

1 Hold your strength! Motivation, attention, and emotion as potential psychological mediators
2 between cognitive and physical self-control

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1 **Abstract**

2 The process model of self-control posits motivation, emotion, and attention as psychological
3 mediators in the relationship between cognitive and physical self-control. However, this model
4 has never been tested in a sport context. Participants ($N = 69$) completed two isometric biceps
5 endurance trials (physical self-control task; T1 and T2), separated by a 6-min cognitive
6 manipulation of self-control. Motivation and emotion were assessed prior to the respective
7 biceps task, and attention was assessed in terms of gaze behavior on task relevant in comparison
8 to task irrelevant stimuli during the biceps task (T1 and T2). To test the hypothesis that
9 motivation, emotion, and attention mediated the relationship between cognitive and physical
10 self-control, a parallel multiple mediator model was calculated. The results indicate that
11 motivation, emotion, and attention (relative change between T1 and T2) did not mediate the
12 relationship between cognitive and physical self-control ($b = -0.01$, 95% BCa CI [-0.06, 0.03])
13 and that the exertion of cognitive self-control did not necessarily lead to impaired performance.
14 Future studies should investigate the role of task demands and other potential mediators of self-
15 control (e.g., belief about a limited willpower).

16 *Keywords:* self-regulation, process model, psychological mediators, sports, mediation
17 model

1 Hold your strength! Motivation, attention, and emotion as potential psychological mediators
2 between cognitive and physical self-control

3 **Introduction**

4 Why do some athletes experience a drop in performance in high-pressure situations
5 during competitive sports? Why do some individuals fail to adhere to their workout plans?
6 Performing at the highest level or being physically active on a regular basis can be difficult and
7 is not always achieved (Englert, 2016; Hagger, Wood, Stiff, & Chatzisarantis, 2010a; Van
8 Cutsem et al., 2017). To attain their goals, individuals need to achieve and retain control. Self-
9 control can be defined as the ability to volitionally control or alter predominant response
10 tendencies or to resist immediate gratification to achieve more desirable long-term goals (e.g.,
11 Baumeister, Vohs, & Tice, 2007). Performing well under pressure necessitates the regulation of
12 negative emotions (e.g., anxiety). To be physically active, it is important to resist immediate
13 temptations (Englert, 2017; Hagger et al., 2010a). For example, self-control helps maintain a
14 demanding workout plan despite attractive alternatives (e.g., going out with friends) or the
15 presence of distractors such as stress (Englert & Rummel, 2016). Self-control is also required in
16 order to persist with tasks that are unpleasant or physically demanding (e.g., the last miles of a
17 marathon) or to regulate impulses that might otherwise interfere with performance (e.g., Furley,
18 Bertrams, Englert, & Delphia, 2013; MacMahon, Schücker, Hagemann, & Strauss, 2014;
19 McEwan, Martin Ginis, & Bray, 2013).

20 **Self-Control in Sporting and Exercise Contexts**

21 Existing research has shown that lapses in self-control occur quite frequently in many
22 sporting and exercise contexts (Englert, 2016; Hagger et al., 2010a; Van Cutsem et al., 2017).
23 For instance, Marcora, Staiano, and Manning (2009) demonstrated that an experimental group

1 who had first completed an exhausting cognitive self-control task showed less persistence in a
2 strenuous cycling task (i.e., shorter time to exhaustion) than a control group who had watched a
3 documentary prior to the main task, although cardiorespiratory and musculoenergetic parameters
4 were not affected. Similarly, Martin Ginis and Bray (2010) found that inactive participants
5 exhibited decreased endurance after having first completed a cognitively demanding self-control
6 task. These findings suggest that sport-related performance may be affected by one's ability to
7 control certain behavioral tendencies as well as by changes in certain physiological mechanisms
8 (e.g., Van Cutsem et al., 2017).

9 One of the key components of self-control is volitional attention regulation, which
10 influences all of its other elements (e.g., Schmeichel & Baumeister, 2010). Most sport- and
11 exercise-related tasks require attention regulation—that is, the ability to inhibit irrelevant stimuli
12 and to focus on relevant aspects of the given task (Furley et al., 2013). For example, to
13 successfully complete a free throw in basketball, one must ignore heckling from the audience
14 and cope with any internal, anxiety-related thoughts (Oudejans, Van de Langenberg, & Hutter,
15 2002). In a dart-throwing task, Englert, Zwemmer, Bertrams, and Oudejans (2015) showed that
16 participants under pressure who first completed a cognitive task requiring self-control displayed
17 less efficient attention regulation, operationalized through gaze behavior (significantly shorter
18 final fixation durations), resulting in a significantly lower dart score, compared to a control group
19 with temporarily available self-control strength. Similarly, Englert, Bertrams, Furley, and
20 Oudejans (2015) demonstrated that participants under pressure performed worse in a basketball
21 free-throw task (lower free-throw percentage) after completing a self-control task and paid more
22 attention to an irrelevant additional task (audio stream), compared to a control group who did not
23 have to regulate themselves beforehand. With respect to emotions, research has shown that the

1 regulation of emotions is important for completing physical tasks (e.g., increased feelings of
2 tiredness; Van Cutsem et al., 2017; Englert, 2017; Hagger et al., 2010a). In particular, Brown and
3 Bray (2017a) found that participants' emotions were affected after completing a difficult self-
4 control task. Thereby, they showed significant less positive emotional states after a 6, 8 or 10
5 minutes handgrip endurance task, but unaffected emotional states when completing the task for
6 0, 2 or 4 minutes.

7 In summary, self-control is important in sporting and exercise contexts for successful
8 regulation of attention (Englert, Bertrams et al., 2015; Englert, Zwemmer et al., 2015) and
9 emotions (Brown & Bray, 2017a; Englert, 2017; Hagger et al., 2010a) and for persistence in
10 completing physically demanding self-control tasks (Marcora et al., 2009; Martin Ginis & Bray,
11 2010). As demonstrated in the above examples, individuals cannot always achieve the necessary
12 self-control, and it remains unclear how these lapses can be explained.

13 **Possible Explanations for Lapses of Self-Control in Sporting and Exercise Contexts**

14 **Resource models.** One of the best-known explanations of lapses in self-control is the
15 strength model (Baumeister, Bratslavsky, Muraven, & Tice, 1998), which assumes that self-
16 control is regulated by an individual's limited capacity in terms of strength or resources. After a
17 primary act of self-control, one's strength of self-control may be temporarily depleted and may
18 not be immediately replenished. In this state of so-called *ego depletion*, one may be less able to
19 efficiently execute secondary self-control tasks or to resist immediate temptations or impulses
20 (Hagger, Wood, Stiff, & Chatzisarantis, 2010b; Muraven & Baumeister, 2000). Additionally, the
21 strength model postulates that acts of self-control are not domain-specific, as this strength is
22 assumed to energize all forms of self-control, including persistence and emotion regulation
23 (Hagger et al., 2010b). This means that a seemingly unrelated, preliminary self-control task may

1 negatively impact subsequent exercise-related behavior that requires self-control (e.g., Martin
2 Ginis & Bray, 2010); for example, a strenuous non-sports-related cognitive task requiring self-
3 control (e.g., letter *e* and *n* task; see method section) can impair performance in a second
4 physical task requiring self-control, such as basketball throwing (Englert, Bertrams, et al., 2015).

5 While many studies in sporting and exercise contexts report empirical evidence of this
6 ego depletion effect and associated performance impairments (for an overview, see Englert,
7 2017; Hagger et al., 2010a), several recent studies were unable to find evidence of this effect. For
8 instance, one meta-analysis demonstrated that the effect size for ego depletion was close to zero,
9 and a preregistered multilab replication study also failed to find any evidence of such an effect
10 (Carter, Kofler, Forster, & McCullough, 2015; Hagger et al., 2016). Others have raised questions
11 about the underlying mechanisms of the ego depletion effect (Hagger & Chatzisarantis, 2018),
12 and some studies have found that the effect could be eliminated by offering depleted participants
13 motivational incentives (e.g., Boksem, Meijman, & Lorist, 2006; Muraven & Slessareva, 2003)
14 or by inducing a positive mood after a preliminary act of self-control (e.g., Schmeichel & Vohs,
15 2009). These findings challenge the strength model's assumptions, as participants were able to
16 perform well even when supposedly "depleted" by a prior self-control task (Inzlicht &
17 Schmeichel, 2012). Clearly, then, existing studies of the ego depletion effect have delivered
18 inconsistent results (Friese, Loschelder, Gieseler, Frankenbach, & Inzlicht, 2018), meaning that
19 further research is needed.

20 **Process model of self-control.** The process model of self-control is a prominent
21 alternative theory (Inzlicht & Schmeichel, 2012; Inzlicht & Schmeichel, 2016; Inzlicht,
22 Schmeichel, & Macrae, 2014). According to this model, failures of self-control are not caused by
23 temporary depletion of a limited resource (as in the strength model) but are a consequence of

1 prioritization or preference in relation to the task at hand (Kurzban, Duckworth, Kable, & Myers,
2 2013b). In other words, individuals seek a balance between tasks that have to be done (so-called
3 *have-to* tasks, involving a sense of duty, obligation, or guilt), and therefore require self-control,
4 and less strenuous tasks that are personally rewarding and joyful, requiring less self-control (so-
5 called *want-to* tasks). The process model assumes that working on a have-to task (comparable to
6 the ego depletion effect in the strength model of self-control; Baumeister et al., 2007) influences
7 motivation, emotion, and attention, and the model further postulates that individuals are less
8 motivated to work on a subsequent have-to task, resulting in a shift away from control and
9 toward gratification. The model also assumes that individuals assign more negative emotions to
10 subsequent have-to tasks and instead divert their attention to more pleasant want-to tasks
11 (Inzlicht et al., 2014; Inzlicht & Schmeichel, 2012; Milyavskaya & Inzlicht, 2018). According to
12 the process model, these three *shifts* serve as mediators between first and second have-to tasks.
13 Transferring these assumptions to sports-related contexts, athletes who have first worked on a
14 have-to task (cognitive self-control task) involving, for instance, difficult arithmetic and
15 balancing (Dorris, Power, & Kenefick, 2012) may be less motivated to work on a demanding
16 second have-to task (e.g., involving endurance; physical self-control task). If they perceive this
17 second task as less pleasant than an alternative activity (e.g., relaxing), they are likely to shift
18 their attention to more pleasant stimuli (e.g., friends).

19 According to the process model, *shifts in motivation* occur when one is not motivated to
20 work on a second have-to task. After one strenuous have-to task, individuals may feel they have
21 done enough to justify investing less effort in the second have-to task; this self-licensing (de Witt
22 Huberts, Evers, & Ridder, 2012) may reflect a shift in motivation rather than a deficit in self-
23 control resources (Inzlicht & Schmeichel, 2012). For example, a decrease in endurance

1 performance (Martin Ginis & Bray, 2010) after engaging in an unpleasant cognitive have-to task
2 may reflect a lack of motivation because of the effort already expended, which is seen to justify
3 slacking off or engaging in other, more inherently joyful activities such as taking a break, instead
4 of exerting control again.

5 As part of the shift in motivational priorities, the process model suggests that having
6 worked on a first have-to task might cause a *shift of attention* from subsequent stimuli that signal
7 effort toward stimuli that signal personal reward. According to the process model, people fail to
8 notice the need to control their attention following a have-to task (Inzlicht & Schmeichel, 2012).
9 Inzlicht and Gutsell (2007) showed that attentional control was poorer in the second of two self-
10 control tasks (both were Stroop Color and Word Test¹), suggesting that depletion might weaken
11 monitoring of self-control failures, resulting in goal neglect and blinding notification of the need
12 for regulation and control (Inzlicht & Gutsell, 2007; Inzlicht & Schmeichel, 2012). Schmeichel,
13 Harmon-Jones, and Harmon-Jones (2010) found that depleted participants were better able to
14 identify stimuli associated with reward (a dollar sign) than stimuli that were not (a percent sign)
15 and that these participants were quicker than the control group (who were not depleted) to find
16 the reward-related sign. Importantly, the depletion group were not generally better in perceptual
17 terms; rather, they were better at detecting reward-relevant symbols. These findings support the
18 process model account of shifting attentional priorities. According to the process model,
19 individuals who must first perform a have-to task may be less apt to focus their attention on a
20 subsequent have-to task, as self-monitoring may be decreased and attention realigned to stimuli
21 that signal reward (Inzlicht et al., 2014).

22 As a third mechanism, the process model posits an *emotional shift*, based on the
23 assumption that working on a primary have-to task may cause feelings of fatigue, boredom, and

1 general emotional negativity in respect of a subsequent have-to task (Hagger et al., 2010b;
2 Inzlicht et al., 2014). The model proposes that having worked on a first have-to task may dampen
3 emotions related to a subsequent have-to task and that these negative emotions may redirect
4 behavior toward want-to tasks by preventing fixation on current activities (Inzlicht et al., 2014;
5 Kurzban, Duckworth, Kable, & Myers, 2013a). For example, instead of doing another strenuous
6 set of push-ups, the individual may choose to do more rewarding things (e.g., taking a break) to
7 improve their negative emotional state.

8 To summarize, the process model (like the strength model) proposes that lapses in
9 performance may happen after a demanding have-to (self-control) task. The model explains these
10 lapses in terms of motivational, attentional, and emotional shifts. To our knowledge, however,
11 the assumptions of the process model have never been subjected to rigorous empirical testing,
12 and the goal of the present study was to address this shortcoming. In general, we proposed that
13 motivation, attention, and emotion would mediate the relationship between cognitive and
14 physical self-control.² More precisely, we hypothesized that the relationship between the
15 cognitive self-control task (have-to task) and the physical self-control task (have-to task)
16 operates through reduced motivation, more negative emotions, and a less efficiently located
17 attention (as operationalized through gaze behavior) to the second trial of the physical self-
18 control task.

19 Method

20 Participants and Design

21 Prior to data collection, the study was preregistered (URL:
22 <https://aspredicted.org/zq3xh.pdf>),³ indicating how we determined sample size, data exclusions,
23 and all manipulations and measures (cf. Simmons, Nelson, & Simonsohn, 2011). An a priori

1 analysis of statistical power using G*Power revealed an optimal sample size of 74 (version
2 3.1.9.4, specifications: linear multiple regression, fixed model, single regression coefficient;
3 $\alpha = .008$; $1 - \beta = .80$; $f^2 = 0.15$; 6 predictors, i. e. five mediators and one independent variable).
4 However, to hedge against data loss due to potential technical problems with the eye-tracking
5 system, we succeeded in collecting data from 86 participants.

6 Data from 16 participants were excluded for technical reasons (e.g., malfunctioning of the
7 eye tracker or the online platform did not work), and one further participant had to be excluded
8 because outlier analysis identified their data as a multivariate outlier (Tabachnick & Fidell,
9 2007). The final sample comprised 69 sport science students in their first year (31 females, 38
10 males; $M_{\text{age}} = 20.35$ years, $SD_{\text{age}} = 1.55$). Participation was accredited as a university course
11 requirement. The study used a single-blind, quasi-randomized experimental pre-post design with
12 a two-level independent variable (cognitive self-control task: yes vs. no) and one dependent
13 measure (physical self-control task performance). The study was approved by the institutional
14 ethics committee.

15 Measures

16 **Experimental manipulation.** Cognitive self-control was manipulated using a well-
17 established transcription task (e.g., Englert & Bertrams, 2012; Schmeichel, 2007), in which the
18 participant had to transcribe a neutral text (i.e., a historical description of a city) from the
19 computer screen on a separate sheet of paper as fast and as correctly as they could, for a period
20 of six minutes (cf. Brown & Bray, 2017a). While the control group simply transcribed the text in
21 conventional fashion, the experimental group had to omit all letters *e* and *n*, which are the most
22 common letters in the German language. Self-control is required for successful completion of
23 this task because the participants must override their usual writing habits (Schmeichel, 2007)

1 while conventional text transcription does not require this form of self-control. Therefore,
2 according to the process model, the task had a have-to character for the participants in the
3 experimental group.

4 **Primary outcome measure.** The dependent variable was a physical self-control task. An
5 isometric biceps endurance task (participant's dominant arm) was assessed using a multi-muscle
6 machine (model M3; Schnell instruments, Peutenhausen, Germany) with graphic computer
7 interface (Diagnos 2000; Schnell instruments). A threshold average of 70% of the participant's
8 maximum voluntary contraction (MVC) had to be pulled across two endurance trials (T1 and
9 T2), and time to failure was counted. This task requires self-control in that one must exert
10 controlled effort and resist the temptation to quit, as the task becomes uncomfortable over time
11 as a result of muscular fatigue (Hagger & Chatzisarantis, 2018), reflecting a have-to character in
12 the process model. During the biceps task, the participant could see their target force represented
13 by a static bar (60–80% MVC threshold) and could control the personal biceps strength curve on
14 a 17-inch computer monitor providing visual feedback of their performance.

15 **Manipulation checks.** To determine the effectiveness of the cognitive self-control
16 manipulation, the transcription task was followed by a three-item check (“How difficult did you
17 find the transcription task?” “How effortful did you find the transcription task?” “How strongly
18 did you have to regulate your writing habits?”; $\alpha = .70$), measuring participants' ratings of
19 *perceived mental exertion* during the text transcription on a Likert-type scale ranging from 1 (*not*
20 *at all*) to 4 (*very much so*) (Englert & Bertrams, 2012). The number of transcribed letters and
21 errors was counted in each case (cf. Englert, Zwemmer et al., 2015), based on the assumption
22 that the experimental group would transcribe fewer words and make more mistakes because of
23 the difficulty of overriding one's writing habits (Schmeichel, 2007). *Perceived physical exertion*

1 was assessed as a manipulation check after each isometric biceps task trial. Marcora et al. (2009)
2 showed that after cognitive self-control exertion, participants rated their perceived physical effort
3 higher in a physical performance test, compared to participants who did not exert self-control.
4 Therefore, participants were asked to rate their perceived physical exertion on the Borg Scale,
5 ranging from 6 (*no exertion at all*) to 20 (*maximal exertion*) (Borg, 1998; Borg & Kaijser, 2006).

6 **Potential mediators and covariate.**

7 **Motivation.** Two measures were used to assess motivation (cf. Graham & Bray, 2015) as
8 potential psychological mediators. The single-item Task Motivation Scale (TMS; Hutchinson et
9 al., 2011) assessed motivation to persist with a task and the effort one intends to exert, using an
10 11-point Likert-type scale ranging from 0 (*not at all motivated*) to 10 (*extremely motivated*).
11 Additionally, the subscale *Effort and Importance* from the Intrinsic Motivation Inventory (IMI)
12 (Ryan, 1982) asked a number of questions with the stem “For the biceps task I am about to
13 do...” (for example, “... I am going to try very hard on that task.”). Since, to the best of our
14 knowledge, no German translation of the IMI exists, two independent translators who were
15 fluent in English translated and back translated the items, following the procedure suggested by
16 Beaton, Bombardier, Guillemin, and Ferraz (2000). In contrast to other studies (e.g., Graham
17 & Bray, 2015: $\alpha > .70$), internal consistency was found to be low (T1: $\alpha = .57$; T2: $\alpha = .52$).

18 **Emotion.** The German version of the Positive and Negative Affect Schedule (PANAS)
19 (Krohne, Egloff, Kohlmann, & Tausch, 1996) assessed participants’ emotions with regard to the
20 upcoming biceps task and was used as a potential mediator. Ten items assessed positive affect
21 (e.g., “happy”; T1: $\alpha = .87$; T2: $\alpha = .77$), and ten items assessed negative affect (e.g., “angry”;
22 T1: $\alpha = .77$; T2: $\alpha = .68$) on a Likert-type scale ranging from 1 (*not at all*) to 5 (*extremely*). We
23 calculated an averaged mean score for each subscale.

1 **Attention.** Attention as a potential mediator was operationalized by participants' gaze
2 behavior in regard to relevant stimuli. Therefore, an eye-tracking system was fitted, using a
3 head-mounted eye tracker (SensoMotoric Instruments, Teltow, Germany; SMI) with a sampling
4 rate of 60 Hz. Eye data were recorded using I-View X software developed by SMI. Using a one-
5 point calibration and validation procedure, only error values below 0.8° were accepted. In order
6 to perform the biceps task successfully, participants had to pay attention to their strength on the
7 main monitor in front of them. On a second monitor of the same size (next to the main screen),
8 positive stimuli (International Affective Picture System; Lang, Bradley, & Cuthbert, 2008) were
9 displayed in random order every 10 s. Each of the 13 color images fell into one of four
10 categories: nature (5), food (5), sport (2), or happy people (1). As proposed in the process model,
11 these positive stimuli possessed a want-to character associated with gratification, leisure, and
12 pleasure (Inzlicht et al., 2014). To meet the requirements of the process model, the characteristic
13 from all 13 images had a high score on the pleasure dimension ($M = 7.23$, $SD = 0.44$) and a
14 moderate score on the arousal dimension ($M = 5.17$, $SD = 0.48$). Furthermore, according to Lang
15 et al. (2008), there were no gender effects in the utilized categories of the picture content. All
16 images appeared in the middle of the screen, and efficiency of gaze behavior was measured by
17 relative dwell time (%), defined as the time spent watching a certain area of interest (AOI)—that
18 is, the summed time during which the gaze coordinates fell within the AOI (Vansteenkiste,
19 Cardon, Philippaerts, & Lenoir, 2015). We predicted that the main monitor where the strength
20 curve was visible would be the most relevant AOI for the task. For example, Gwizdka (2014)
21 used dwell time in information search as an indicator of one's interest in a reading task. Thus, a
22 higher dwell time on this main monitor means that participants were able to focus their attention
23 on relevant (main monitor) rather than irrelevant stimuli (locations other than the main monitor).

1 Eye movement data were analyzed using BeGaze™ behavioral and gaze analysis
2 software (SensoMotoric Instruments, Teltow, Germany), based on fixations of more than 80 ms
3 (cf. Martarelli, Chiquet, Laeng, & Mast, 2017). The software automatically detects blink events
4 in the original gaze stream and eliminates these from the data. AOIs were defined as gaze
5 behavior directed to the main screen (AOI1), to the second screen displaying intermittent
6 positive stimuli (AOI2), and to any direction other than AOI1 and AOI2 (defined as AOI3). The
7 mediation analysis employed dwell time (%) at AOI1, summing fixation times (ms) for AOI1,
8 AOI2, and AOI3 as 100% and calculating percentage dwell time for AOI1, which allowed
9 comparison between participants with varying task duration. The eye movement data were
10 analyzed by a student blinded to the experimental group.

11 **Potential covariate.** Trait self-control was assessed as a potential covariate using the
12 German short version of the Self-Control Scale (SCS-K-D) (Bertrams & Dickhäuser, 2009). The
13 13 items assessed general self-control (sample item: “I am good at resisting temptation”; $\alpha = .75$)
14 on a scale ranging from 1 (*not at all*) to 5 (*very much*). We calculated an averaged mean score.

15 **Procedure**

16 Participants were recruited via e-mail, using a course accreditation mailing list,
17 considering only those who (a) had no physical, orthopedic, or neurological problems; (b) wore
18 lenses rather than corrected glasses (if needed); and (c) were not dyslexic. All participants were
19 German speaking, and all had normal or corrected-to-normal visual acuity. They were tested
20 individually in single sessions at the physiology laboratory.

21 Upon arrival, all participants provided written informed consent, followed by a short
22 physical warm-up (Marschall & Gail, 2011) for the physical performance task that followed. The
23 participant was then quasi-randomized in either the control (cognitive self-control task: no) or

1 the experimental group (cognitive self-control task: yes). To measure attention, the eye tracking
2 system was fitted, followed by the calibration and validation procedure.

3 To determine the threshold for the physical self-control task, the participants performed
4 two 5-s 100% MVC, pulling their dominant biceps isometrically, with a three-minute break (cf.
5 Graham & Bray, 2015). The higher peak force of the two measurements was used to determine
6 the threshold. After the task, the participant provided demographic information (gender, age,
7 German language comprehension, and field of study), and their current physical state was
8 assessed by an item asking about how strongly the dominant biceps muscle was used during the
9 previous 24 hours from 1 (*not at all*) to 5 (*very much*) (cf. Stocker, Englert, & Seiler, 2018).
10 Additionally, trait self-control was assessed (SCS-K-D) (Bertrams & Dickhäuser, 2009) as a
11 potential covariate to determine whether the experimental and control groups differed in this
12 regard. All questionnaires were administered via an online survey tool (Unipark, QuestBack
13 GmbH, Köln, Germany) on a laptop.

14 After this rest period, the experimenter set up the visual feedback monitor with the static
15 green bar at the 70% ($\pm 10\%$) MVC criterion value, and the participants completed a 10-s practice
16 trial to become familiar with the biceps task (cf. Graham & Bray, 2015). Prior to the associated
17 biceps trials (T1 and T2), the participants completed the questionnaires assessing their
18 motivation and emotion about the upcoming physical self-control task. After answering the
19 questionnaires, the participants performed the first endurance biceps trial (T1). The trial ended
20 when the participant was no longer able to pull within the personal threshold (60–80% MVC) for
21 more than 1 s, followed by the rating of perceived physical exertion (Borg Scale; Borg, 1998;
22 Borg & Kaijser, 2006). No information or feedback was provided to the participants about how
23 long they were pulling, and the experimenter did nothing to enforce motivation.

1 Following the first endurance biceps trial (T1), cognitive self-control was manipulated
2 using the transcription task (e.g., Englert & Bertrams, 2012; Schmeichel, 2007), followed by the
3 rating of perceived mental exertion (Englert & Bertrams, 2012). Afterwards, each participant
4 completed again the questionnaires about motivation and emotion in regard to the upcoming
5 second physical self-control trial (T2), followed by the performance of the physical self-control
6 trial, and time in the required biceps position (as in the first trial) was measured. After finishing
7 the second trial, the perceived physical exertion was assessed as in the first trial. During both
8 biceps trials (T1 and T2), attention was assessed via the eye tracker. At the end of the study,
9 additional information about the participants' expectations was gathered (open-ended questions).
10 Before the participants left, we thanked them and advised them of an e-mail debriefing once all
11 data were collected (see Figure 1 for procedure).

12 - Figure 1 about here -

13 **Data Analysis**

14 Four missing values from two participants (5.5% of overall raw data) related to time
15 spent on AOI1 were singly imputed using the expectation maximization algorithm (IBM SPSS
16 MVA). Based on all study variables, an outlier analysis (Tabachnick & Fidell, 2007) was
17 conducted for each time measurement in each group. Four extremely high dwell-time values
18 from three participants (5.5 % of overall raw data) were defined as missing values, and these
19 were estimated using expectation maximization to reduce bias in the direction of a normal
20 distribution.

21 A series of independent sample t-tests was performed for between-group comparison at
22 T1 of intrinsic and task motivation, positive and negative affect, attention, and age, as well as
23 manipulation checks on the transcription and biceps tasks. As relative differences have been

1 shown to provide a better estimate than real change (Twisk, 2010, p. 168), these values were also
2 calculated (in s) between T1 and T2 for the dependent variable and for all mediators: intrinsic
3 motivation (IMI), task motivation (TMS), positive and negative affect (PANAS), and attention
4 (dwell time for AOI1). These analyses were performed using SPSS version 24 (IBM).

5 To test the hypothesis that motivation, emotion, and attention mediated the relationship
6 between cognitive self-control and physical self-control, a parallel multiple mediator model
7 (Hayes, 2013) was specified using the R package psych (Revelle, 2017). Five mediators (relative
8 change scores) were included in the analysis: intrinsic and task motivation, positive and negative
9 affect, and dwell time. Bias-corrected bootstrap procedures utilizing 5,000 simulations were
10 computed (Hayes & Scharkow, 2013). As κ is no longer considered an appropriate effect size for
11 parallel multiple mediation, and as no alternative measure is available (Wen & Fan, 2015), no
12 effect size could be reported.

13 Results

14 Demographics and Measurements at T1

15 Participants in the experimental group did not significantly differ from those in the
16 control group with regard to age ($t(67) = 1.12, p = .266$, or gender, $\chi^2(1) = 0.02, p = .894, \eta^2 =$
17 $.02$). Gender was balanced across the two groups (experimental: 16 females, 19 males; control:
18 15 females, 19 males). Table 1 shows descriptive statistics for demographics and measurements
19 at T1, including potential mediators and covariate (by group). The groups did not significantly
20 differ in terms of measurements for the biceps task (s) or for trait self-control, activity intensity
21 in the previous 24 hours, or any of the potential mediators at T1 ($p > .110$ in all cases).

22 Manipulation Checks

23 Table 1 summarizes the results of the manipulation checks. Participants' ratings of

1 perceived mental exertion during the transcription task revealed statistically significant
2 differences between the groups ($t(67) = 5.08, p \leq .001$), with the experimental group returning
3 higher scores than the control group. Additionally, the experimental group transcribed fewer
4 characters than the control group, $t(46.38) = 11.19, p \leq .001$, indicating successful manipulation
5 of self-control strength. However, the groups did not differ significantly in number of errors
6 produced, $t(67) = 0.23, p = .409$.

7 The groups differed statistically in their ratings of perceived physical exertion, both at
8 T1, $t(67) = 2.64, p = .010$, and at T2, $t(67) = 2.65, p = .005$. For both measurements, the control
9 group rated physical exertion during the biceps task significantly lower on the Borg scale than
10 the experimental group (see Table 1).

11 - Table 1 about here -

12 Main Analyses

13 Table 2 shows Pearson's correlations between the independent and dependent variables
14 and the potential mediators. Using a simple linear regression to predict a potential cognitive
15 effect on physical self-control, the total effect was estimated at $b = 0.05, p = .219$. The mediation
16 analysis [$R^2 = .09, F(6, 62) = 1.02, p = .424$] showed no significant direct cognitive effect on
17 physical self-control ($b = 0.07, t = 1.46, p = .150$). In the mediation model, the potential
18 mediators (motivation, attention, and emotion) showed no significant indirect cognitive effect on
19 physical self-control from intrinsic (IMI) and task motivation (TMS), positive and negative
20 affect (PANAS), or attention (dwell time) ($b = -0.01, 95\% \text{ BCa CI } [-0.06, 0.03]$). Figure 2 shows
21 regression coefficients for the five mediators, none of which reached statistical significance.

22 - Table 2 about here -

23 - Figure 2 about here -

1 **Discussion**

2 Self-control is an important element of successful sport performance, as one must resist
3 feelings of discomfort and the urge to quit during an effortful physical task (e.g., Englert, 2017).
4 According to the process model of self-control (Inzlicht et al., 2014; Inzlicht & Schmeichel,
5 2012; Inzlicht & Schmeichel, 2016), the relationship between cognitive and physical self-control
6 may be mediated by factors such as motivation, attention, and emotion. We predicted a negative
7 relationship between cognitive and physical self-control. We further predicted that this
8 relationship would be mediated through a reduction of motivation to accomplish the biceps
9 endurance task, more negative emotions concerning the physical self-control task, and a lower
10 attentional efficiency during the second biceps trial.

11 Contrary to our predictions, the results indicate that motivation, attention, and emotion
12 did not mediate the relationship between cognitive and physical self-control. In addition,
13 contrary to the strength model of self-control (Baumeister et al., 1998), the effortful cognitive
14 self-control task did not lead to impaired physical self-control, as physical performance did not
15 differ between the experimental and control groups (total effect in the mediation model). In
16 short, the present findings do not support either the process model or the strength model of self-
17 control.

18 Previous research has shown that motivation does not influence physical performance
19 when motivation is assessed by self-report (e.g., Brown & Bray, 2017a; Marcora et al., 2009;
20 Pageaux, Marcora, & Lepers, 2013; Schücker & MacMahon, 2016). In the present study,
21 intrinsic and task motivation did not mediate the influence of the self-control manipulation on
22 biceps performance and was not associated with cognitive or physical self-control. However,
23 Brown and Bray (2017b) manipulated motivation and demonstrated that motivation counteracts

1 the negative effects of self-control exertion on physical endurance when participants are awarded
2 a monetary incentive. The fact that motivation has been operationalized in different ways may
3 explain the inconsistency of previous findings; the present results support earlier research that
4 assessed task and intrinsic motivation by means of self-report.

5 Our hypothesis that attentional efficiency during the biceps task would be reduced
6 following a strenuous transcription task was not supported, as we found no association between
7 attention and cognitive or physical self-control. While most previous studies have found that
8 attention is less efficient following self-control-related exertion (Englert, Bertrams et al., 2015;
9 Englert, Zwemmer et al., 2015; McEwan et al., 2013), our results support the findings of Furley
10 et al. (2013), who found no evidence of any such attentional shift. In their computer-based study,
11 basketball players' decision-making under auditory distraction remained efficient both with and
12 without a prior self-control task. However, as reported in more detail below, we assessed only
13 visual attention (not perceptual attention), and peripheral detection of intermittently displayed
14 stimuli remains a possibility.

15 Our results show no increased negative valence in relation to a subsequent self-control
16 task after engaging in a first. While this contradicts the finding that positive affect is reduced and
17 feelings of mental fatigue are heightened following manipulation of cognitive self-control (e.g.,
18 MacMahon et al., 2014; Marcora et al., 2009), many other studies have reported no negative or
19 positive change in emotion following self-control exertion (cf. Hagger et al., 2010b). The only
20 relevant mediation analysis to date found no evidence that emotion mediates the relationship
21 between self-control exertion and physical performance (Brown & Bray, 2017a). In summary,
22 the present findings did not find empirical support for the process model's prediction of
23 emotional changes following an effortful self-control task, and therefore, the findings underpin

1 previous studies.

2 One possible explanation for this absence of support for the process model may relate to
3 the specific demands of the physical task. While there is evidence that isometric endurance
4 performance decreases after completing a prior effortful self-control task, many of those studies
5 used isometric endurance tasks involving handgrip or knee extensor muscles (e.g., Audiffren &
6 André, 2015; Carter et al., 2015). Given this support for isolated muscle endurance tasks, we
7 believe that the biceps task was an appropriate means of testing our hypothesis. However,
8 because participants were pulling their biceps muscle to at least 60% MVC for at most 100 s, one
9 could also argue that decision-making processes may be limited by the “all-out” strategy (cf. Van
10 Cutsem et al., 2017)—that is, anaerobic exercises of short-duration (< 75 s) in local muscles
11 (Thompson, 2014). In the present study, mean time to exhaustion varied between 45 and 50 s in
12 the experimental group and between 43 and 51 s in the control group. It can therefore be argued
13 that shifting priorities may be undermined by this short but intense physical task. From this
14 perspective, one might further argue that the task represents an anaerobic rather than an
15 endurance task (Thompson, 2014; Van Cutsem et al., 2017). Even though we did not find a
16 statistically significant effect of a first self-control task on performance in a second self-control
17 task on a behavioral level, we did find differences in the subjectively experienced level of
18 perceived exertion. Apparently, there is a mismatch between subjective experiences and actual
19 behavior. This is in line with a recent study on eye tracking and self-control performance
20 (Englert, Koroma, Bertrams, & Martarelli, 2019).

21 In relation to the manipulation of self-control, there is evidence that not all self-control
22 tasks are appropriate for inducing perceived mental exertion (e.g., Carter et al., 2015; Dang,
23 2017; Hagger et al., 2010b). However, one meta-analysis (Dang, 2017) confirmed that the

1 transcription task is reliable in this regard and that it is perceived as mentally demanding. One
2 might further argue that the transcription task was too short in duration to induce a state of
3 mental exertion. However, as Brown and Bray (2017b) showed that physical performance
4 (handgrip task) was impaired following 6- to 10-min exertion of self-control (using a Stroop
5 Color and Word Test), we can assume that our transcription task was of sufficient duration to
6 manipulate self-control. This interpretation is supported by our results, which show higher
7 perceived mental effort in the experimental group.

8 It should be further noted that method variance arising from intra-individual variability in
9 performance may have distorted effects, influencing our results. Hagger and Chatzisarantis
10 (2018) pointed out that this may still be the case with baseline measurement of the physical task
11 (T1 in this study). Job, Dweck, and Walton (2010) demonstrated that only individuals who
12 believe that willpower is limited showed a decrease in performance after a prior self-control task.
13 Furthermore, several other physiological explanations might explain the results, like cardiac
14 vagal activity (cf. Laborde, Mosley, & Mertgen, 2018). Future studies should therefore assess
15 whether or not participants perceive self-control to be limited and additionally measure vagal
16 tone.

17 Turning to potential shortcomings of the present study, it should first be noted that the
18 participants were physically active first-year sport science students. For that reason, the results
19 may not be generalizable to other populations (e.g., less active or untrained individuals).
20 Additionally, both the experimental and control groups may have rated their motivation to
21 participate in a sport-related study as rather high, and Kotabe and Hofmann (2015) suggested
22 that self-control failures can be avoided if physical performance is internalized and
23 autonomously driven. As sport science students seem likely to assign positive value to a sport-

1 specific task associated with leisure, the goal of doing one's best may have personal meaning
2 that is "concordant with one's true sense of self" (Taylor, Boat, & Murphy, 2018, p. 10), and the
3 biceps task may have been perceived as want-to rather than have-to. This echoes Inzlicht et al.'s
4 (2014) assumption that individuals may not always make a clear-cut distinction between have-to
5 and want-to tasks. This assumption might undermine performance decreases and associated
6 shifts in motivation, attention, and emotion.

7 Another limiting factor concerns the number of participants. Given the dropout rate, only 69 of
8 86 participants were included in the analysis, but according to the a priori power analysis, 74
9 would have been required for a medium effect size. Due to this difference in the calculated and
10 actual sample size, the study had a rather low power. Future research should therefore examine
11 the process model with more participants from another population—for example, inactive
12 individuals who are not sport science students—to increase statistical power and generalizability.

13 An additional methodological limitation refers to the low internal consistency (T1 and T2) of the
14 subscale Effort and Importance from the Intrinsic Motivation Inventory (Ryan, 1982). The low
15 internal consistency might have impacted our data. A possible explanation for the low internal
16 consistency might date back to the translation from the English to the German language because
17 to our knowledge, so far, no German version of this subscale exists. However, the items were
18 back-and-forth translated by two independent translators who are fluent in English, following the
19 procedure suggested by Beaton, Bombardier, Guillemin, and Ferraz (2000). Nevertheless, future
20 studies should consider validating this scale beforehand. Additional limitations must be
21 acknowledged regarding the study design, as it is not a fully-fledged randomized-controlled
22 study. However, oftentimes complete randomization cannot be achieved in real world
23 experimental studies, as a balanced number of female and male participants in the control and

1 experimental group is highly desired. Although we cannot rule out any unintended effects, we
2 are confident that they were kept at a minimum.

3 A further limitation relates to the assessment of attention by means of eye tracking.
4 During the biceps task, participants' gaze focused on the main screen, following their strength
5 curve rather than images popping up on the second screen. While gaze position is generally a
6 good indicator of where attention is directed, participants may have detected the images through
7 peripheral vision (Boucart, Moroni, Thibaut, Szaffarczyk, & Greene, 2013). This means that
8 while eye tracking is a more objective method of measurement than self-report, it cannot detect
9 whether attention is directed to the gaze location or to a peripheral location. In addition,
10 Tenenbaum and Hutchinson (2007) reported that attention may shift from external (e.g.,
11 environment) to internal (e.g., bodily sensations, thoughts) when workload increases in physical
12 endurance tasks. Again, however, this kind of attention is not accessible using eye tracking, and
13 future studies might usefully combine validated questionnaires, thinking-aloud protocols (Boren
14 & Ramey, 2000), and eye tracking for more effective measurement. Furthermore, as performance
15 on the biceps task was not overly dependent on visual information, future studies could use tasks
16 in which visual information has a higher impact on physical self-control performance (e.g., dart-
17 throwing; Englert, Zwemmer et al., 2015).

18 The above findings and limitations have implications both for sport and exercise
19 performance and for future research on self-control. With regard to the former, the findings show
20 that cognitive self-control exertion does not necessarily lead to decreased performance in
21 physical self-control tasks. In any case, motivation, attention, and emotion do not seem to
22 mediate this relationship; rather, lower performance may relate to the specific demands of the
23 physical task. In line with other research on self-control exertion (Van Cutsem et al., 2017),

1 high-intensity anaerobic exercise of short duration (e.g., bodybuilding) may be unaffected by
2 prior effortful self-control tasks, and motivation, attention, and emotions may play a subordinate
3 role in these processes. To prevent suboptimal physical performance, then, it may be important
4 for coaches and athletes to recognize situations that necessitate high cognitive self-control
5 investment during or prior to competition.

6 These findings also have theoretical implications for the process model of self-control
7 (Inzlicht et al., 2014; Inzlicht & Schmeichel, 2012; Milyavskaya & Inzlicht, 2018). While the
8 process model proposes a mechanistic explanation of lowered performance, task perception may
9 depend on other or additional factors beyond motivation, attention, and emotion, as well as on
10 the character of the task. For that reason, it seems necessary to further investigate how and when
11 dilemmas are experienced in relation to self-control (Milyavskaya & Inzlicht, 2018). While the
12 present study investigated the process model by crossing over the nature of the task from
13 cognitive on physical performance, performance decrease might be further observed for
14 consecutive tasks of a similar nature (e.g., cognitive on cognitive) (Van Cutsem et al., 2017).
15 Further studies are needed to assess the process model in relation to cognitive tasks rather than
16 physical performance.

17 In sum, the present study is the first to test the process model of self-control in a sporting
18 and exercise context. Previous research on self-control has reported inconsistent findings as to
19 whether motivation, emotion, or attention may exert an influence (cf. Taylor et al., 2018). The
20 present findings suggest that other factors (e.g., nature of the physical self-control task,
21 individual characteristics, beliefs about willpower) may influence the relationship between
22 cognitive and physical self-control performance. Future research should compare different self-

- 1 control tasks and potential mediators (e.g., belief about willpower or pleasure in the self-control
- 2 task) of the cognitive–physical self-control relationship.

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1 Footnotes

2 ¹The Stroop Color and Word Test (Stroop, 1935) asks participants to work on a series of
3 color words. They are either displayed in a color matching the semantic meaning (i.e., congruent
4 trial; e.g., “green” written in green font) or in a color that does not match the semantic meaning
5 (i.e., incongruent trial; “red” written in blue font). Thereby, the participants have to ignore the
6 semantic meaning of the respective word and name the font color instead. The incongruent trials
7 therefore require self-control (e.g., Wallace & Baumeister, 2002).

8 ²According to the process model, both tasks represent a have-to character. Therefore, in the
9 following section, we use the term “self-control task.” However, the terms “have-to task” and
10 “self-control task” are interchangeable in this sense.

11 ³Besides the described preregistered variables, we also assessed trait self-control as a
12 potential covariate (SCS-K-D; Bertrams & Dickhäuser, 2009).

13

1 Figure Captions

2 *Figure 1.* Study procedure in the experiment. The self-control tasks represent the have-to
3 tasks in the process model of self-control (Inzlicht et al., 2014; Inzlicht & Schmeichel, 2012). To
4 get familiar with the biceps endurance task, participants performed the task for 10 s
5 (familiarization task). The criterion values for this task and the biceps endurance trials (T1 and
6 T2) were set at 70% ($\pm 10\%$) maximum voluntary contraction (MVC). MC = Manipulation
7 Check.

8 *Figure 2.* Mediating role of motivation (task motivation and intrinsic motivation),
9 emotion (positive and negative affect), and attention in explaining the relation between cognitive
10 and physical self-control.

11

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Table 1

Descriptive Statistics: Means and Standard Deviations for Age, Primary Outcome Measure, Potential Mediators and Covariate, and Manipulation Checks

Variable	Experimental Condition				<i>p</i>	<i>d</i>
	Control Group (<i>n</i> = 34)		Experimental Group (<i>n</i> = 35)			
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>		
Age	20.58	1.52	20.14	1.57	.254	0.29
Primary Outcome Measure						
Biceps Task T1	50.76	13.40	49.93	9.05	.761	0.06
Potential Mediators (T1) and Covariate						
Intrinsic Motivation	5.87	0.80	5.97	0.69	.598	0.13
Task Motivation	8.18	1.60	8.23	1.56	.891	0.00
Positive Affect	2.77	0.70	3.01	0.55	.115	0.39
Negative Affect	1.30	0.35	1.19	0.19	.108	0.40
Dwell Time	95.68	7.01	95.43	5.76	.891	0.00
Trait Self-Control	3.34	0.52	3.30	0.44	.740	0.08
Manipulation Checks						
Perceived Mental Exertion	6.18	1.68	8.14	1.54	<.001	1.24
Transcribed Characters	753.12	147.01	442.83	68.48	<.001	2.76
Number of Errors	10.56	21.65	11.63	16.36	.409	0.06
Perceived Physical Exertion (T1)	16.41	1.46	17.34	1.47	.010	0.64
Perceived Physical Exertion (T2)	16.56	1.67	17.60	1.59	.005	0.65

Table 2.

Correlation Coefficients (Pearson's r) for Condition, Physical Self-Control, Intrinsic Motivation, Task Motivation, Positive and Negative Affect, and Attention

Measures	1	2	3	4	5	6
1 Cognitive Self-Control	–					
2 Physical Self-Control	.15	–				
3 Task Motivation	.04	.22	–			
4 Intrinsic Motivation	.14	.05	.32	–		
5 Positive Affect	-.15	.14	.36	.19	–	
6 Negative Affect	.01	.01	.05	-.07	-.09	–
7 Attention	-.11	.05	-.02	.13	-.13	.07

Note. The critical r value ($df = 67$, $\alpha = 5\%$, two-sided) is .24.



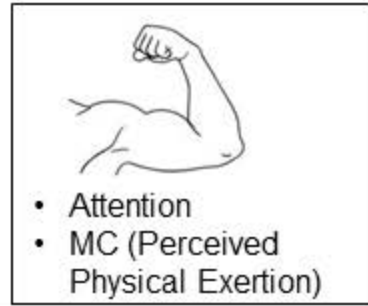
- Demographics
- Trait Self-Control Scale

100% MVC

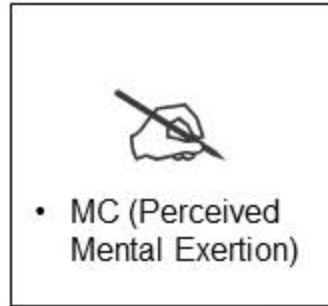


Familiarization Task

Questionnaires:
• Emotion
• Motivation

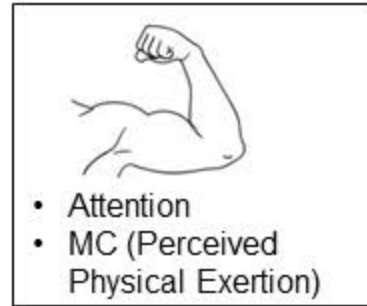


Physical Self-Control
T1

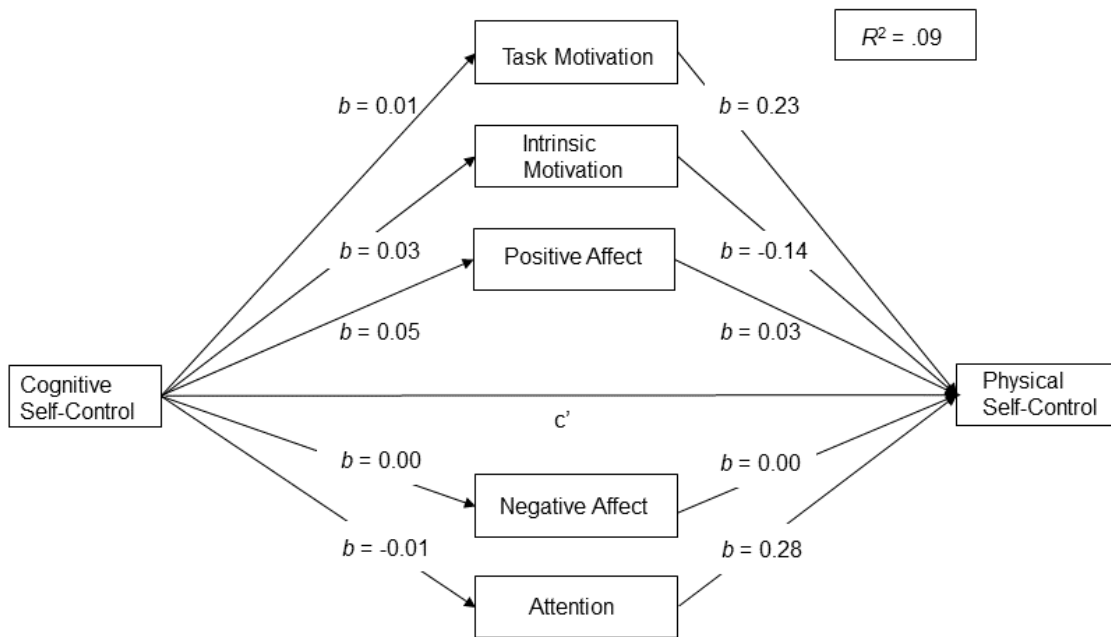


Cognitive Self-Control

Questionnaires:
• Emotion
• Motivation



Physical Self-Control
T2



Direct effect c' , $b = 0.07$, $p = .150$
 Indirect effect, $b = -0.01$, 95% BCa CI [-0.06, 0.03]