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Dispositional Individual Differences in Cognitive Effort Investment: Establishing the Core Construct

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Abstract

It is commonly assumed that individuals tend to avoid effort, be it physical or cognitive. Yet, recent evidence suggests that individual differences exist and that personality traits related to the willingness to invest cognitive effort in goal-directed behavior are associated with experimental measures of cognitive effort investment. The personality traits need for cognition (NFC) and self-control were found to be related to behavioral measures of effort discounting and demand avoidance, respectively. Given that NFC and self-control are only moderately related, this evidence raises the question whether these associations are specific for these traits or whether they reflect a common core that these traits both involve cognitive effort investment. If so, the common core of both traits might be related to behavioral measures of the avoidance of cognitive effort in a more systematic fashion. Thus, the present study aimed at specifying a core construct of cognitive effort investment that reflects dispositional differences in the willingness and tendency to exert effortful control. Therefore, we conducted an online-study ($N = 613$) with questionnaires related to cognitive motivation and effort investment including the NFC and the self-control scale. Our findings support the hypothesized correlations between the assessed traits, where the relationship of NFC and self-control is specifically mediated via an aspect that can be conceptualized as goal-directedness. We found that a hierarchical factor model of cognitive motivation and effortful self-control can explain the shared variance of these two first-order factors by a second-order factor of cognitive effort investment. These findings

are backed up by results of an independent second sample ($N = 244$). Taken together, our results integrate currently only loosely related research strands on cognitive motivation and self-control and provide a basis for further experimental research on the role of dispositional individual differences in goal-directed behavior.

1 Introduction

People tend to avoid or at least reduce not only physical (Morel et al., 2017; Prevost et al., 2010) but also cognitive effort (Chong et al., 2018; Ostaszewski et al., 2013). The experimental series of Kool et al. (2010) demonstrates a general tendency of individuals to avoid cognitive demand across different choice settings and demand manipulations. As this tendency was diminished by monetary reward, the authors concluded that mental effort is subjectively considered costly. This conclusion plays an important role for research in motivation and cognitive control where it is assumed that decision-making relies on cost-benefit analyses (Kool & Botvinick, 2014; Kurzban et al., 2013a; Shenhav et al., 2013). Consequently, the net value of a specific benefit has been described as the result of both its objective amount and the perceived effort needed to attain it. In practice, this would mean that rewards related to less effort are favored over rewards of the same amount but that require more effort. This phenomenon is commonly discussed as effort discounting (Botvinick et al., 2009; Massar et al., 2016; Westbrook et al., 2013).

Interestingly, individuals do not discount effort to the same extent, which may be explained by dispositional individual differences in personality. Indeed, two seminal findings support this notion: First, Westbrook et al. (2013) obtained a positive correlation between the personality trait Need for Cognition (NFC) and the subjective value of performing tasks of increasing difficulty within their so-called cognitive effort discounting paradigm (COG-ED). Individuals high in NFC showed less effort discounting. Second, Kool et al. (2013) showed that when having to choose between two visual patterns that were associated with tasks of differing demand, individuals generally tended to choose the low demand option in this so-called demand selection task (DST). However, individuals high in trait self-control showed less demand avoidance. This relation was present for self-reported as well as behavioral measures of self-control.

Given that NFC and self-control are only moderately related, this evidence raises the question whether these associations are specific for these traits or whether they reflect a common core of NFC and self-control, in which both traits involve cognitive effort investment, as we outline in the following.

Need for cognition (NFC) describes “[...] an individual’s tendency to engage in and enjoy effortful cognitive endeavors.” (Cacioppo et al., 1984, p. 306). NFC correlates positively with personality dimensions associated with dispositional approach-behavior, activity, persistence and goal orientation (Fleischhauer et al., 2010). NFC has also been found to be highly related to achievement motivation (Bless et al., 1994). On a psychophysiological basis, Mussel et al. (2016) investigated theta oscillations as an indicator of cognitive effort: individuals high in NFC dynamically recruited cognitive resources in line with task demands, i.e., spent less cognitive effort in easier than in harder tasks. The resulting effect on performance was that individuals high in NFC performed better in the harder condition compared to individuals with lower NFC. With regard to the effort discounting phenomenon, the estimation of costs might contrast cognitive effort with cognitive boredom. Individuals high in NFC might integrate the additional motivational attraction into the cost-benefit-analysis.

Self-Control is an important variable in the context of goal-directed behavior, as it refers to the capacity of adapting one’s immediate state to achieve higher-order goals (Tangney et al., 2004).

For example, self-control has been found to correlate positively with self-esteem and academic success in terms of grades and negatively with the presence of dysfunctional and impulsive behavior like problematic drinking and eating patterns (Tangney et al., 2004). The strength model of self-control (Baumeister et al., 2007) assumes self-control as a limited resource that expends while applying it. A meta-analysis (Hagger et al., 2010) on this so-called ego-depletion effect reveals evidence in favor but also against it: on the one hand ego-depletion influences effort and subjective task difficulty but on the other hand motivational incentives or practicing self-control reduce ego-depletion, whereas the anticipation of an upcoming self-control task strengthens it. Inzlicht et al. (2014) proposed an alternative account of self-control depletion: people generally tend to balance their motivation between two poles, namely exploration vs. exploitation, leisure vs. labor or want-to vs. have-to goals. These authors understand ego-depletion as a motivated adaptation to task preferences. As to self-control and effort investment, a study of Lindner et al. (2018) demonstrated that individuals high in self-control spent consistently more effort during an exam than individuals low in self-control.

Taken together, self-control and NFC play an important role for effort investment but by their definitions seem to represent quite distinct constructs. This is also reflected in an only moderate correlation between the two traits (Bertrams & Dickhäuser, 2009a). However, there may be a common motivational core of self-control and NFC, which is related to the willingness to invest mental effort. Specifically, NFC is associated with personality traits indicating goal-directedness (Fleischhauer et al., 2010), as well as highly associated to achievement motivation (Bless et al., 1994). In addition, self-control has been expectedly found to be related to conscientiousness and to better task performance (Tangney et al., 2004). Furthermore, both NFC and self-control show a positive effect on school performance (Bertrams & Dickhäuser, 2009a). In summary, both constructs seem to have in common the aspect of goal orientation (Baumeister et al., 2007). Interestingly, the intellect framework (Mussel, 2013) incorporates exactly this aspect as follows.

Mussel (2013) specifies intellect as “[...] a dispositional variable motivating behavior related to intellectual achievements.” (p. 886). His theoretical framework structures prevailing personality traits referring to this context: NFC, typical intellectual engagement, curiosity, intrinsic motivation, goal orientation, as well as openness to ideas. The framework consists of two dimensions: operations and processes. Operations discriminate between think, learn and create, whereas processes divide into seek and conquer. Seek refers to the general openness to approach intellectually demanding situations and its corresponding affect, while conquer captures motivational processes in these situations, e.g., effort, diligence and persistence. Experimental findings (Smillie et al., 2016) support the assumption that intellect covers both seek and conquer processes. These authors found a positive relation of intellect and task performance variables and emphasize the utility of high intellect for learning and performance. The intellect framework locates NFC in the intercept of the operation think and the process seek, as NFC motivates to perform demanding tasks and to handle complex data and, in addition, is predominantly related to a positive attitude towards cognitively demanding situations (Mussel, 2013). Here, we assume that NFC also relates to conquer, due to its already-mentioned relationships with traits related to approach-behavior, persistence and goal-directedness (Fleischhauer et al., 2010). To sum up, we hypothesize that (I) the relationship of NFC and self-control is mediated via intellect and, in particular, in terms of the intellect framework, via the process conquer.

In view of the two central findings of Westbrook et al. (2013) and Kool et al. (2013), we assume that both NFC and self-control might be integrated based on the common aspect of cognitive effort investment, i.e., dispositional individual differences in the willingness and tendency to

exert effortful control. An integrative model of cognitive effort investment would enable addressing research questions, in a systematic fashion, about individual differences in effort discounting and demand avoidance to relate the common core of both traits to behavioral measures of the avoidance of cognitive effort. Establishing such a model via structural equation modeling requires, however, that one needs at least one further scale related to NFC (or more generally cognitive motivation) and to self-control (or more generally the effortful exertion of self-control). Note that we are not aiming at a comprehensive theoretically exhaustive integration of NFC and self-control, but rather at addressing the question, whether we can derive a common core construct that provides for a single measure of cognitive effort investment to relate to behavioral measures of effort discounting and demand avoidance. At the same time, this model should allow for retaining a differentiation into cognitive motivation and self-control aspects of cognitive effort investment.

To this end, we chose two additional traits. We selected intellect as one further trait related to cognitive motivation, and effortful control from the Adult Temperament Questionnaire as one further trait related to effortful self-control (ATQ; Rothbart et al., 2000). These two selected traits seemed appropriate for this purpose, for the following reasons. As discussed above, intellect has a relation to NFC. Also, if we could confirm our mediation hypothesis that NFC relates to self-control via intellect, this would strengthen the construct overlap. We selected effortful control because it refers to “[...] the ability to focus attention and shift to desired channels.” (Wiltink, 2006, p. 3). Consequently, effortful control allows individuals to act in accordance to their long-term goals even in challenging situations. Just like self-control, effortful control has a negative relation to dysfunctional and impulsive behavior, i.e., problematic buying and eating behavior (Claes et al., 2011; Mackey et al., 2019). On a cognitive level, effortful control is highly related to executive functions, especially to updating and monitoring processes in working memory (Bridgett et al., 2013). Finally, self-control and effortful control are strongly correlated and load on a common self-control factor (Grass et al., 2019). In summary, we postulate that there are two main clusters having an impact on cognitive effort investment: The first refers to dimensions associated with cognitive motivation, i.e., NFC and intellect. The second is about effortful self-control, i.e., self-control and effortful control. Here, we hypothesize (II) the just described relations between dispositional variables and (III) the integration of the shared variances of these variables in a pragmatic model of cognitive effort investment (Figure 1).

Figure 1. Hypothesized structural model of dispositional cognitive effort investment. CEI = cognitive effort investment, COM = cognitive motivation, ESC = effortful self-control, NFC = need for cognition, INT = intellect, SCS = self-control, ECO = effortful control, ζ = residuals of the first-order factors set equal, ε = error variances of the indicator variables set equal, 1 = loadings of the indicator variables fixed to 1.

Finally, we hypothesize (IV) that the construct of cognitive effort investment intercorrelates with other theoretically related traits that target goal-directed behavior. We were interested in its predictive value for these traits in a validating manner. For this reason, we additionally collected information about participants' manifestation of general self-efficacy and personality traits of the Five Factor Model of Personality due to the following considerations. We selected general self-efficacy because it belongs to the general perception of one's ability to perform new or challenging tasks including coping with daily troubles (Scholz et al., 2002). Highly self-efficacious individuals are optimistic and self-confident about task performance and outcomes, aim higher, go for more challenging tasks, invest more effort, persist longer, keep their goals and overcome setbacks faster (Luszczynska, et al., 2005; Scholz et al., 2002; Schwarzer et al., 1999). Therefore, self-efficacy seems a promising trait in the context of effort investment and we expected general self-efficacy to be positively related with cognitive effort investment in general as well as with both cognitive motivation and effortful self-control in particular. In addition, we included general dimensions of personality into our validating analysis to put cognitive effort investment in a more global context of personality. Personality traits of the Five Factor Model of Personality provide an appropriate description of higher-order traits including neuroticism, extraversion, openness, agreeableness and conscientiousness (Costa & McCrae, 1992). Moreover, these traits show substantial correlations with the traits we focused on in the present research: Conscientiousness is moderately correlated with NFC (Fleischhauer et al., 2010) and intellect (Mussel, 2013) and strongly correlated with self-control (Tangney et al., 2004) and effortful control (Wiltink, 2006). Consequently, we assumed conscientiousness to be stronger related to the first-order latent variable of effortful self-control. Openness correlates moderately with NFC (Fleischhauer et al., 2010; Furnham & Thorne, 2013) and highly with intellect (Mussel, 2013). Especially the facet openness to ideas connects closely to both concepts. According to DeYoung et al. (2005), openness and intellect represent aspects of the same fundamental construct. On this basis, the authors define Openness/Intellect "[...] as motivated cognitive flexibility, or cognitive exploration [...]" (DeYoung et al., 2005, p. 850 et seq.) being associated with general cognitive ability, and specifically with fluid intelligence. This suggests that openness is closely related to the first-order latent variable of cognitive motivation. Neuroticism is moderately related to NFC (Fleischhauer et al., 2010; Furnham &

Thorne, 2013). However, there is a strong association between emotional stability and self-control (Tangney et al., 2004), as well as dispositional negative affect and effortful control (Bridgett et al., 2013; Wiltink, 2006). In total, the evidence indicates a stronger relation to the latent first-order variable of effortful self-control. The association of extraversion with NFC is at best moderate (Furnham & Thorne, 2013), as it is with effortful control (Wiltink, 2006). Thus, we expected extraversion to be at least slightly related to the overall latent variable of cognitive effort investment. Agreeableness displays a moderate correlation with self-control (Tangney et al., 2004) and effortful control (Wiltink, 2006) indicating a small relation to the first-order latent variable of effortful self-control. We conducted two studies that addressed the above stated four main aims including replication of the findings of the first study in the second one.

2 Study 1

Materials and Methods

We report how we determined our sample size, all data exclusions (if any), all manipulations, and all measures in the study (cf. Simmons et al., 2012). The dataset and all analyzing scripts for Study 1 can be found at OSF website (Kührt et al., 2019).

Participants

In total, 613 participants (70% female, 85% university entrance diploma, 31% students; age $M \pm SD$: 29.1 ± 10.8 years) completed an online assessment. Participants optionally assigned to a lottery (possible winnings: 1 x 100 Euro, 2 x 50 Euro, 4 x 25 Euro). All participants gave informed consent in accordance with the Declaration of Helsinki upon entering the online questionnaire. The ethics board of the TU Dresden approved the study protocol, *reference number*: EK 3012016.

213 *Procedure and Materials*

214 We recruited participants via social networks, websites and advertisements at the TU Dresden
 215 and other German universities. There existed no ad hoc inclusion nor exclusion criteria. We
 216 aimed for a sample size of $N = 782$ to detect small correlations ($r = .10$, $\alpha = 0.05$, $\beta = 0.80$). At
 217 a total of $N = 923$ entries we stopped recruiting due to time constraints, but had to register $n =$
 218 310 incomplete questionnaires, leaving us with a final sample size of $N = 613$. This still allowed
 219 us to detect correlations of $r = .11$ ($\alpha = 0.05$, $\beta = 0.80$). The online personality assessment lasted
 220 approximately 25 minutes and included the following questionnaires:

221 *Sociodemography*. Multiple-choice questions assessed age, sex, education, current occupation
 222 and field of study.

223 *Need for Cognition (NFC)*. NFC was assessed with the 16-item short version of the German
 224 NFC Scale (Bless et al., 1994). Responses to each item (e.g., "I really enjoy a task that involves
 225 coming up with new solutions to problems.", Cacioppo & Petty, 1982) were recorded on a 7-
 226 point Likert scale ranging from -3 (disagree strongly) to +3 (agree strongly). The scale shows
 227 comparably high internal consistency with Cronbach's $\alpha > .80$ (Bless et al., 1994; Fleischhauer
 228 et al., 2010).

229 *Intellect Scale*. To measure intellect, we employed the Intellect Scale by Mussel (2013). It has
 230 24 items to assess individual differences in the two intellectual processes (seek and conquer)
 231 and the three intellectual operations (think, learn, and create). The combination of each process
 232 and operation gives six facets of intellect that are measured by 4 items each (e.g., "I enjoy
 233 solving complex problems" for the seek/think facet or "When I'm developing something new,
 234 I can't rest until it's completed" for the intercept of create and conquer). Items are rated on a 7-
 235 point Likert scale ranging from -3 (disagree strongly) to +3 (agree strongly). Internal
 236 consistency is high (Cronbach's $\alpha = .94$ for the total Intellect score and $\geq .86$ for the six
 237 facets, Mussel, 2013).

238 *Self-control*. self-control was measured using the short form of the German Self-Control Scale
 239 (SCS-K-D, Bertrams & Dickhäuser, 2009b) that comprises 13 items (e.g., "I am able to work
 240 effectively toward long-term goals") with a 5-point Likert scale ranging from -2 (disagree
 241 strongly) to +2 (agree strongly). The scale shows comparably high reliability (Cronbach's α
 242 $\sim .80$, 7-week retest reliability $rtt = .82$, Bertrams & Dickhäuser, 2009a).

243 *Effortful Control*. Effortful control was assessed with the respective scale of the German Adult
 244 Temperament Questionnaire (ATQ, Wiltink, 2006). It comprises 19 items on executive control
 245 in everyday life. Responses to items (e.g., "Even when I feel energized, I can usually sit still
 246 without much trouble if it's necessary") are given on a 7-point Likert scale from -3 (disagree
 247 strongly) to +3 (agree strongly). Internal consistency of the scale is acceptable (Cronbach's
 248 $\alpha = .74$, Wiltink, 2006).

249 In addition, we also used the following scales for validation purposes:

250 *Self-Efficacy*. The German version of the General Self-Efficacy Scale (Schwarzer & Jerusalem,
 251 1995) was applied to record the general sense of perceived competence to cope with manifold
 252 stressful situations. It contains 11 items (e.g., "I can usually handle whatever comes my way.")
 253 with response option on a 4-point scale ranging from 1 (not at all true) to 4 (exactly true).
 254 Internal consistency ranges from acceptable to good (Cronbach's $\alpha = .82 - .93$; Schwarzer
 255 et al., 1995).

Higher-order traits. Neuroticism, Extraversion, Openness to Experience, Agreeableness and Conscientiousness were measured using the Big Five Inventory Short Form (Rammstedt & John, 2005). This economic operationalization of the Five Factor Model of Personality consists of 21 items (e.g. “I see myself as someone who is curious about many different things” for the factor Openness) and contains a 5-point Likert scale ranging from 1 (disagree strongly) to 5 (agree strongly). Internal consistencies range from acceptable to good (Cronbach’s alpha = .64 - .86, Rammstedt & John, 2005).

Statistical Analyses

All analyses were performed using RStudio (RStudio Team, 2016) with R 3.6.1 (R Core Team, 2017) using the additional packages *pwr* for power analyses (version 1.2.2, Champely et al., 2018), *psych* (version 1.8.12, Revelle, 2018), *lavaan* (version 0.6.5, Rosseel, 2012), *semTools* (version 0.5.2, Jorgensen et al., 2019), *shape* (version 1.4.4, Soetaert, 2018), and *papaja* (version 0.1.0.9842, Aust et al., 2019). All trait variables were normalized using Blom’s formula $((r - 3/8) / (n + 1/4))$, with r being the rank of observations and n the sample size; (Blom, 1958) and standardized. The normalized variables did not deviate from univariate normality (Shapiro-Wilk tests, $p \geq .20$), except for the dimensions of the Five Factor Model of Personality and general self-efficacy (Shapiro-Wilk tests, $p \leq .05$).

First, using *psych*, we calculated correlations as Pearson correlations with p-values corrected for multiple testing using Holm’s method (Holm, 1979). Second, using *lavaan*, we tested mediation models based on the manifest variables. A model with the intellect total score as mediator was estimated first. Then, to assess whether the two intellect aspects seek and conquer show different mediator effects, a model with these two variables as mediators was estimated, with their residuals allowed to correlate. Mediation models were estimated using maximum likelihood estimation with robust (Huber-White) standard errors. Third, using *lavaan*, we performed a confirmatory factor analysis with the NFC score and the intellect total score as indicator variables of the latent variable cognitive motivation and the self-control and effortful control scores as indicator variables for the latent variable effortful self-control. From these latent variables, we derived a higher-order latent variable cognitive effort investment. As to indicator variables, loadings were fixed to one and error variances were set to equal. Residuals of first-order factors were set to equal. Loadings of cognitive effort investment were freely estimated. Note that this model specification was done during data analysis, so that strictly speaking, we ran exploratory analyses. Therefore, we replicated the analysis using the same model in Study 2. Model parameters were estimated using maximum likelihood estimation with robust (Huber-White) standard errors. Model fit was evaluated via the scaled estimates of the scaled comparative fit index (CFI), scaled root mean square error of approximation (RMSEA), and standardized root mean square residual (SRMR), with values of $CFI \geq .95$, $RMSEA \leq .06$, and $SRMR \leq .08$ indicating good model fit (Hu & Bentler, 1999). Using *semTools*, reliability of the factors was determined as McDonald’s ω . We tested this model against a non-hierarchical model with cognitive effort investment being directly estimated from the four indicators using scaled χ^2 difference tests. Fourth, using *lavaan* and *psych* we calculated correlations as Pearson correlations between the factor scores of latent variables, i.e., cognitive motivation, effortful self-control and cognitive effort investment, and general self-efficacy as well as dimensions of the Five Factor Model of Personality, i.e., neuroticism, extraversion, openness, agreeableness and conscientiousness. Correction for multiple testing was again done using Holm’s method.

Results

Correlation analysis. Table 1 shows the intercorrelations and internal consistencies of the trait variables. As expected, NFC and intellect were highly correlated, $r = .70$, $p < .001$, as were self-

control and effortful control, $r = .74$, $p < .001$, while the correlations between the former two scales and the latter measures were only moderate, $.28 < r < .37$, $p < .001$.

Table 1

Intercorrelations and internal consistencies of all variables (Study 1)

Variable	1	2	3	4	5	6
1 NFC	.87					
2 Intellect	.70	.96				
3 Seek ¹	.71	.94	.93			
4 Conquer ¹	.61	.95	.78	.93		
5 Self-Control	.28	.31	.26	.33	.83	
6 Effortful Control	.34	.37	.35	.35	.74	.83

Notes. Coefficients are Pearson correlations (all $p < .001$); values in the diagonal give the internal consistencies (Cronbach's α); ¹ correlations with seek and conquer are not part-whole-corrected, part-whole corrected correlations equal the bivariate correlation between seek and conquer.

Mediation Models. Figure 3 depicts the mediation models based on manifest variables: Trait intellect partially mediated the relationship between NFC and self-control, indirect effect = 0.15, 95% CI [0.07, 0.23], $p < .001$; direct effect = 0.14, 95% CI [0.02, 0.25], $p = .017$. When using the intellect subscales seek and conquer as separate mediators, the relationship between NFC and self-control was specifically mediated via the conquer aspect of intellect, indirect effect = 0.19, 95% CI [0.10, 0.27], $p < .001$, but not via its seek aspect, indirect effect = -0.07, 95% CI [-0.18, 0.04], $p = .232$, direct effect = 0.17, 95% CI [0.05, 0.28], $p = .004$.

Figure 2. Mediation models (Study 1). (A) Mediator effect of the intellect total score. (B) Mediator effects of the intellect aspects – seek and conquer. Unstandardized coefficients are given. Significant paths are bold-faced. Residuals are not shown for reasons of simplicity. Note that the residuals of seek and conquer are significantly correlated (*).

322

323 *Confirmatory factor analysis.* We conducted a confirmatory factor analysis for the hierarchical
 324 model (Figure 3) that showed a good fit, $\chi^2 = 8.94$, $df = 4$, $p = .063$, CFI = .99, RMSEA = .04
 325 with 90% CI [0.00, 0.08], SRMR = .02. Additionally, we estimated the parameters of a model
 326 without first-order factors, i.e., with cognitive effort investment being directly estimated from
 327 the four indicators. This model showed a poor fit, $\chi^2 = 267.43$, $df = 5$, $p < .001$, CFI = .66,
 328 RMSEA = .29 with 90% CI [0.27, 0.32], SRMR = .15. The fit was significantly worse than that
 329 of the hierarchical model, $\chi^2_{diff} = 147.91$, $df_{diff} = 1$, $p < .001$.

Figure 3. Structural model of dispositional cognitive effort investment in Study 1 (completely standardized solution). CEI = cognitive effort investment, COM = cognitive motivation, ESC = effortful self-control, NFC = need for cognition, INT = intellect, SCS = self-control, ECO = effortful control.

Validation analysis. Table 2 depicts intercorrelations of the factor scores derived from the hierarchical model with general self-efficacy and dimensions of the Five Factor Model of Personality. The cognitive effort investment factor score substantially correlated with general self-efficacy, $r = .57, p < .001$. Here, the first-order factors showed equal-sized associations with general self-efficacy, both $r = .50, p < .001$. Second-order cognitive effort investment was substantially related with conscientiousness, $r = .65, p < .001$, mainly due to a strong relation of the latter with first-order effortful self-control, $r = .68, p < .001$. To a lesser extent, it was also associated with openness, $r = .30, p < .001$, mainly due to a correlation of the latter with first-order cognitive motivation, $r = .43, p < .001$. Moreover, cognitive effort investment was negatively correlated with neuroticism, $r = -.38, p < .001$, mainly due to a higher correlation of neuroticism with first-order effortful self-control, $r = -.43, p < .001$.

346 Table 2

347 Intercorrelations and internal consistencies of factor scores, general self-efficacy and higher-order variables (Study 1)

Variable	1	2	3	4	5	6	7	8	9
1 Cognitive Effort Investment	.88								
2 Cognitive Motivation	.87***	.84							
3 Effortful Self-Control	.88***	.52***	.84						
4 General Self-Efficacy	.57***	.50***	.50***	.88					
5 Neuroticism	-.38***	-.23***	-.43***	-.53***	.82				
6 Extraversion	.11*	.19***	.01	.39***	-.27***	.84			
7 Openness	.30***	.43***	.11*	.16**	.04	.21***	.76		
8 Agreeableness	.15**	.08	.18***	.11*	-.15**	.19***	.08	.64	
9 Conscientiousness	.65***	.46***	.68***	.45***	-.20***	.16***	.16***	.16**	.71

348 Notes. Coefficients are Pearson correlations (***) $p < .001$, ** $p < .01$, * $p < .05$); values in the diagonal give reliability estimates (McDonald's ω for
 349 entries 1-3 and Cronbach's α for entries 4-9).

Discussion

The results of Study 1 support our hypotheses: First, the relation of NFC and self-control was partially mediated via trait intellect, precisely via its conquer aspect but, as hypothesized, not via its seek aspect (hypothesis I). Second, traits related to effort investment intercorrelated in the expected manner (hypothesis II), i.e., strong associations between NFC and intellect, as between self-control and effortful control, but moderate associations between the two former and the two latter scales. Third, we found the proposed structure of the core construct of cognitive effort investment (hypothesis III), i.e. traits related to effort investment could be integrated into a hierarchical factor model with the first-order factors cognitive motivation and effortful self-control and the second-order factor cognitive effort investment. Fourth, we found that cognitive effort investment substantially correlated with general self-efficacy as well as conscientiousness, openness and neuroticism of the Five Factor Model of Personality (hypothesis IV). The differentiation in first- and second-order factors also enabled us to examine in more detail which aspect of cognitive effort investment correlated more strongly with the respective broad personality traits. This indicates the validity of the model to predict other personality traits that are relevant in the context of effort investment. One limitation of Study 1 is that some specifications of the hierarchical factor model such as imposing model constraints were selected during data analysis. For a truly confirmatory factor analysis, we needed to test the final model in a separate sample, see Study 2.

3 Study 2

Study 2 was a direct replication of Study 1: We applied the same measures in an online assessment in order to validate the hierarchical factor model.

Materials and Methods

We report how we determined our sample size, all data exclusions (if any), all manipulations, and all measures in the study (cf. Simmons et al., 2012). The dataset and all analyzing scripts for Study 2 are accessible at OSF website (Kührt et al., 2019).

Participants

244 participants (72% female, 99% university entrance diploma, 86% students, 13% with job; age $M \pm SD$: 23.4 ± 4.3 years) completed the online assessment used in Study 1 on tablet in an experimental setting. Participants received 8 euro per hour plus 10 euro extra for attending a second appointment. They signed a written informed consent form in accordance with the Declaration of Helsinki. The ethics board of the TU Dresden approved the study protocol, *reference number*: EK 3012016.

Procedure and Materials

We recruited participants via university websites for online inscription to psychological research and advertisements at Dresden's universities. Inclusion criteria were an age between 18 and 38 years, speaking German fluently, right-handedness, normal or normal-corrected vision. Exclusion criteria were psychological, psychiatric or neurological dysfunctions, substance misuse, psychotropic medication, and other reasons for non-participation. We aimed at a sample size of $N = 200$ for other analyses reported separately (Strobel et al., in prep.). To detect correlations of $r = .28$ as obtained for NFC and self-control in Study 1 an $N = 97$ is appropriate ($\alpha = 0.05$, $\beta = 0.80$). The total sample size of $N = 244$ completed questionnaires is sensitive to correlations of $r = .18$ ($\alpha = 0.05$, $\beta = 0.80$). The online personality assessment was

embedded in a laboratory experiment with two appointments separated by an interval of 5 weeks. At both appointments, participants performed a cognitive task battery (20 min), two versions of a demand selection task (30 min each), responding questionnaires and the online assessment (25 min) presented on tablet. Each appointment lasted approximately 2 hours.

Statistical analyses

The statistical analyses based upon the responses of the online assessment during the first appointment only. We performed all analysis steps (correlation analysis, mediation analyses, confirmatory factor analysis, and validation analysis) as described in Study 1. The normalized variables did not deviate from univariate normality (Shapiro-Wilk tests, $p > .20$), except for the dimensions of the Five Factor Model of Personality (Shapiro-Wilk tests, $p \leq .20$).

Results

Correlation analysis. Intercorrelations and internal consistencies of trait variables are displayed in **Fehler! Verweisquelle konnte nicht gefunden werden.** As expected, NFC and intellect were highly correlated, as were self-control and effortful control, both $r = .64$, $p < .001$, while the correlation between the former two scales and the latter measures were only moderate, $.26 < r < .30$, $p < .001$.

Table 3

Intercorrelations and internal consistencies of all variables (Study 2)

Variable	1	2	3	4	5	6
1 NFC	.86					
2 Intellect	.64***	.93				
3 Seek ¹	.66***	.91***	.88			
4 Conquer ¹	.53***	.93***	.71***	.88		
5 Self-Control	.30***	.27***	.20**	.29***	.79	
6 Effortful Control	.30***	.26***	.22**	.28***	.64***	.78

Notes. Coefficients are Pearson correlations (***) $p < .001$, ** $p < .01$, * $p < .05$; values in the diagonal give reliability estimates (Cronbach's α); ¹ correlations intellect with seek and conquer are not part-whole-corrected, part-whole corrected correlations equal the bivariate correlation between seek and conquer.

Mediation Models. Figure 3 displays the mediation models based on manifest variables: In this sample, the relationship between NFC and self-control was not significantly mediated via intellect, indirect effect = 0.09, 95% CI [-0.02, 0.20], $p = .122$, direct effect = 0.21, 95% CI [0.04, 0.38], $p = .015$. However, when including seek and conquer as separate mediators in the model, the relationship between NFC and self-control was again specifically mediated via the conquer aspect of intellect, indirect effect = 0.14, 95% CI [0.06, 0.23], $p = .001$, but not via its seek aspect, indirect effect = -0.10, 95% CI [-0.23, 0.02], $p = .092$, direct effect = 0.26, 95% CI [0.09, 0.43], $p = .003$.

Figure 4. Mediation models (Study 2). (A) Mediator effect of the intellect total score. (B) Mediator effects of the intellect aspects – seek and conquer. Unstandardized coefficients are given. Significant paths are bold-faced. Residuals are not shown for reasons of simplicity. Note that the residuals of seek and conquer are significantly correlated (*).

Confirmatory factor analysis. A confirmatory factor analysis of the hierarchical model (Figure 5) yielded an excellent fit, $\chi^2 = 0.35$, $df = 4$, $p = .986$, CFI = 1, RMSEA = .00 with 90% CI [.00, .00], SRMR = .01. Additionally, we tested a one-factor-model, which yielded a poorer fit, $\chi^2 = 71.81$, $df = 5$, $p < .001$, CFI = .72, RMSEA = .23 with 90% CI [.20, .27], SRMR = .13, and that was significantly worse than that of the hierarchical model, $\chi^2_{diff} = 39.13$, $df_{diff} = 1$, $p < .001$.

Figure 5. Structural model of dispositional cognitive effort investment in Study 2 (completely standardized solution). CEI = cognitive effort investment, COM = cognitive motivation, ESC = effortful self-control, NFC = need for cognition, INT = intellect, SCS = self-control, ECO = effortful control.

Validation analysis. Intercorrelations of factor scores, general self-efficacy and traits of the Five Factor Model of Personality are shown in Table 4. The cognitive effort investment factor score significantly correlated with general self-efficacy, $r = .44$, $p < .001$. In detail, the first-order factors showed equal-sized associations with the latter, $.37 < r < .40$, $p < .001$. Second-order cognitive effort investment was strongly associated with conscientiousness, $r = .56$, $p < .001$, mainly due to a substantial relation of the latter with first-order effortful self-control, $r = .67$, $p < .001$. Cognitive effort investment was not associated with openness, $r = .09$, $p = 1$, albeit a correlation of the latter with first-order cognitive motivation existed, $r = .21$, $p = .018$. Its correlation with neuroticism was medium-sized, $r = -.30$, $p < .001$, and almost equal-sized with first-order latent variables, $-.27 < r < -.25$, $p = .001$ and $p = .002$.

449 Table 4

450 Intercorrelations and internal consistencies of factor scores, general self-efficacy and higher-order variables (Study 2)

Variable	1	2	3	4	5	6	7	8	9
1 Cognitive Effort Investment	.84								
2 Cognitive Motivation	.87***	.78							
3 Effortful Self-Control	.88***	.53***	.78						
4 General Self-Efficacy	.44***	.40***	.37***	.80					
5 Neuroticism	-.30***	-.25**	-.27**	-.49***	.76				
6 Extraversion	.06	.11	-.01	.22*	-.22**	.81			
7 Openness	.09	.21*	-.06	.11	.03	.13	.70		
8 Agreeableness	.07	.02	.11	.02	-.14	.25**	.10	.65	
9 Conscientiousness	.56***	.31***	.67***	.22*	-.04	.05	-.13	.08	.69

451 Notes. Coefficients are Pearson correlations (***) $p < .001$, ** $p < .01$, * $p < .05$); values in the diagonal give reliability estimates (McDonald's ω for
 452 entries 1-3 and Cronbach's α for entries 4-9).

Discussion

The findings of Study 2 mainly support our hypotheses and replicate the results of Study 1: First, although in this sample trait intellect did not mediate the relation of NFC and self-control, we again found that the conquer aspect did and the seek aspect did not mediate this relation (hypothesis I). Second, traits related to effort investment intercorrelated in line with our hypothesis II, albeit lower in size compared to correlations found in Study 1. Thus, the hypothesized mediating effect by conquer was present indicating that NFC and self-control share an aspect that can be conceptualized as goal-directedness. Third, we replicated the structure of the hierarchical factor model of cognitive effort investment (hypothesis III). Fourth, effort-related traits correlated with relevant latent variables of the model (hypothesis IV); however, as compared to Study 1, the obtained correlations were smaller. The main reason for differences in the results compared to Study 1 might be due to the homogeneous sample.

4 General discussion

The main aim of the present two studies was to establish a reliable and pragmatic model of cognitive effort investment for further studies, based on the view of cognitive effort investment as self-reported dispositional differences in the willingness and tendency to exert effortful control. To this end, we intended (I) to demonstrate a mediating role of intellect and particularly conquer in the relationship of NFC and self-control, (II) to investigate the hypothesized relations among relevant traits related to effort investment, i.e., NFC, intellect, self-control and effortful control, (III) to establish a core construct of cognitive effort investment that incorporates these traits in an hierarchical manner, and (IV) to validate the model with relevant traits, i.e., general self-efficacy and personality traits of the Five Factor Model of Personality. Finally, we aimed at replicating our findings in an independent second sample.

First, given the moderate correlation of NFC and self-control and their impact on effort investment (Kool et al., 2013; Westbrook et al., 2013), we assumed that their relationship is because both traits capture goal-directedness. To provide evidence supporting this assumption, we referred to a third trait variable, intellect, that comprises the processes seek (targeting the approach of mentally challenging situations) and conquer (representing the accomplishment of goals). We tested whether intellect and specifically, its conquer process, plays a mediating role in the relationship between NFC and self-control. We found that intellect partially mediates the relationship between NFC and self-control in Study 1, but not in Study 2. The non-significant effect might be due to the smaller and more homogeneous sample of Study 2. In both studies, however, we found that at the process level, conquer mediated the relationship between NFC and self-control. These results suggest that, as hypothesized (hypothesis I), goal-directedness that defines conquer is the aspect that both NFC and self-control have in common. This commonality might be relevant in the context of effort discounting. These findings give new insight into the conceptual scope of NFC. In contrast to the assumptions of the intellect framework (Mussel, 2013), we interpret our findings such that NFC is not restricted to the seek aspect of intellect. Instead, it also overlaps with the process of conquer. This finding should be considered in the conceptualization of the intellect framework in order to secure the validity of the intellect scale.

Second, we analyzed the relation of all effort-related variables. In both studies, we obtained high correlations between NFC and intellect as well as between self-control and effortful control. Associations between the former and the latter two variables were only moderate. These associations are in line with previous findings: Bertrams and Dickhäuser (2009a) found NFC and self-control moderately related with each other. Moreover, Mussel (2013) observed the same strong relationship between NFC and intellect. Taken together, intercorrelations

revealed the hypothesized (hypothesis II) and robust associations between effort-related traits pointing to a core construct of cognitive effort investment.

Third, the confirmatory factor analyses verified the hypothetical structure of cognitive effort investment (hypothesis III) via comparison against a poorer fitting non-hierarchical one-factor model and replication in a second sample. Based on the findings that self-control and NFC play a crucial role in demand avoidance and effort discounting (Kool et al., 2013; Westbrook et al., 2013), but have been regarded as quite distinct constructs (Bertrams & Dickhäuser, 2009a), we were able to integrate NFC and self-control into a pragmatic and replicable hierarchical factor model of cognitive effort investment. As the model still allows for the discrimination between cognitive motivation and effortful self-control, it enables researchers to assess both common and distinct aspects of cognitive effort investment in a parsimonious fashion.

Fourth, we examined the predictive value of our model of cognitive effort investment by relating it to other relevant constructs that target goal-directed behavior. In both studies, first- and second-order factors of our model were substantially related to relevant variables (hypothesis IV). In detail, first- and second-order factors revealed substantial correlations with general self-efficacy. These findings are in line with our hypothesis proving the broad character of general self-efficacy being beneficial in highly demanding situations in a motivational, self-controlling as well as goal-directed manner as implicated by previous studies (Luszczynska et al., 2005; Scholz et al., 2002; Schwarzer et al., 1999). As to traits of the Five Factor Model of Personality, cognitive effort investment was substantially related to conscientiousness, openness (Study 1 only) and neuroticism. In addition, the model provided differentiated information about the association of these traits with first-order factors: as expected, cognitive motivation was more strongly related to openness, whereas effortful self-control revealed stronger relations to conscientiousness and neuroticism. However, correlations of openness were smaller than expected, and in Study 2 even only significant for cognitive motivation. Reported correlations of openness with NFC and intellect (Fleischhauer et al., 2010; Furnham & Thorne, 2013; Marcionetti & Rossier, 2016; Mussel, 2013) contrast with the comparably low correlations in our studies. Recent research of DeYoung et al. (2007) on Big Five traits suggest the coexistence of two different aspects within each dimension of the Five Factor Model of Personality. This finding based on factor analyses of domain's facets and is backed up by an essential and reasonable distinction in content. Hence, openness incorporates both openness and intellect as particular aspects. Considering this and the selection of items of the applied short-form of the Big Five Inventory, there seems to be a bias towards the aspect of openness as only one of five items target intellect. In contrast, comprehensive questionnaires assessing domains and facets like NEO-PI-R and NEO-FFI (Costa & McCrae, 1992) as applied in the discussed studies cope with both aspects. We conclude that we were not able to obtain strong intercorrelations of latent variables with openness, as we did not assess the scope of this dimension. Furthermore, neither extraversion nor agreeableness were consistently associated with latent variables of our model of cognitive effort investment. This might not be surprising when considering the comparably low correlations, i.e. zero to almost moderate, with manifest variables previously reported by other researchers (Fleischhauer et al., 2010; Furnham & Thorne, 2013; Mussel, 2013; Tangney et al., 2004; Wiltink, 2006). In summary, our model of cognitive effort investment allows for testing global as well as specific hypotheses in the context of effort investment.

Limitations

Among the limitations of our study, sample composition may be the most crucial. In Study 1 we aimed at examining personality traits of the general population including a wide age span

and different educational backgrounds. That is why we used different recruitment approaches like social networks, online websites and advertisements. Nevertheless, the finally obtained sample is biased regarding age, sex, education. The same holds for Study 2, where we recruited at our university. Thus, the results presented here should be replicated in the general population. In addition, the results of both studies are based on self-reported data and thus are subject to social desirability bias. Future studies should therefore strive to obtain peer-report data as well. Furthermore, the selection of traits was based on pragmatic considerations. There may be additional relevant and informative variables that we did not include. For example, sensation seeking, daydreaming, cognitive processing capacity, willpower, or mindfulness meditation are supposed to affect the cost-benefit analysis on an individual basis (Kurzban et al., 2013b). In addition, a study of Malesza and Ostaszewski (2013) revealed a negative correlation of effort discounting with harm avoidance and reward dependence, respectively, and a positive one with persistence. Nevertheless, the model presented here can be viewed as a starting point for the construction of a more comprehensive model of cognitive effort investment.

Significance

Our work extends our current knowledge on traits related to effort investment and, thus, contributes to better understanding the role of individual differences in high demanding situations that require goal orientation. Consequently, this new knowledge might improve predictions of individual control adjustments across a variety of tasks. As to the theoretical significance, the examined traits allow to discriminate individuals regarding their motivation to invest effort in specific tasks and, thus, their goal-directed behavior. Consequently, decision-making does not fully rely on cost-benefit analyses but is significantly influenced by individual factors. Although there are effort-discounting models and theories, these typically do not account for individual differences (Kurzban et al., 2013a; Shenhav et al., 2013), or only for particular ones, like cognitive skills (Botvinick & Braver, 2015). Instead of treating interindividual variability as noise, we consider it useful to integrate dispositional individual differences in effort investment in present and to-be-developed motivational models to further improve our understanding about the underlying mechanisms of goal-directed behavior.

Conclusion and further research

With the present work, we provide an integrative model of cognitive effort investment that at the same time differentiates between cognitive motivation and effortful self-control. This model can be used for more systematic inquiries into the role of dispositional cognitive effort investment in the modulation of effort-avoidant behaviors. Given that replication reports of the seminal findings by Westbrook et al. (2013) and Kool et al. (2013) are currently not detectable in the literature, the present model might be beneficial. We consider establishing the relationship between dispositional differences in cognitive effort investment and actual effort recruitment as well as the expenditure using objective effort indicators as an important endeavor. Under the condition that such relationships will be replicated, they would open an exciting avenue for further research: the integration of traits related to cognitive effort investment into cost-benefit-models like the opportunity-cost model (Kurzban et al., 2013a), the expected value of control model (Shenhav et al., 2013) or other recent computational accounts like the active inference framework (Friston et al., 2017) in order to predict individual goal-directed behavior.

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Conflict of Interest Statement

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Contribution to the Field Statement

Individuals tend to avoid physical as well as cognitive effort. This phenomenon is commonly referred to as effort discounting. However, some people diverge from this pattern, which can be explained by dispositional individual differences. In this context, the personality traits need for cognition (NFC) and self-control were found to be related to behavioral measures of effort discounting and demand avoidance, respectively. As both traits are only moderately related, we assumed that they share a common core. The questions we addressed were: (I) what have NFC and self-control in common?, (II-III) can both traits be integrated into one general measure of cognitive effort investment?, (IV) is this general measure associated with other effort-related traits? To address these questions we conducted two independent studies with the following outcomes: the relationship of NFC and self-control is specifically mediated via an aspect that can be conceptualized as goal-directedness; a hierarchical factor model of cognitive effort investment (second-order factor) allows the differentiation into cognitive motivation and effortful self-control (first-order factors). Taken together, our findings integrate currently only loosely related research strands on cognitive motivation and self-control and provide a basis for further experimental research on the role of dispositional individual differences in goal-directed behavior.

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