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No relation of Need for Cognition to basic executive functions

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Abstract

Objective: Need for Cognition (NFC) refers to a personality trait describing the relatively stable intrinsic motivation of individuals to invest cognitive effort in cognitive endeavors. Higher NFC is associated with a more elaborated, central information processing style and increased recruitment of resources in cognitively demanding situations. To further clarify the association between cognitive resources and NFC, we examined in two studies how NFC relates to executive functions as basic cognitive abilities.

Method: In Study 1, 189 healthy young adults completed an NFC scale and a battery of six commonly used inhibitory control tasks (Stroop, antisaccade, stop-signal, flanker, shape-matching, word-naming). In Study 2, 102 healthy young adults completed the NFC scale and two tasks for each of the three executive functions inhibitory control (go-nogo, stop-signal), shifting (number-letter, color-shape), and working memory updating (two-back, letter-memory).

Results: Using a Bayesian approach to correlation analysis, we found no conclusive evidence that NFC was related to any executive function measure. Instead, we obtained even moderate evidence for the null hypothesis.

Conclusions: Both studies add to more recent findings that shape the understanding of NFC as a trait that is less characterized by increased cognitive control abilities but rather by increased willingness to invest effort and exert self-control via motivational processes.

KEYWORDS

Bayesian statistics, executive functions, inhibitory control, investment traits, Need for Cognition

1 | INTRODUCTION

The investment trait Need for Cognition (NFC; Cacioppo & Petty, 1982; von Stumm & Ackerman, 2013) refers to relatively stable interindividual differences in the tendency to engage in and enjoy cognitively challenging tasks (Cacioppo et al., 1996). NFC has been examined in a large number of studies. Respective research has especially focused on its relations to individual differences in information processing (Cacioppo et al., 1996), to other cognitive (e.g., Fleischhauer

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et al., 2014; Hill et al., 2016) and personality variables (e.g., Fleischhauer et al., 2010) as well as to academic success (Grass et al., 2017; Luong et al., 2017; Strobel et al., 2019). Previous studies on NFC and cognitive ability have mainly focused on relations to intelligence (e.g., Fleischhauer et al., 2010; Hill et al., 2016). However, it remains unclear whether NFC relates to rather basic cognitive functions and what may be processes behind the small to moderate but positive association of NFC with intelligence. Such basic cognitive abilities are executive functions (EF) that describe superordinate abilities to coordinate and control cognitive processes, closely linked to goal-oriented behavior (Miyake & Friedman, 2012; Miyake et al., 2000). A central component of EF is inhibitory control, which describes the ability to actively inhibit or delay a dominant response to achieve a goal (Miyake & Friedman, 2012; Miyake et al., 2000). Recent research has shown inhibitory control to account for the common variance in EF tasks, indicating inhibitory control as the unifying EF (Miyake & Friedman, 2012).

Although there are some studies that investigated the relationship between NFC and self-control (Bertrams & Dickhäuser, 2009, 2012b; Grass et al., 2018; Grass, Krieger, et al., 2019; Nishiguchi et al., 2016), hardly any study examined the relationship between NFC and inhibitory control or other EF. One study investigated correlations of NFC with performance in the Stroop task and found no correlation with mean reaction times in interference trials when administering a Stroop task without a previous depleting task (Bertrams & Dickhäuser, 2012a). Another study provided evidence that NFC is not directly associated with working memory but that working memory moderates how NFC relates to intelligence (Hill et al., 2016). Additional empirical indications of an association between NFC and EF come from studies on the NFC-related trait Openness to Experience that report associations with working memory and shifting ability (Ayotte et al., 2009; DeYoung et al., 2009; Murdock et al., 2013).

From a theoretical perspective, examining NFC together with EF is suggested for several reasons: Ample research has linked NFC to elaborated, effortful information processing (for a review, see Cacioppo et al., 1996) and to goal-oriented behavior (Fleischhauer et al., 2010). There is first evidence that individuals with higher NFC levels actually recruit more resources when confronted with higher cognitive demands (Grass, Krieger, et al., 2019; Mussel et al., 2016). Similarly, cognitive effort is less aversive for individuals with higher NFC levels (Westbrook et al., 2013). Altogether, those variations accompanying interindividual differences in NFC suggest that higher NFC promotes an increased willingness to exert cognitive control, which should be reflected in better executive control performance. Additionally, better cognitive control may support higher NFC levels by succeeding in situations with increased cognitive demands, leading to increased motivation to approach cognitive challenges. Vice versa, the frequent confrontation with cognitively challenging situations in higher NFC levels may improve EF abilities. This line of reasoning reflects a theoretical view close to the OFCI model by Ziegler et al., (2012).

The present study aimed at following up on previous research on the relationship of NFC to intelligence (e.g., Fleischhauer et al., 2010) and self-control (e.g., Bertrams & Dickhäuser, 2012a, 2012b) by examining how NFC relates to EF as basic cognitive abilities. Because NFC promotes increased motivation to invest the cognitive effort needed to solve behavioral and cognitive conflicts, we assumed a positive association of NFC with executive control performance. The present article reports the results of two studies: Whereas Study 1 focused on inhibitory control, Study 2 took a broader perspective also including shifting and working memory updating. Data analyses and routines for both studies are available in the Open Science Framework at http://doi.org/10.17605/osf.io/93gs6 (Grass, Gärtner, et al., 2019). Both studies have not been preregistered.

2 | STUDY 1

2.1 | Materials and methods

Study 1 is a reanalysis of data collected within a larger project that aimed at investigating cognitive correlates of emotion regulation. Some results from that project have been already presented in Gärtner and Strobel (2021) but refer to research aims different from the present article (that is, results on replicating the proposed latent structure for inhibitory control when accounting for individual differences in performance and speed-accuracy trade-offs). We report how we determined our sample size, all data exclusions, all manipulations, and all measures in the study (cf. Simmons et al., 2012). Data, analysis routines, and a complete list of all measures including those that are not relevant for the present study can be found at https://osf.io/2fwm4 (Gärtner & Strobel, 2019).

2.1.1 | Participants

The sample comprised 190 healthy adults recruited at a university campus. There was a dropout of one participant who did not complete the NFC scale, resulting in a final sample of $N = 189$ ($M = 23.8$ years, $SD = 4.7$; 92 male, 97 female; for power considerations, see Statistical analyses). In a semi-structured interview for psychiatric and neurological disorders or treatment, no participant reported any current or past (in the last year) medical, neurological or psychiatric illness, or treatment that might influence cognition or motor performance. All participants were non-smokers, reported

German as their mother tongue, had normal or corrected to normal vision and no color blindness, and reported no regular substance or alcohol use. All participants provided written informed consent and received compensation for their participation. The study was conducted in accordance with the Declaration of Helsinki and followed the ethical guidelines of the German Psychological Association. The study design was approved by the local ethics committee (EK 357,092,014).

2.1.2 | Procedure

Upon arrival, participants were briefly familiarized with the laboratory setting, informed about the upcoming experiment, and provided demographic information and ratings on their current mood. Afterward, participants performed six inhibitory control tasks in randomized order. Finally, participants were debriefed, reimbursed, and thanked. All sessions were conducted between 9 a.m. and 5 p.m. Each session lasted about 90 min. The sessions were carried out in testing booths to ensure undisturbed testing. Participants were allowed breaks of self-chosen duration following the completion of each task inside the testing booth. All participants were instructed to pause for 5 min by leaving the testing booth after completing the first three tasks. The NFC scale was filled out among other questionnaires assessing general personality factors in an online survey within the next two weeks. Within the larger project, all participants returned for a second session about two weeks later to work on an emotion regulation paradigm. The respective data are not reported here.

2.1.3 | Measures

Apparatus

Behavioral data were acquired using Presentation® software (version 17.0, Neurobehavioral Systems, Inc., Berkeley, CA, www.neurobs.com), running at LCD screens with a resolution of 1,080 × 1,024. Questionnaire responses were recorded using Limesurvey (http://www.limesurvey.org).

Inhibitory control

Six tasks adapted from Friedman and Miyake (2004) were used to assess the participants' inhibitory control abilities: three for distractor interference (Eriksen flanker task, shape-matching task, word-naming task) and three for response inhibition (antisaccade task, stop-signal task, Stroop task). Resistance to distractor interference relates to an initial perceptual stage of information processing and focuses on the selection of relevant versus irrelevant information. In contrast, prepotent response inhibition has been associated with a later stage of information processing, focusing on the inhibition of motor responses and behavioral impulses (Friedman & Miyake, 2004). The tasks were adopted from Friedman and Miyake (2004) and Enge and colleagues (2014) and presented in random order across participants to control for order effects. A detailed description of all tasks including data trimming, statistical analyses, and descriptive statistics of the inhibitory control tasks can be found in the Supporting Information. Dependent variables were the proportion of errors in the antisaccade task, the reaction time difference between incongruent and congruent trials in the Stroop task, SSRT in the stop-signal task, the reaction time difference between no-noise and noise incompatible trials in the flanker task, and the reaction time difference between the distractor and no-distractor trials in the shape-matching and word-naming task.

Most tasks required participants to give speeded responses while maintaining accuracy. The resulting speed-accuracy trade-off may be balanced differently by participants (Bogacz, 2014) so that performance could often not be accurately quantified by either error rate (ER) or response time (RT). Hence, we followed previous research (cf. Wolff et al., 2016) and calculated *inverse efficiency scores* (IES; Bruyer & Brysbaert, 2011; Townsend & Ashby, 1983) that combine RT and ER in a single score. IES resulted from dividing the mean RT of correct responses by the proportion of correct responses (RT/[1 − ER]). IES are expressed in ms because RTs in ms are divided by proportions. IES were not used for the stop-signal task because the stop-signal reaction time (SSRT) already accounts for accuracy (Study 1, see Logan et al., 2014) or because ERs were held approximately constant across participants by an adaptive tracking algorithm (Study 2), and the letter-memory task, which required no speeded responses.

Need for Cognition

NFC was assessed with the German 16-item short scale (Bless et al., 1994; for example, "I find it especially satisfying to complete an important task that required a lot of thinking and mental effort"). Responses were recorded on a 7-point Likert scale, anchored at –3 (*not at all*) and +3 (*very much*), and aggregated to a sum score. The scores ranged from −22 to 43 with $M = 15.86$, $SD = 11.61$. Cronbach's α was 0.85.

2.1.4 | Statistical analyses

Data were analyzed with a Bayesian approach using *RStudio* (Version 1.1.463; RStudio Team, 2016) with *R* (Version 3.6.1; R Core Team, 2018). Specifically, as some variables showed a skewed distribution (see Table 1 and Supporting Information Figure S1), we calculated nonparametric Kendall's τ between NFC and the IES obtained in the six

TABLE 1 Descriptive statistics of NFC and the inhibitory control tasks

	M	*SD*	Min	Max	Skew	Kurtosis
NFC	15.86	11.61	−22.00	43.00	−0.22	−0.05
Stroop	49.57	52.68	−60.25	200.68	0.66	−0.13
Antisaccade	571.19	285.17	292.07	2,651.18	4.07	22.06
Stop-signal	321.98	42.39	200.00	436.50	0.30	−0.12
Flanker	51.20	59.77	−96.90	319.47	0.92	2.60
Shape-Matching	164.30	95.35	−46.43	528.82	1.21	1.60
Word-Naming	131.33	91.50	−132.09	425.00	0.52	0.50

Note: N = 189. *Min* =minimum; *Max* =maximum; provided are statistics for inverse efficiency scores except for the stop-signal task, where the stop-signal reaction time (SSRT) was used; lower values in inhibitory control tasks indicate better performance; please note that the minimum of 200 ms for the SSRT results from the data trimming procedure.

inhibitory control tasks as a nonparametric alternative to Pearson correlations for which a Bayesian estimation algorithm exists (van Doorn et al., 2018). It is implemented in the software *JASP* (JASP Team, 2018) and is also available as an *R* script (https://osf.io/b9qhj). All analyses were repeated for task performance based on reaction times (see Supporting Information). Pearson correlations, as well as intercorrelations of all inhibitory control tasks, are provided in the Supporting Information.

We used the default stretched beta prior width of 1 that assumes correlations between –1 and 1 to be equally likely, but we also performed Bayes factor robustness checks assuming beta prior widths ranging from 0.01 to 1 (for a visualization see Supporting Information Figure S2). We report the median posterior probability of Kendall's τ together with 95% credible intervals, based on 10,000 samplings of Kendall's τ together with the respective Bayes factors (BF10) that quantify the evidence for the alternative hypothesis: Given the data, the alternative hypothesis is moderately, strongly, or very strongly more likely than the null hypothesis if BF10 is larger than 3, 10, or 30. That is, the data are 3, 10, or 30 more likely under the assumption of the alternative hypothesis than under the null hypothesis. Conversely, a BF10 of smaller than 1/3, 1/10 or 1/30 indicates moderate, strong, or very strong evidence in favor of the null hypothesis, whereas only anecdotal evidence for the null or the alternative hypothesis is indicated by $1/3 \leq \text{BF10} \leq 3$ (c.f. Wetzels et al., 2011).

Because Bayes factors depend on sample size, we performed an analog to classical power analysis. Therefore, we ran a simulation to determine what proportion of 10,000 random samples of $n = 189$ would produce Bayes factors in favor of the null hypothesis (BF01) or in favor of the alternative hypothesis (BF10) if those samples were drawn from a population of $N = 1{,}000$ where a Pearson correlation ranging from $r = 0.02$ to $r = 0.40$ exists (approximately equaling $\tau = 2/3{*}r$, i.e., $\tau = 0.01$ to $\tau = 0.27$). We set a BF10 and BF01 of > 3 as a threshold, that is, at least moderate evidence for the respective hypothesis, given a prior width of 1. This analysis (see Supporting Information Figure S3) indicated that, with our sample size, a BF01 > 3 was obtained in at least 80% of the samples for $r \leq 0.04$ (approximately equaling Kendall's $\tau \leq 0.03$). Vice versa, a BF10 > 3 was obtained in at least 80% of the samples for $r \geq 0.26$, (approximately equaling Kendall's $\tau \geq 0.17$). Thus, in terms of classical power analysis, we had 80% power to find at least moderate evidence for a null effect if it was $\tau \leq 0.03$ and 80% power to find at least moderate evidence for a true effect if it was $\tau \geq 0.17$.

2.2 | Results

The descriptive statistics of all measures are shown in Table 1. Table 2 gives the intercorrelations of NFC and inhibitory control tasks and Figure 1 visualizes the results. All correlations were small ranging from $\tau = -0.10$ to $\tau = 0.06$. NFC correlated negatively with IES derived from the Stroop and antisaccade task, both $\tau = -0.10$ with 95% confidence intervals (CI) not including zero. That indicates somewhat better inhibitory control in individuals with

TABLE 2 Correlations of NFC with performance in inhibitory control tasks

Task[a]	Kendall's τ	95% CI	BF10
Stroop	−0.10	[−0.19, −0.00][b]	0.68
Antisaccade	−0.10	[−0.20, −0.01]	0.98
Stop-signal	−0.08	[−0.18, 0.01]	0.40
Flanker	−0.04	[−0.13, 0.06]	0.12
Shape-Matching	−0.04	[−0.13, 0.06]	0.12
Word-Naming	0.06	[−0.04, 0.15]	0.19

Note: N = 189. CI =confidence interval; BF10 = Bayes factors in favor of the alternative hypothesis; Kendall's τ gives the medians and 95% CI the 95% credible intervals of the posterior distributions based on 10,000 samplings of Kendall's τ together with the respective Bayes factors (BF10).

[a]Dependent variables are inverse efficiency scores except for the stop-signal task, where the stop-signal reaction time (SSRT) was used; lower values in inhibitory control tasks indicate better performance.

[b]Upper bound of −0.00 indicates that the actual value (−0.0012) is lower than zero.

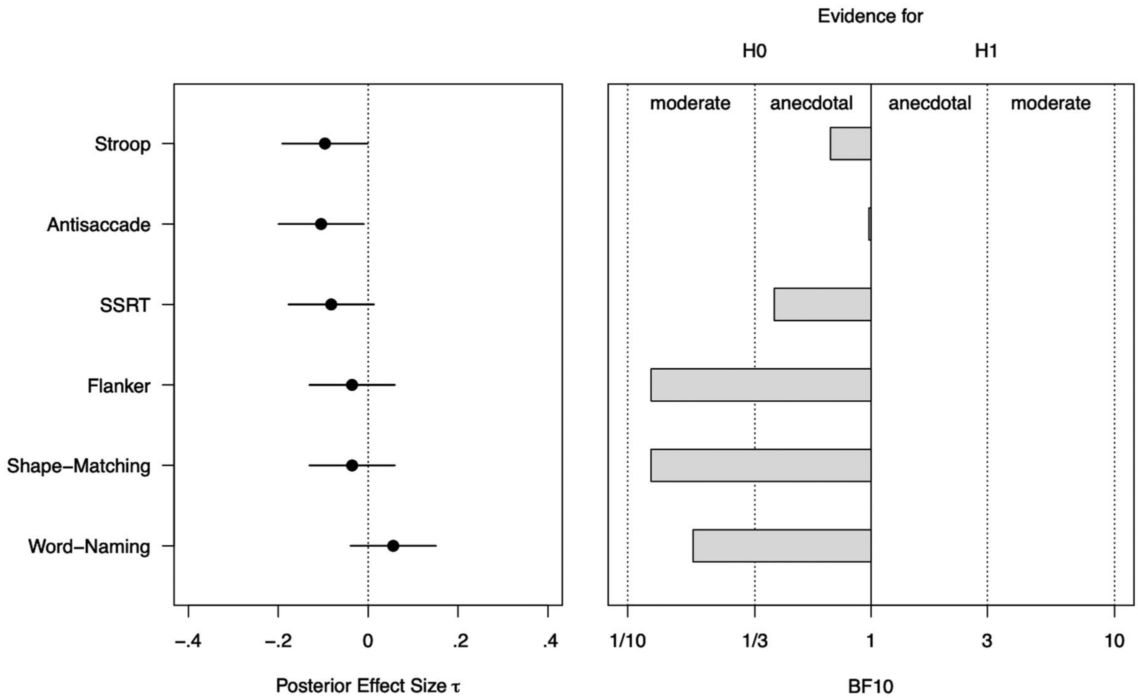

FIGURE 1 Results of Bayesian correlation analyses. The left panel gives the effect size Kendall's τ as median together with 95% credible intervals (CI) of the posterior distribution based on 10,000 samplings of Kendall's τ. The right panel depicts the respective Bayes factors (BF10); please note that the upper bound of the 95% CI for the Stroop task is lower than zero

higher NFC scores. The Bayes factors for the correlations of NFC with performance in the Stroop, antisaccade, and stop-signal task ranged from BF10 = 0.98 to BF10 = 0.40. Thus, they fall between 1/3 and 1 and provide no conclusive evidence, neither in favor of the alternative hypothesis nor in favor of the null hypothesis. In contrast, for the flanker, shape-matching, and word-naming tasks, the Bayes factors ranged from BF10 = 0.19 to BF10 = 0.12. Expressed as BF01 (i.e., 1/BF10), Bayes factors ranged from BF01 = 5.26 to BF01 = 8.33. Thus, given the data, the null hypothesis of no correlation between NFC and performance in the flanker, shape-matching, and word-naming tasks was five to eight times more likely than the alternative hypothesis.[1]

Bayes factor robustness checks showed that overall larger BF10 were obtained with narrower widths of the stretched beta prior (see Supporting Information Figure S4). Nevertheless, in all cases, the above statements held: The hypothesis of no relation between NFC and performance in the flanker, the shape-matching, and the word-naming task would be also supported if we had used the default prior width of Bayesian (Pearson) correlations realized in the *BayesFactor* package (Morey & Rouder, 2018), that is, 1/3. Likewise, with this prior width, the BF10 for the Stroop and the antisaccade task, albeit being larger than 1 in this case, remained below 3, and hence, did not provide conclusive evidence for the alternative or the null hypothesis.

Alternatively using reaction time-based performance measures (see Supporting Information, Table S2 as well as Figures S5 and S6) confirmed the conclusions stated above: Bayes factors provided moderate to strong evidence for the null hypothesis of no relation between NFC and performance in the flanker, antisaccade, and word-naming tasks that remained moderate when using a narrower prior width of 1/3. For the other tasks, no conclusive evidence in favor of the null or the alternative hypothesis could be obtained.

2.3 | Discussion

In Study 1, we examined whether NFC is related to performance in inhibitory control tasks. Because NFC promotes increased motivation to invest cognitive effort to solve behavioral and cognitive conflicts, we assumed a positive relation with inhibitory control. Using a Bayesian approach to correlation analysis, we found no conclusive evidence of a correlation for three of the tasks (Stroop, antisaccade, and stop-signal task) and moderate evidence in favor of the null hypothesis for the remaining tasks. This result essentially held if we used other reasonable prior distributions, but differed to some extent when using reaction time-based measures of inhibitory control. However, in no case, evidence in favor of the alternative hypothesis emerged. Thus, our results do not lend support to the notion that inhibitory control and NFC are related to a substantial degree.

3 | STUDY 2

Based on Study 1, Study 2 took a broader perspective and examined whether NFC relates not only to inhibition but also to shifting and working memory updating. The study was embedded in a more comprehensive data collection aiming at studying NFC in the context of study-related success (Grass et al., 2017) and its relation with different cognitive abilities.

3.1 | Materials and methods

Data, analysis routines, and an overview of the laboratory procedure for Study 2 can be found at https://osf.io/93gs6/.

3.1.1 | Participants

The participants of this study belonged to two different samples. The first sample of 61 students participated in an online survey first before taking part in a laboratory session. They were recruited via internet and mail platforms of German universities, social media, and advertisements at a university campus. The online part included additional variables that have been already presented in Grass et al. (2017) and refer to research questions different from the present article. The laboratory codes of four participants could not be matched to online data. We identified two participants when they collected their course credit and asked them to fill in the main online questionnaires again per paper pencil. The remaining two participants could be not included in our data set. Another participant could not be included due to technical problems. The second subsample consisted of 54 students recruited at a university after the data of the first subsample had been collected. For this subsample, the recruitment aimed especially at non-Psychology students in order to obtain a more generalizable sample. From both subsamples, eight participants were excluded from the analysis who were no native speakers in order to ensure proper understanding of instructions. One person was excluded due to a standardized value of intelligence of 76. Thus, the finally analyzed sample consisted of $N = 102$ students aged 18 to 35 years ($M = 23.9$ years, $SD = 3.2$; 60 female, 42 male; for power considerations, see Statistical analyses). As compensation, Psychology students could get course credit after participating in the laboratory, participants of subsample 2 could get 15 Euros.

3.1.2 | Procedure

The procedure was evaluated by the local ethics committee (V-080-15-SM-JG-Denken-060220015) and considered not to contain aspects of ethical relevance. In both subsamples, the most relevant data were collected in the laboratory session with not more than four participants being tested simultaneously. Participants gave written informed consent and then proceeded with a survey about their current condition before they completed the cognitive functioning tasks. Subsample 1 provided self-reports on their NFC ahead of the session in an online survey; subsample 2 completed the NFC scale ahead of the cognitive task battery (as well as afterwards, but the scores reported here refer to the first assessment only). The testing sessions took about 150–180 min.

3.1.3 | Measures

Apparatus

Online questionnaires were presented via EFS Survey (EFS 10.5; Questback GmbH, 2015). The EF tasks were implemented using the Psychophysics Toolbox in MATLAB (Brainard, 1997). Stimuli were presented on a 22-inch LED monitor, and responses were entered by a German layout (i.e., QWERTZ) keyboard.

Need for Cognition

As in Study 1, NFC was assessed with the German 16-item short scale (Bless et al., 1994). The scores ranged from −23 to 40 with $M = 15.97$, $SD = 13.25$. Cronbach's α was 0.90.

Executive functions

All participants completed six computerized EF tasks (two tasks per function), each taking approximately 10 min. Participants could work self-paced. They wore headphones to decrease disturbing noises. Participants could choose to pause after completing each task and had to take a five-minute break after three tasks. They were instructed to remain seated for the whole task battery if possible. Each task was preceded by on-screen instructions and a short practice block. Task order was counterbalanced with regard to the targeted EF. Within each task, the order of stimuli was pseudorandomized in the same way for all participants. All administered tasks were similar to Wolff et al., (2016; see here for more details).

Inhibition tasks. Inhibitory control was measured with a go-nogo and stop-signal task. For go-nogo, performance was indicated by the IES as the mean RT in correct go trials divided by the proportion of correct responses on nogo trials. Thus, higher scores indicate lower inhibition. For stop-signal, the rate of stop-trial errors was held constant at approximately

50% for all participants using an adaptive tracking algorithm. Performance was indicated by the SSRT estimated according to the quantile method (Congdon et al., 2012): All correct go trials of a participant were arranged in ascending order, and the RT whose quantile corresponded to the participant's ER on stop trials was selected. The SSRT was then calculated by subtracting the average stop-signal delay from this quantile RT. Thus, higher scores indicate less inhibitory control over initiated responses.

Shifting tasks. Shifting tasks were a number-letter and color-shape task. Each task comprised two different subtask sets. On each trial, a cue indicated what subtask should be performed. Compared to each preceding trial, there were switch trials and no-switch trials. The outcome of each task was the switch cost, that is, the IES difference between switch and no-switch trials. Thus, higher scores indicate lower shifting capacities.

Updating tasks. Updating was measured with a spatial two-back task and a letter-memory task. The outcome measure of two-back was the IES across all trials. Thus, higher scores indicated lower capacities for updating spatial information. In the letter-memory task, participants were presented with sequences of letters, followed by a prompt to recall the last three letters of the sequence. As speeded responses were not required in this task, the outcome was the rate of incorrectly remembered letters, with higher scores indicating lower updating capacities.

All parts of trimming and preprocessing the EF tasks were similar to Wolff et al. (2016).

Further variables. In both subsamples, we assessed age, gender, and grade of the university entrance diploma. Fluid and crystallized intelligence were assessed as complex cognitive abilities, mental speed as basic ability, and self-estimated reasoning as intelligence self-concept; all referring to research questions different from the present article. Further personality variables were included in previous analyses published in Grass et al., (2017) or assessed for exploratory purposes out of the scope of the present article.

3.1.4 | Statistical analyses

Data were analyzed as described for Study 1. Bayesian Kendall's τ between NFC and the six EF tasks was determined because of the skewed distributions of some of the variables (see Table 3 and Supporting Information Figure S7). Task parameters used were again IES except for the stop-signal task, where we again relied on SSRT, and the letter-memory task, where we used the proportion of errors. A stretched beta prior width of 1 was used for the correlation analyses, and robustness checks were performed as in Study 1. Finally, all analyses were repeated with reaction time-based measures of EF (see Supporting Information). Additionally, Pearson correlations, as well as intercorrelations of all EF tasks, are provided in the Supporting Information.

A Bayesian analog to power analysis was performed that indicated that with a sample size of $N = 102$, a BF01 > 3 was obtained in at least 80% of the random samples for $r \leq 0.06$ (approximately equaling Kendall's $\tau \leq 0.04$). Vice versa, a BF10 > 3 was obtained in at least 80% of the samples for $r \geq 0.36$, (approximately equaling Kendall's $\tau \geq 0.24$). Therefore, in terms of classical power analysis, we had 80% power to find at least moderate evidence for a null effect if it was $\tau \leq 0.04$ and 80% power to find at least moderate evidence for a true effect if it was $\tau \geq 0.24$ (see Supporting Information Figure S8).

3.2 | Results

For all measures, descriptive statistics are shown in Table 3. Table 4 and Figure 2 provide the intercorrelations of NFC and EF tasks. All correlations were small ranging from $\tau = -0.10$ to $\tau = 0.06$. All 95% CI included zero. All Bayes factors were below 1, BF10 ≤ 0.37. Expressed as BF01, Bayes factors ranged from BF01 = 2.70 to BF01 = 7.69. This indicates that, given the data, the null hypothesis of no correlation between NFC and performance in the EF tasks was

TABLE 3 Descriptive statistics of NFC and the EF tasks

	n	*M*	*SD*	Min	Max	Skew	Kurtosis
NFC	102	15.97	13.25	−23.00	40.00	−0.66	0.10
Go-NoGo	102	397.57	75.81	274.44	664.05	0.95	1.06
Stop-Signal	96	197.67	59.28	55.08	314.99	−0.54	−0.15
Number-Letter	93	369.12	216.25	−182.10	972.83	0.53	0.32
Color-Shape	100	163.38	122.94	−21.23	529.87	1.14	1.15
Two-Back	97	542.47	158.16	319.91	1,027.26	1.12	0.96
Letter-Memory	102	0.18	0.13	0.00	0.51	0.22	−0.46

Note: $N = 102$, variation in subsample size n due to exclusions during data preprocessing (see Methods). *Min* = minimum; *Max* = maximum; provided are statistics for inverse efficiency scores except for the stop-signal task, where the stop-signal reaction time (SSRT) was used, and the letter-memory task where we relied on the proportion of errors; lower values in executive function tasks indicate better performance.

TABLE 4 Correlations of NFC with performance in EF tasks

Task[a]	n	Kendall's τ	95% CI	BF10
Go-NoGo	102	−0.01	[−0.14, 0.12]	0.13
Stop-Signal	96	0.06	[−0.08, 0.19]	0.19
Number-Letter	93	0.04	[−0.09, 0.18]	0.16
Color-Shape	100	0.06	[−0.07, 0.19]	0.20
Two-Back	97	−0.10	[−0.23, 0.04]	0.37
Letter-Memory	102	−0.06	[−0.19, 0.07]	0.19

Note: $N = 102$, variation in subsample size n due to exclusions during data preprocessing (see Methods). CI = confidence interval; BF10 = Bayes factors in favor of the alternative hypothesis. Kendall's τ gives the medians and 95% CI the 95% credible intervals of the posterior distributions based on 10,000 samplings of Kendall's τ together with the respective Bayes factors (BF10).

[a]Dependent variables are inverse efficiency scores except for the stop-signal task, where the stop-signal reaction time (SSRT) was used, and the letter-memory task where we relied on the proportion of errors; lower values in executive- function tasks indicate better performance.

about three to eight times more likely than the alternative hypothesis.

Bayes factor robustness checks showed that overall larger BF10 were obtained with narrower widths of the stretched beta prior (see Supporting Information Figure S9). For the go-nogo and the number-letter task, the respective BF10 would still provide moderate evidence in favor of the null hypothesis if we had used a prior width of 1/3. However, for the remaining tasks, the Bayes factors did not provide conclusive evidence in favor of the null hypothesis.

Essentially similar results were obtained for the reaction time-based performance measures (see Supporting Information, Table S4 as well as Figures S10 and S11). Here, all Bayes factors fell between 1/10 and 1/3, thus providing moderate evidence for the null hypothesis. With a prior width of 1/3, however, only three of the correlations yielded Bayes factors below 1/3.

3.3 | Discussion

Study 2 took a broader perspective on the relation of NFC to EF and examined whether NFC is related to shifting and working memory updating besides inhibitory control performance. Because previous research has shown that individuals with higher NFC actually recruit more resources when being confronted with higher cognitive demands (Grass, Krieger, et al., 2019; Mussel et al., 2016), we assumed a positive association of NFC with executive control. The results of Study 2 mirror those of Study 1: With Bayes factors smaller than 1, they provide no evidence for the alternative hypothesis of a correlation between NFC and the performance in tasks that assess basic EF. Using the default prior width of 1, we obtained even moderate evidence for the null hypothesis. It remains to be noted that using a different prior width of 1/3 led to evidence in favor of the null hypothesis only for two of the tasks: go-nogo and number-letter. Still, Study 2 does not provide support for the assumption that NFC is related to basic EF.

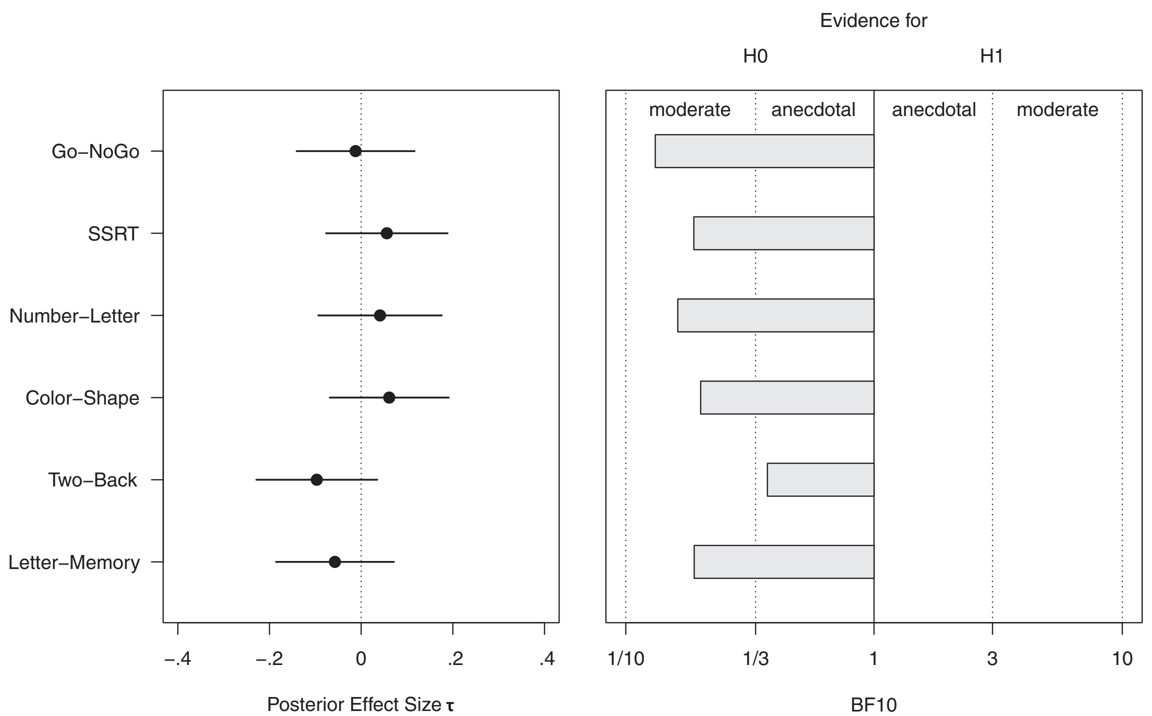

FIGURE 2 Results of Bayesian correlation analyses. The left panel gives the effect size Kendall's τ as median together with 95% credible intervals of the posterior distribution based on 10,000 samplings of Kendall's τ. The right panel depicts the respective Bayes factors (BF10)

4 | GENERAL DISCUSSION

In order to further clarify the relation between cognitive abilities and NFC, we examined whether and how EF are associated with NFC. Whereas Study 1 focused on inhibitory control, Study 2 considered also shifting and working memory updating. Using a Bayesian approach to correlation analysis, we found no conclusive evidence that NFC is related to any EF measure. Instead, the results suggest that NFC and basic cognitive abilities are largely independent of each other.

Because null hypothesis testing traditionally focuses on rejecting the null hypothesis, we analyzed the data with a Bayesian approach to examine whether the data support evidence in favor of the null hypothesis. This approach allowed for explicitly quantifying how much more likely the data are under the null hypothesis compared to the alternative hypothesis. In fact, Bayes factors for the respective correlation coefficients were smaller than one and, thus, indicated that most of the correlations suggested anecdotal or even moderate evidence for the null hypothesis. The finding of no substantial association between NFC and EF might seem surprising at first glance, given that basic EF are considered crucial processes for human information processing (Diamond, 2013; Miyake et al., 2000). However, in line with previous research (Bertrams & Dickhäuser, 2012a), the results indicate that NFC is at best weakly related to basic EF. They further confirm results of a recent study reporting no significant association of NFC to EF tasks for working memory updating (two-back), shifting (number-letter), and inhibitory control (Go-nogo; Fleischhauer et al., 2019). Complementary to the results reported here, mainly mental speed (and not basic EF) could be associated with NFC so that difference measures (i.e., IES) would disguise such effects. In Study 2 (see Further variables under 3.1.3 Measures), mental speed was assessed with a variant of the trail making test (Oswald & Roth, 1987) and not significantly associated with NFC (r_s = 0.16; p =.108). Hence, even the descriptive strength of that association was too small for disguising EF-related effects.

The present results contradict the assumption that individuals with higher NFC prefer to think more deeply mainly because of more pronounced EF as an example for basic cognitive abilities. Instead, NFC might rather be related to the way how individuals allocate their cognitive resources. This assumption is suggested by experimental evidence on relationships of NFC with higher mental effort investment (Mussel et al., 2016) and lower effort discounting (Westbrook et al., 2013) as well as correlational findings on associations of NFC with dispositional resource recruitment (Grass, Krieger, et al., 2019), with early stages of information processing (cf. Strobel et al., 2015), and with goal-oriented personality traits (Fleischhauer et al., 2010). The present results thereby indirectly support the assumption that relations of NFC to academic performance, knowledge, and decisional processes (e.g., Cacioppo et al., 1996; Grass et al., 2017) are attributable not mainly to differences in cognitive ability, especially when referring to EF as very basic cognitive abilities. They underline the motivational character of NFC and the notion that individuals with higher NFC levels are willing to invest more effort during goal pursuit (e.g., Westbrook et al., 2013), which is also mirrored in relations of higher NFC to intensified information-seeking behaviors (for an overview, see Cacioppo et al., 1996).

Taking into account previous research on NFC and fluid intelligence reporting associations about $r = 0.3$ (e.g., Fleischhauer et al., 2010), the present results hint at differences in empirical findings depending on the measure and aggregation level of cognitive abilities. This conclusion supports the general advice for research on personality-ability relations to consider carefully the symmetry concerning the breadth of constructs (Kretzschmar et al., 2018). As NFC describes motivational tendencies across situations, it may be closer related to cognitive abilities when they have to be used persistently or become more complex. Indeed, there is evidence linking NFC to complex problem solving (Rudolph et al., 2018). Therefore, examining the role of NFC in more complex cognitive abilities than EF such as complex problem-solving or planning in more detail seems to be a fruitful aim for future research. On a task level, high NFC individuals engage more in processing complex rather than simple information (See et al., 2009) and are less prone to extrinsic incentives for task performance (Sandra & Otto, 2018). Hence, task characteristics like subjective cognitive demands may—in addition to the complexity of measured abilities—influence how much effort individuals invest in their task preformance. Due to the monotonous character of the tasks we used to assess (basic) EF, higher NFC individuals might be confronted with tasks that did not match their desired level of task complexity in order to trigger their intrinsic motivation for cognitive processing and may have caused an NFC x situation interaction on individual task-related motivation (See et al., 2009)—additionally to differences in abilities depending on NFC that we wanted to measure. To gain more insight into the origin of our results and the role of motivation on a task level versus the association of NFC with basic EF on a construct level, prospective studies should examine the intrinsic value and subjective cognitively challenging character of basic cognitive tasks like those we used in the present two studies for individuals with different NFC levels. Increased knowledge about such individual evaluations of task characteristics would be beneficial for a valid interpretation of (non) correlations of NFC with tasks that assess different psychological variables. For measures that assess intelligence or higher-order EF like planning both may be true: They mirror higher-order cognitive processes (referring to construct symmetry) and use tasks that should be perceived as rather complex (referring to subjective task complexity) so that stronger associations with NFC are likely to be found. In addition, other more abstract instead of more basic cognitive abilities might represent promising targets for future studies, for example working memory updating and short-term storage, which represent important constructs when it comes to learning and knowledge acquisition. Ideally, these further contructs should be systematically investigated together with other investment traits to complete the picture.

Another methodological consideration refers to the measuring of EFs in general. Research has shown low zero-order correlations between EF tasks (e.g., Friedman & Miyake, 2017; Huizinga et al., 2006; van der Sluis et al., 2007). These might arise from the task impurity problem, but more likely occur due to the generally low between-subject variance in most EF tasks (Hedge et al., 2018). Alternative measurement and statistical approaches are discussed in the literature (e.g., Draheim et al., 2019; Hedge et al., 2018), thus, we applied IES that combine reaction times and accuracy in a single score (cf. Wolff et al., 2016). Although task correlations were somewhat higher when using IES compared to standard RT difference scores, they were still relatively small and often insignificant. More recent findings suggest the reliance on accuracy-based measures (Draheim et al., 2019) or accounting for trial-by-trial variability (Rouder & Haaf, 2019) as more promising approaches.

Some limitations of our studies have to be noted. First, the correlational design does not allow for sound conclusions on developmental processes or causal assumptions. NFC is considered a relatively stable trait in adults. The same applies for EF, albeit critical developmental phases have been proposed. Thus, it remains unclear whether the relationship of NFC and EF differs when comparing younger and older adults or children. Second, we investigated mostly students. As indicated by intelligence scores of the sample in Study 2 (standard values in the CFT 20-R (Weiß, 2006): $M = 110.95$, $SD = 11.85$) their general cognitive (control) ability may have been relatively high compared to the general population or clinical samples (e.g., ADHD), resulting in relatively homogenous performance (cf. Hill et al., 2016). Further studies are needed to compare more heterogeneous samples with regard to EF. Third, our sample size only enabled us to find moderate to large effects. Further studies with larger samples (that is, > 200) are necessary to account for small effect sizes that are more likely in the field of psychology and individual differences (e.g., Gignac & Szodorai, 2016). Fourth, some task reliabilities in our study were only moderate or poor which might have influenced the results. However, as for Study 1, where reliabilities of the inhibitory control tasks were determined (see Supporting Information Table S1), a correction for attenuation based on the highest observed (absolute) correlation of Kendall's $\tau = 0.10$ (r_{xy}), the reliability of the NFC scale of Cronbach's $\alpha = 0.85$ (r_{xx}) and the lowest reliability of the inhibitory control tasks of 0.31 (r_{yy}) would—according to the formula $r_{x'y'} = r_{xy}/\mathrm{sqrt}(r_{xx}*r_{yy})$—result in a corrected correlation of $r_{x'y'} = 0.19$ and therefore in a still small correlation. In addition, even if the reliabilities would have been higher, recent research suggests that robust cognitive tasks do not necessarily produce reliable individual differences that might be related to NFC (Hedge et al., 2019; the so-called reliability paradox). Thus, other parameters than difference measures (e.g., accuracy measures or drift duffusion parameters) might be more promising. Future studies should pay particular attention to appropriate tasks and measures with good reliabilities, larger samples, and task effects that allow for investigating individual differences.

5 | CONCLUSION

Taken together, the present research extends the previous literature by comprehensively examining the relation of NFC to EF. It shows that the relation of NFC to EF is weak at best, suggesting that individual differences in NFC do not or only marginally rely on individual differences in executive functioning. Future research may explore the role of more complex abilities such as planning depth or complex problem solving as critical correlates of NFC together with implications of NFC for the implementation of basic abilities in more complex situations of everyday life.

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CONFLICT OF INTEREST

All authors had no conflict of interest.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are openly available in the Open Science Framework at http://doi.org/10.17605/osf.io/93gs6 (Grass, Gärtner, et al., 2019).

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ENDNOTE

[1] Please note that in order to address the task impurity problem, we also correlated NFC to a latent factor "Response-Distractor Inhibition" derived from the IES of four out of the six tasks (antisaccade, Stroop, shape-matching, and word-naming), as only such

a model showed satisfying fit indices (i.e., CFI ≥ 0.95, RMSEA ≤ 0.06, SRMR ≤ 0.06; Hu & Bentler, 1999). Please see Gärtner and Strobel (2021) for details on model estimation. Yet, despite controlling for measurement error by a latent variable, the results were similar to that obtained using the individual tasks, $\tau = -0.08$, 95% CI [−0.18; 0.01], BF10 = 0.39, i.e., inconclusive evidence for a true correlation of NFC and a latent factor representing core aspects of inhibitory control.

REFERENCES

Ayotte, B. J., Potter, G. G., Williams, H. T., Steffens, D. C., & Bosworth, H. B. (2009). The moderating role of personality factors in the relationship between depression and neuropsychological functioning among older adults. *International Journal of Geriatric Psychiatry*, *24*(9), 1010–1019. https://doi.org/10.1002/gps.2213

Bertrams, A., & Dickhäuser, O. (2009). High-school students' need for cognition, self-control capacity, and school achievement: Testing a mediation hypothesis. *Learning and Individual Differences*, *19*(1), 135–138. https://doi.org/10.1016/j.lindif.2008.06.005

Bertrams, A., & Dickhäuser, O. (2012a). On the relationship between need for cognition and self-control capacity. *Psychology and Education*, *49*(3/4), 46–55.

Bertrams, A., & Dickhäuser, O. (2012b). Passionate thinkers feel better: Self-control capacity as mediator of the relationship between need for cognition and affective adjustment. *Journal of Individual Differences*, *33*(2), 69–75. https://doi.org/10.1027/1614-0001/a000081

Bless, H., Wänke, M., Bohner, G., Fellhauer, R. F., & Schwarz, N. (1994). Need for cognition: Eine Skala zur Erfassung von engagement und Freude bei Denkaufgaben: Need for cognition: A scale measuring engagement and happiness in cognitive tasks. *Zeitschrift Für Sozialpsychologie*, *25*, 147–154.

Bogacz, R. (2014). Speed-Accuracy Trade-Off. In D. Jaeger, & R. Jung (Eds.), *Encyclopedia of computational neuroscience*. Springer.

Brainard, D. H. (1997). The psychophysics toolbox. *Spatial Vision*, *10*, 433–436. https://doi.org/10.1163/156856897X00357

Bruyer, R., & Brysbaert, M. (2011). Combining speed and accuracy in cognitive psychology: Is the inverse efficiency score (IES) a better dependent variable than the mean reaction time (rt) and the percentage of errors (pe)? *Psychologica Belgica*, *51*(1), 5–13. https://doi.org/10.5334/pb-51-1-5

Cacioppo, J. T., & Petty, R. E. (1982). The need for cognition. *Journal of Personality and Social Psychology*, *42*(1), 116–131. https://doi.org/10.1037/0022-3514.42.1.116

Cacioppo, J. T., Petty, R. E., Feinstein, J. A., & Jarvis, W. B. G. (1996). Dispositional differences in cognitive motivation: The life and times of individuals varying in need for cognition. *Psychological Bulletin*, *119*(2), 197–253. https://doi.org/10.1037/0033-2909.119.2.197

Congdon, E., Mumford, J. A., Cohen, J. A., Galvan, A., Canli, T., & Poldrack, R. A. (2012). Measurement and reliability of response inhibition. *Frontiers in Psychology*, *3*, 37.

DeYoung, C. G., Shamosh, N. A., Green, A. E., Braver, T. S., & Gray, J. R. (2009). Intellect as distinct from openness: Differences revealed by fMRI of working memory. *Journal of Personality and Social Psychology*, *97*(5), 883–892. https://doi.org/10.1037/a0016615

Diamond, A. (2013). Executive functions. *Annual Review of Psychology*, *64*(1), 135–168. https://doi.org/10.1146/annurev-psych-113011-143750

Draheim, C., Mashburn, C. A., Martin, J. D., & Engle, R. W. (2019). Reaction time in differential and developmental research: A review and commentary on the problems and alternatives. *Psychological Bulletin*, *145*(5), 508–535. https://doi.org/10.1037/bul0000192

Draheim, C., Tsukahara, J. S., Martin, J., Mashburn, C., & Engle, R. (2019). A toolbox approach to improving the measurement of attention control. *PsyArXiv*. https://doi.org/10.31234/osf.io/q985d

Enge, S., Behnke, A., Fleischhauer, M., Küttler, L., Kliegel, M., & Strobel, A. (2014). No evidence for true training and transfer effects after inhibitory control training in young healthy adults. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *40*(4), 987–1001. https://doi.org/10.1037/a0036165

Fleischhauer, M., Enge, S., Brocke, B., Ullrich, J., Strobel, A., & Strobel, A. (2010). Same or different? Clarifying the relationship of need for cognition to personality and intelligence. *Personality and Social Psychology Bulletin*, *36*(1), 82–96. https://doi.org/10.1177/0146167209351886

Fleischhauer, M., Miller, R., Enge, S., & Albrecht, T. (2014). Need for cognition relates to low-level visual performance in a metacontrast masking paradigm. *Journal of Research in Personality*, *48*, 45–50. https://doi.org/10.1016/j.jrp.2013.09.007

Fleischhauer, M., Miller, R., Wekenborg, M. K., Penz, M., Kirschbaum, C., & Enge, S. (2019). Thinking against burnout? An individual's tendency to engage in and enjoy thinking as a potential resilience factor of burnout symptoms and burnout-related impairment in executive functioning. *Frontiers in Psychology*, *10*. https://doi.org/10.3389/fpsyg.2019.00420

Friedman, N. P., & Miyake, A. (2004). The relations among inhibition and interference control functions: A latent-variable analysis. *Journal of Experimental Psychology: General*, *133*(1), 101–135. https://doi.org/10.1037/0096-3445.133.1.101

Friedman, N. P., & Miyake, A. (2017). Unity and diversity of executive functions: Individual differences as a window on cognitive structure. *Cortex*, *86*, 186–204. https://doi.org/10.1016/j.cortex.2016.04.023

Gärtner, A.Strobel A. (2021). Individual differences in inhibitory control: A latent variable analysis. *Journal of Cognition*, *4*(1). http://dx.doi.org/10.5334/joc.150

Gärtner, A., & Strobel, A. (2019). Individual differences in inhibitory control: A latent variable analysis. *Open Science Framework*. https://osf.io/2fwm4/

Gignac, G. E., & Szodorai, E. T. (2016). Effect size guidelines for individual differences researchers. *Personality and Individual Differences*, *102*, 74–78. https://doi.org/10.1016/j.paid.2016.06.069

Grass, J., Gärtner, A., Wolff, M., Goschke, T., Strobel, A., & Strobel, A. (2019). No relation of Need for Cognition to basic executive functions. *Open Science Framework*. https://doi.org/10.17605/osf.io/93gs6

Grass, J., John, N., & Strobel, A. (2018). Freude am Denken als Schlüssel zum Erfolg? Die Bedeutung von Need for Cognition für subjektives Erleben und Leistung im Studium [The joy of thinking as the key to success? The importance of Need for Cognition for subjective experience and achievement in academic studies]. *Zeitschrift für Pädagogische Psychologie*, *32*(3), 145–154. https://doi.org/10.1024/1010-0652/a000222

Grass, J., Krieger, F., Paulus, P., Greiff, S., Strobel, A., & Strobel, A. (2019). Thinking in action: Need for cognition predicts self-control together with action orientation. *PLoS One*, *14*(8), e0220282. https://doi.org/10.1371/journal.pone.0220282

Grass, J., Strobel, A., & Strobel, A. (2017). Cognitive investments in academic success: The role of need for cognition at University. *Frontiers in Psychology*, *8*. https://doi.org/10.3389/fpsyg.2017.00790

Hedge, C., Powell, G., & Sumner, P. (2018). The reliability paradox: Why robust cognitive tasks do not produce reliable individual differences. *Behavior Research Methods*, *50*(3), 1166–1186. https://doi.org/10.3758/s13428-017-0935-1

Hill, B. D., Foster, J. D., Sofko, C., Elliott, E. M., & Shelton, J. T. (2016). The interaction of ability and motivation: Average working memory is required for Need for Cognition to positively benefit intelligence and the effect increases with ability. *Personality and Individual Differences*, *98*, 225–228. https://doi.org/10.1016/j.paid.2016.04.043

Hu, L., & Bentler, P. M. (1999). Cutoff criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives. *Structural Equation Modeling: A Multidisciplinary Journal*, *6*(1), 1–55. https://doi.org/10.1080/10705519909540118

Huizinga, M., Dolan, C. V., & van der Molen, M. W. (2006). Age-related change in executive function: Developmental trends and a latent variable analysis. *Neuropsychologia*, *44*(11), 2017–2036. https://doi.org/10.1016/j.neuropsychologia.2006.01.010

Kretzschmar, A., Spengler, M., Schubert, A.-L., Steinmayr, R., & Ziegler, M. (2018). The Relation of Personality and Intelligence—What can the Brunswik symmetry principle tell us? *Journal of Intelligence*, *6*(3), 30. https://doi.org/10.3390/jintelligence6030030

Logan, G. D., Van Zandt, T., Verbruggen, F., & Wagenmakers, E.-J. (2014). On the ability to inhibit thought and action: General and special theories of an act of control. *Psychological Review*, *121*(1), 66–95. https://doi.org/10.1037/a0035230

Luong, C., Strobel, A., Wollschläger, R., Greiff, S., Vainikainen, M.-P., & Preckel, F. (2017). Need for cognition in children and adolescents: Behavioral correlates and relations to academic achievement and potential. *Learning and Individual Differences*, *53*, 103–113. https://doi.org/10.1016/j.lindif.2016.10.019

Miyake, A., & Friedman, N. P. (2012). The nature and organization of individual differences in executive functions: Four general conclusions. *Current Directions in Psychological Science*, *21*(1), 8–14. https://doi.org/10.1177/0963721411429458

Miyake, A., Friedman, N. P., Emerson, M. J., Witzki, A. H., Howerter, A., & Wager, T. D. (2000). The unity and diversity of executive functions and their contributions to complex "frontal lobe" tasks: A latent variable analysis. *Cognitive Psychology*, *41*(1), 49–100. https://doi.org/10.1006/cogp.1999.0734

Morey, R. D., & Rouder, J. N. (2018). *BayesFactor: Computation of Bayes Factors for Common Designs* (R package version 0.9.12-4.2). [Computer software].

Murdock, K. W., Oddi, K. B., & Bridgett, D. J. (2013). Cognitive correlates of personality: Links between executive functioning and the Big Five Personality Traits. *Journal of Individual Differences*, *34*(2), 97–104. https://doi.org/10.1027/1614-0001/a000104

Mussel, P., Ulrich, N., Allen, J. J. B., Osinsky, R., & Hewig, J. (2016). Patterns of theta oscillation reflect the neural basis of individual differences in epistemic motivation. *Scientific Reports*, *6*(1). https://doi.org/10.1038/srep29245

Nishiguchi, Y., Takano, K., & Tanno, Y. (2016). The need for cognition mediates and moderates the association between depressive symptoms and impaired effortful control. *Psychiatry Research*, *241*, 8–13. https://doi.org/10.1016/j.psychres.2016.04.092

Oswald, W. D., & Roth, E. (1987). *Der Zahlen-Verbindungs-Test (ZVT) [The numbers connecting test (ZVT)]*. Hogrefe.

R Core Team. (2018). *R: A language and environment for statistical computing* (Version 3.6.1) [Computer software]. R Foundation for Statistical Computing. https://www.R-project.org/

Rouder, J. N., & Haaf, J. M. (2019). A psychometrics of individual differences in experimental tasks. *Psychonomic Bulletin & Review*, *26*(2), 452–467. https://doi.org/10.3758/s13423-018-1558-y

RStudio Team. (2016). RStudio: Integrated development environment for R (Version 1.1.463) [Computer software]. RStudio, Inc. http://www.rstudio.com/

Rudolph, J., Greiff, S., Strobel, A., & Preckel, F. (2018). Understanding the link between need for cognition and complex problem solving. *Contemporary Educational Psychology*, *55*, 53–62. https://doi.org/10.1016/j.cedpsych.2018.08.001

Sandra, D. A., & Otto, A. R. (2018). Cognitive capacity limitations and Need for Cognition differentially predict reward-induced cognitive effort expenditure. *Cognition*, *172*(2018), 101–106. https://doi.org/10.1016/j.cognition.2017.12.004

See, Y. H., Petty, R. E., & Evans, L. M. (2009). The impact of perceived message complexity and need for cognition on information processing and attitudes. *Journal of Research in Personality*, *43*(5), 880–889. https://doi.org/10.1016/j.jrp.2009.04.006

Simmons, J. P., Nelson, L. D., & Simonsohn, U. (2012). A 21 Word Solution. *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.2160588

Strobel, A., Behnke, A., Gärtner, A., & Strobel, A. (2019). The interplay of intelligence and need for cognition in predicting school grades: A retrospective study. *Personality and Individual Differences*, *144*, 147–152. https://doi.org/10.1016/j.paid.2019.02.041

Strobel, A., Fleischhauer, M., Enge, S., & Strobel, A. (2015). Explicit and implicit Need for Cognition and bottom-up/top-down attention allocation. *Journal of Research in Personality*, *55*, 10–13. https://doi.org/10.1016/j.jrp.2014.11.002

Townsend, J. T., & Ashby, F. G. (1983). *Stochastic modeling of elementary psychological processes*. Cambridge University Press.

van der Sluis, S., de Jong, P. F., & van der Leij, A. (2007). Executive functioning in children, and its relations with reasoning, reading, and arithmetic. *Intelligence*, *35*(5), 427–449. https://doi.org/10.1016/j.intell.2006.09.001

van Doorn, J., Ly, A., Marsman, M., & Wagenmakers, E.-J. (2018). Bayesian Inference for Kendall's Rank Correlation Coefficient. *The American Statistician*, *72*(4), 303–308. https://doi.org/10.1080/00031305.2016.1264998

von Stumm, S., & Ackerman, P. L. (2013). Investment and intellect: A review and meta-analysis. *Psychological Bulletin*, *139*(4), 841–869. https://doi.org/10.1037/a0030746

Weiß, R. H. (2006). *Grundintelligenztest Skala 2—Revision (CFT 20-R) mit Wortschatztest und Zahlenfolgentest -Revision (WS/ZF-R)*. Hogrefe.

Westbrook, A., Kester, D., & Braver, T. S. (2013). What is the subjective cost of cognitive effort? Load, trait, and aging effects revealed by economic preference. *PLoS One*, *8*(7), e68210. https://doi.org/10.1371/journal.pone.0068210

Wetzels, R., Matzke, D., Lee, M. D., Rouder, J. N., Iverson, G. J., & Wagenmakers, E.-J. (2011). Statistical evidence in experimental psychology: An empirical comparison using 855 *t* tests. *Perspectives on Psychological Science*, *6*(3), 291–298. https://doi.org/10.1177/1745691611406923

Wolff, M., Krönke, K.-M., Venz, J., Kräplin, A., Bühringer, G., Smolka, M. N., & Goschke, T. (2016). Action versus state orientation moderates the impact of executive functioning on real-life self-control. *Journal of Experimental Psychology: General*, *145*(12), 1635–1653. https://doi.org/10.1037/xge0000229

Ziegler, M., Danay, E., Heene, M., Asendorpf, J., & Bühner, M. (2012). Openness, fluid intelligence, and crystallized intelligence: Toward an integrative model. *Journal of Research in Personality*, *46*(2), 173–183. https://doi.org/10.1016/j.jrp.2012.01.002

SUPPORTING INFORMATION

Additional Supporting Information may be found online in the Supporting Information section.

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