13, 15, 19, 20, 21, 25	15	67	7	27	++

Note. Percentages are rounded to integers so do not always total 100. The “Sum Code” was adapted from Sallis, Prochaska, and Taylor (2000): “0” indicates that 0 – 33% of the supported an association, “?” indicates that 34 – 59% of the studies supported the association, and “+” indicates that 60% or more of the studies supported the association. Codes are doubled (“??”, “00”, or “++” when four or more studies supported the association/lack of association). For the “Reference Number” column coding, please consult the corresponding column in table 1.

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Table 4

Effects of CAT States on Cognitive and Behavioural Task Performance

Performance Outcome	Reference Number	Number of Effects	Percentage of Effects Supporting the Association			Sum Code
			Positive	Negative	None	
Cognitive	- 2, 3, 4, 5, 6, 7, 8, 16, 20, 21, 22, 23, 24, 26, 30	23	65	4	30	++
Behavioural	- 1, 9, 10, 11, 12, 13, 14, 15, 17, 18, 19, 25, 26, 27, 28, 29	19	84	0	16	++

Note. Percentages are rounded to integers so do not always total 100. The “Sum Code” was adapted from Sallis et al. (2000): “0” indicates that 0 – 33% of the supported an association, “?” indicates that 34 – 59% of the studies supported the association, and “+” indicates that 60% or more of the studies supported the association. Codes are doubled (“??”, “00”, or “++” when four or more studies supported the association/lack of association). For the “Reference Number” column coding, please consult the corresponding column in table 1.

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Table 5

Effects of CAT States on Performance Within Different Research Designs

Research Design	Reference Number	Number of Effects	Percentage of Effects Supporting the Association			Sum Code
			Positive	Negative	None	
Experimental (direct)	- 4, 10, 13, 15	6	67	17	17	++
Experimental (indirect)	- 2, 3, 8, 9, 11, 12, 15, 19, 20, 25, 30	12	67	0	33	++
Correlational	- 1, 6, 7, 13, 14, 16, 17, 18, 22, 23, 24, 26, 27, 28, 29	18	78	0	22	++
Quasi-Experimental	- 5, 21	4	100	0	0	++

Note. Percentages are rounded to integers so do not always total 100. The “Sum Code” was adapted from Sallis et al. (2000): “0” indicates that 0 – 33% of the supported an association, “?” indicates that 34 – 59% of the studies supported the association, and “+” indicates that 60% or more of the studies supported the association. Codes are doubled (“??”, “00”, or “++” when four or more studies supported the association/lack of association). For the “Reference Number” column coding, please consult the corresponding column in table 1.

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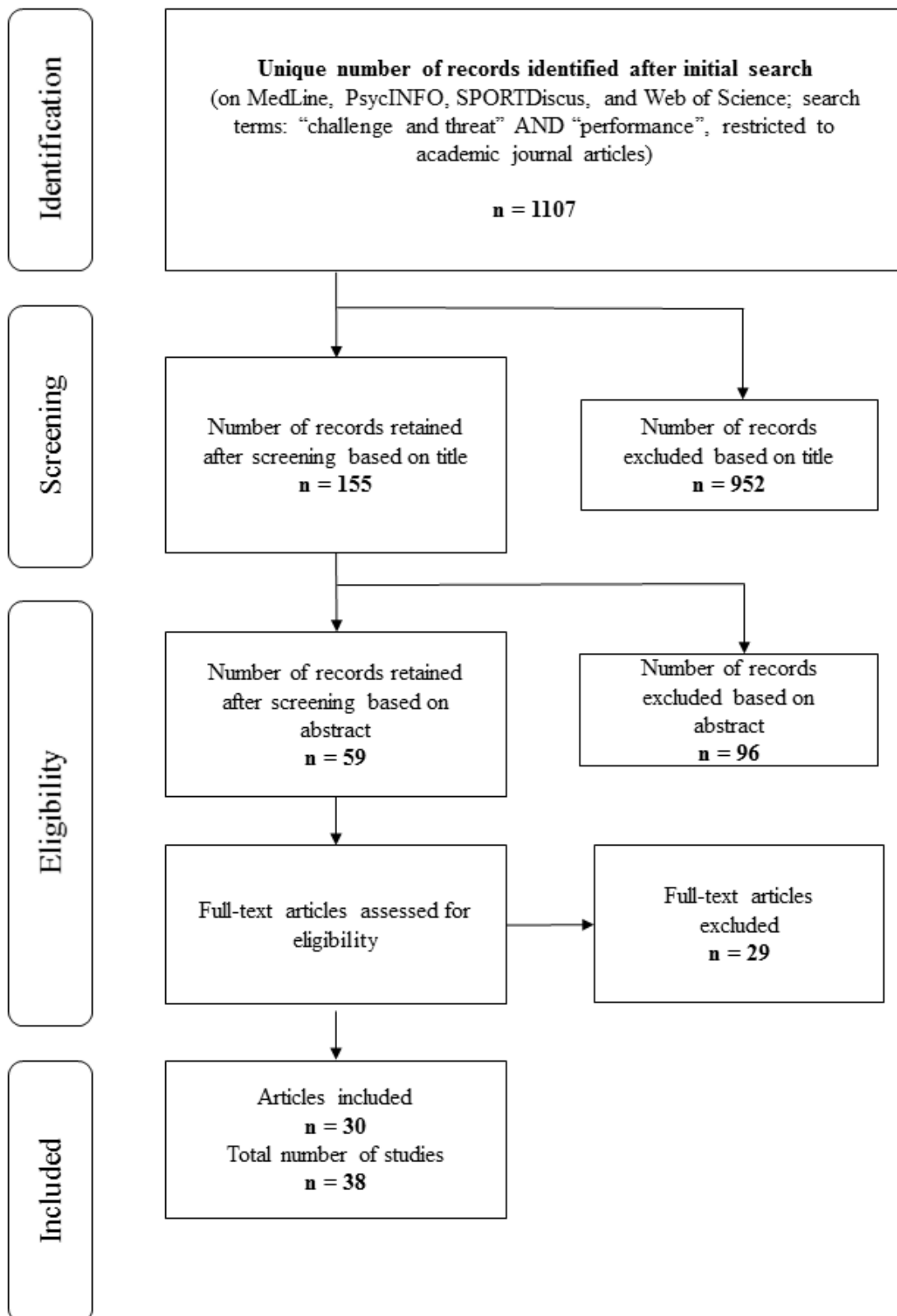


Figure 1. Systematic review search and screening procedure.