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Extraversion, working style, reasoning, and complex problem solving: A study on the mechanisms underlying the link between extraversion and cognitive ability

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Abstract

We explored the behavioral mechanisms underlying the link between extraversion and cognitive ability. We focused on reasoning and complex problem solving as cognitive abilities, and response latencies and action orientation during test taking as behavioral mechanisms indicating working style. Results obtained in a sample of 326 adults generally indicated that specific working styles such as slower response latencies and higher action orientation mediated the link between extraversion and complex problem solving but not reasoning. We discuss the results in light of Eysenck's cortical arousal theory as well as more recent findings and suggest directions for future research.

Keywords: extraversion, reasoning, complex problem solving, working style, mediation

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The relation between personality and cognitive ability continues to be of key interest to researchers in the field of individual differences (Ackermann, 2018). With the advent of computer-based assessments of cognitive ability, indicators of working style have become available for researching the specific mechanisms underlying this relation. For instance, researchers can now study the link between specific test-taking behaviors (e.g., response latencies) by investigating how these overt behaviors are explained through personality traits (e.g., extraversion) and how they result in lower or higher performance on tests of cognitive ability (e.g., reasoning). We focused on the link between extraversion and cognitive ability and the behavioral mechanisms underlying this link by building upon and extending the extant literature in two ways. First, we endorse a broad definition of cognitive ability that includes reasoning as an indicator of fluid intelligence and additionally includes complex problem solving (CPS), an ability that strongly relies on complex cognitive processes beyond reasoning. Second, we investigated several test-taking behaviors (i.e., response latencies and action orientation conceptualized as the ratio of the number of participants' active interventions during the test-taking phase and the time used for this phase) and their mediation of the relation between extraversion and cognitive ability, whereas previous research has focused often on response latencies only.

The literature on the nexus of relations between personality and cognitive ability is extensive with the bulk of studies focusing on extraversion as a predictor of cognitive ability (Zeidner & Matthews, 2000). The meta-analysis by Wolf and Ackerman (2005) reported an average correlation of $\rho = .06$ between extraversion and indicators of intelligence. Previously, Ackerman and Heggestad's (1997) meta-analysis had found a slightly higher average correlation ranging from $\rho = .05$ to .14 depending on which facet of intelligence was investigated. Importantly, both meta-analyses indicate that extraverts perform slightly better on intelligence tests than introverts.

The theoretical implications of this positive albeit small relation are the subject of ongoing scientific inquiry. Eysenck (1994) explains that extraversion and cognitive ability are not theoretically related, but extraversion might be related to certain test-taking behaviors (Wolf & Ackerman, 2005). For instance, Rawlings and Carnie (1989) argue that extraverts, given their lower baseline cortical arousal (Eysenck, 1994), work better under pressure. The arousing environment created by the timed nature of many cognitive ability tests works to the advantage of extraverts, whereas introverts are rather disadvantaged by the perceived over-arousal of the testing situation. Interestingly, Doerfler and Hornke (2010) reported results in the opposite direction. They found that extraverts performed slightly worse than introverts on a reasoning test such that extraverts responded more quickly but with a lower level of accuracy, leading to lower reasoning scores. According to Doerfler and Hornke, this pattern might be explained by Eysenck's (1994) arousal theory as well: Extraverts might perceive the testing situation as not sufficiently arousing. To compensate, they tend to work more quickly and less accurately but in a more action-oriented way (the latter was not tested by Doerfler and Hornke). Wolf and Ackerman (2005) concluded that the extant literature on the empirical mechanisms and theoretical explanations of the link between extraversion and cognitive ability exhibits substantial diversity and is currently inconclusive.

Irrespective of the theoretical underpinnings, the mechanisms assumed to be responsible for the link between extraversion and cognitive ability are usually sought within different working styles and concrete test-taking behaviors (e.g., Doerfler & Hornke, 2010; Rawlings & Carnie, 1989). That is, it is not assumed that extraverts or introverts are less or more intelligent but that specific working styles such as responding quickly or working well under pressure are associated with test performance (for a detailed definition as well as an objective measure of working styles, see for e.g., Kubinger & Ebenhöh, 1996). Indeed, a number of studies have emphasized the seminal importance of working style for performance on cognitive ability tests. For instance, allocating sufficient cognitive resources indicated by higher (i.e., slower) response latencies is a strong predictor of overall reasoning (Klein Entink, Fox, & van der Linden, 2009) and problem-solving performance (Goldhammer et al., 2014). With regard to action orientation, for example, Wittmann and Hattrup (2004) showed that lower risk aversiveness, which in turn was related to higher action orientation, created more learning opportunities and, thus, led to a higher likelihood of obtaining a correct solution in problem-solving tasks. To this end, the focus on working style emphasizes the process rather than the structure of individual differences. Here, extraversion was hypothesized to primarily influence working style, which, in turn, should have a secondary influence on overall performance.

This study

An in-depth understanding of the relation between extraversion and cognitive ability requires an understanding of the underlying mechanisms. Overt behaviors as indicators of working style might be key for further establishing the link between extraversion and performance on tests of cognitive ability (e.g., reasoning and CPS). That is, extraversion influences specific behaviors, among them test-taking behavior, which, in turn, influences test performance. Conceptually, this paper extends previous research in two ways. First, in addition to a reasoning test, we administered a test of CPS to generalize across several measures of cognitive ability. CPS denotes the ability to successfully deal with new, dynamically changing, and intransparent problem situations (Greiff et al., 2013; Greiff et al., 2014). It involves aspects of complex cognition and is usually decomposed into two dimensions: knowledge acquisition and knowledge application (Novick & Bassok, 2005). As a broad and general cognitive ability, CPS is related to and yet distinct from reasoning and other measures of intelligence (Stadler, Becker, Gödker, Leutner, & Greiff, 2015). It is an important predictor of external criteria such as academic achievement (Greiff et al., 2013) or supervisory ratings (Danner, Hagemann, Schankin, Hager, & Funke, 2011). Second, in addition to response latencies, we inspected a measure of action orientation as a second indicator of working style (for the CPS test only). Both response latencies as an indicator of careful and diligent test-taking behavior and action orientation as an indicator of swift and goal-oriented decision making bear the potential to bridge the gap between merely observing and actually understanding the link between extraversion and cognitive ability. We investigated four hypotheses.

Hypothesis 1: Extraversion positively predicts reasoning and CPS.
In line with Wolf and Ackerman's (2005) meta-analysis, we expected extraverts to score slightly higher on both tests of cognitive ability.

Hypothesis 2: Extraversion positively predicts (slower) response latencies and action orientation.
Empirical evidence on the relation between extraversion and response latencies is mixed (see above), but as higher response latencies are usually associated with better performance (Goldhammer et al., 2014), and as we expected extraverts to show better overall performance (see Hypothesis 1; Ackerman & Heggestad, 1997; Wolf & Ackerman, 2005), we expected a weak but positive relation between extraversion and response latencies, although we acknowledge that this hypothesis is somewhat exploratory. In addition, according to the definition of extraversion (Wilt & Revelle, 2017), extraverts should show more action oriented and decisive test-taking behavior.

Hypothesis 3: Response latencies and action orientation positively predict cognitive ability.
Reasoning and CPS are both abilities that involve controlled and nonroutine cognitive processing (see above). Previous research on these abilities has consistently shown that there is a positive relation between response latencies, representing sufficiently allocated cognitive resources, and overall performance (e.g., Goldhammer et al., 2014). Also, a higher action orientation on the CPS test should create more learning opportunities in the problem situation, which, in turn, should be reflected by a better overall performance (Wittmann & Hattrup, 2004).

Hypothesis 4: The positive relation between extraversion and cognitive ability is mediated by working style (i.e., response latencies, action orientation).
Hypothesis 4 poses a comprehensive test of Eysenck's (1994) assumption that extraversion is not associated with cognitive ability per se but with specific test-taking behaviors, which in turn affect the performance on measures of cognitive ability.

Method

Participants and procedure

We tested a convenience sample of 326 German participants (251 male, 66 female, 9 missing sex; $M_{age} = 31.00$, $SD_{age} = 12.22$) who were either undergoing vocational training or working a regular job. Participation was voluntary and took place at work. Participants first completed the CPS and reasoning tasks and then completed a questionnaire that included the extraversion assessment among other measures. All assessments were administered by computer. Due to technical problems with the computer-based assessment and by design (e.g., not all participants were scheduled to take the reasoning test), sample sizes used in the analyses varied from 166 to 320 including missing data patterns. Please note, that there are other publications based on partially overlapping data investigating different research questions.

Materials

Extraversion. We used the two-item extraversion subscale of the German ten-item version of the Big Five Inventory (BFI-10; Rammstedt & John, 2007). Convergent and divergent validity of the BFI-10 have been studied extensively (Rammstedt, 2007; Rammstedt & John, 2007). The items ask participants to rate on a five-point Likert-scale whether they see themselves "as someone who is reserved" (i.e., reversed scored item) or "outgoing, sociable".

Cognitive ability: Reasoning and CPS. The time-limited short version of Raven's Standard Progressive Matrices (SPM; Horn, 2009) was employed to assess reasoning. The SPM is a multiple-choice reasoning test targeting processes of inductive thinking. The 32 items consist of figural patterns that have to be completed according to one or more underlying rules that need to be deduced by the test takers. Answers are chosen from six alternatives, and the overall time limit was 15 min with no separate time limit for each item as recommended in the manual. Each item was scored dichotomously as 1 (correct) or 0 (incorrect).

The fully computer-based MicroDYN approach (Greiff et al., 2013; Greiff, Fischer, Stadler, & Wüstenberg, 2015)) was used to assess CPS. In MicroDYN, participants are faced with complex, dynamic, and intransparent problem situations. Participants have to discover the causal links between a set of input variables and a set of output variables by actively intervening in the system. Apart from changes due to participants' interventions, the output variables might change by themselves. In Phase 1, knowledge acquisition, participants freely explore the problem environment and represent the knowledge they gather on the causal links in a concept map (max 180s). In Phase 2, knowledge application, participants have to plan and carry out a sequence of interventions to reach given target values in the output variables using no more than four steps (max 90s). The two dimensions of knowledge acquisition and knowledge application are usually collapsed into a general CPS factor. A number of studies have established the reliability and validity of the MicroDYN approach (e.g., Greiff et al., 2013; Wüstenberg, Greiff, & Funke, 2012). Each of the seven MicroDYN tasks used in this study yielded a score on knowledge acquisition and knowledge application scored as 1 (correct) or 0 (incorrect).

Working style: Response latencies and action orientation. For reasoning, we extracted response latencies separately for each item as time (in s) from the onset of the item until the onset of the next item. For CPS, response latencies were extracted as time (in s) from the onset of the item until the end of the knowledge acquisition phase. Response latencies in the knowledge application phase were not used because they showed comparably little variation due to the limit of four intervention steps and a maximum of 90s for the knowledge application phase (see MicroDYN description). For CPS, we also calculated the ratio of the number of active interventions during exploration in the knowledge acquisition phase and the time used for this phase, yielding an intervention-per-time ratio (in amount/s) as an indicator of action orientation.

Statistical analyses

We explored the relations between extraversion, working style, and cognitive ability through path analyses and confirmatory factor analyses within the framework of structural equation modeling. To evaluate Hypotheses 1-4, we relied on standardized path solutions and standard goodness-of-fit indices. All analyses were conducted in Mplus 7.0 using full information maximum likelihood estimation to account for missing values (Enders & Bandalos, 2001). To establish the statistical significance of results, type-I-error was set to .05.

Results

Reasoning and CPS were modeled as latent variables. Manifest indicators were assigned to parcels using the item-to-construct balance method introduced by Little, Cunningham, Shahar, and Widaman (2002) to ensure that the number of estimated parameters remained reasonable. Thus, the 32 reasoning items were assigned to three parcels, which then were assigned to a latent reasoning factor. For CPS, separate factors for knowledge acquisition and knowledge application were defined, which were then combined under a general CPS factor. Each of the two CPS factors was comprised of three parcels. Extraversion was modeled as one latent factor with both items loading on it equally strong. All behavioral variables (i.e., response latencies and action orientation) were modeled on a manifest level.

Table 1 displays descriptive statistics and correlations for all variables. Correlations between extraversion and cognitive ability were generally small, but several of them were in the expected direction and statistically significant. Fit indicators for all models used to test Hypotheses 1-4 are provided in Table 2.

Hypothesis 1: Extraversion and cognitive ability

We tested a model (Model 1) in which extraversion predicted cognitive ability. As expected, extraversion was positively related to reasoning ($\beta = .19$, $p = .042$; $R^2 = .038$) and to the overall CPS factor combining knowledge acquisition and knowledge application ($\beta = .19$, $p = .024$; $R^2 = .036$), supporting Hypothesis 1, which predicted that extraversion would be positively related to cognitive ability.

Hypothesis 2: Extraversion and working style

For Hypothesis 2, we first specified a model in which extraversion predicted response latencies in reasoning (Model 2a) and then a model in which extraversion predicted response latencies and action orientation in CPS (Model 2b).[4] Extraversion did not pre-

[4] Please note that a model that included working style measures for both cognitive abilities simultaneously did not converge. Thus, we conducted analyses separately for reasoning and CPS. As these two models included manifest variables only, they had zero *df*, and no goodness-of-fit statistics could be computed.

Table 1

Construct	*N*	*M*	*SD*	*Scale*	1	2	3	4	5	6	7
1. Reasoning	166	27.88	3.58	0 to 32	–	.54	.48	.26	.09	.07*	.30*
2. CPS (Knowledge Acquisition)	226	3.67	2.33	0 to 7		–	.85	.03	.28	.28	.21
3. CPS (Knowledge Application)	226	4.11	2.06	0 to 7			–	.03	.25	.25	.19
4. Response latencies (in sec; reasoning)	166	20.03	5.23	0 to 900				–	.04	.03	.14
5. Response latencies (in sec; CPS)	226	109.94	41.44	0 to 180					–	.07	.30
6. Action Orientation (in amount/sec; CPS)	226	.16	0.11	0 to 1						–	.22
7. Extraversion	320	2.46	1.80	0 to 5							–

Note. M = mean; SD = standard deviation; CPS = Complex Problem Solving. In the correlation table, reasoning and CPS are modeled latent, all other variables are modeled manifest (see text). There was one time limit for the overall test for the reasoning scale (max 900s), whereas each CPS task was timed separately (max 180s). One intervention per second was defined as the maximum for action orientation. * $p < .05$. . p-values are 1-sided.

Table 2

Model	χ^2	df	*p*	RMSEA	CFI	TLI
1	96.16	41	<.001	.065	.949	.931
2a	0.064	1	.800	.000	1.00	1.00
2b	8.185	2	.017	.098	.919	.757
3	100.61	48	<.001	.086	.935	.915

Note: df = degrees of freedom, RMSEA = root mean square error of approximation, CFI = comparative fit index, TLI = Tucker-Lewis index

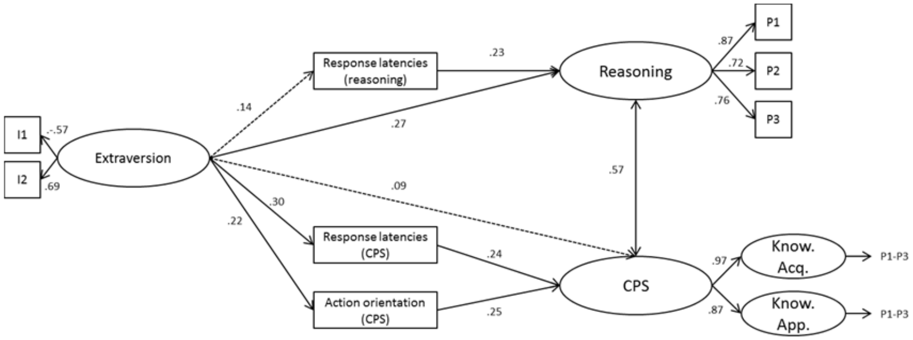
dict response latencies in reasoning ($\beta = .09$, $p = .213$; $R^2 = .006$) but did predict response latencies in CPS ($\beta = .24$, $p = .002$; $R^2 = .055$) and action orientation in CPS ($\beta = .19$, $p = .012$; $R^2 = .035$). Thus, Hypotheses 2 was supported only with regard to the CPS working style indicators.

Hypothesis 3: Working style and cognitive ability

Working style predicted overall test performance in both cognitive abilities (Model 3). Reasoning performance was predicted by response latencies in reasoning ($\beta = .31$, $p < .001$; $R^2 = .097$), and CPS performance was predicted by response latencies in CPS ($\beta = .40$, $p < .001$) and by action orientation in CPS ($\beta = .14$, $p = .044$), supporting Hypothesis 3. The full model explained 20% of the variance in CPS.

Hypothesis 4: Mediation with extraversion, working style, and cognitive ability

In the final model (Model 4), we tested whether the relation between extraversion and cognitive ability was mediated by working style. Figure 1 depicts this model. Extraversion showed a significant direct effect on reasoning ($\beta = .27$; $p = .005$) but no significant indirect effect for the mediation by response latencies ($\beta = .03$; $p = .085$). The model explained 14% of the variance in reasoning. Contrary to this result, the relation between extraversion and CPS was fully mediated by working style. Specifically, both the indirect effect via response latencies ($\beta = .07$; $p = .006$) and the indirect effect via action orientation ($\beta = .06$; $p = .015$) were statistically significant. In the model depicted in Figure 1, the indirect paths to CPS via working style led the direct path from extraversion to CPS to drop to nonsignificance ($\beta = .09$; $p = .160$), indicating full mediation. The model explained 16% of the variance in CPS. Hypothesis 4 was, therefore, partly supported.



I = Item; CPS = Complex problem solving; P = Parcel; Know Acq = Knowledge acquisition; Know App = Knowledge application. Dashed lines indicate nonsignificant paths ($p > .05$). Path coefficients are standardized.

Figure 1:
The final model (Model 4) with extraversion as the predictor, cognitive ability as the criterion, and working style as the mediator.

Discussion

This study was designed to explore the behavioral mechanisms linking extraversion and cognitive ability. We observed weak but significant relations that were similar to previous results. The results on working style as a mediator were mixed: For CPS, the mediation effect of response latencies and action orientation was substantial, whereas there was no clear mediation for reasoning. Concerning the latter, we acknowledge that statistical power might be an issue. Meta-analytic research has revealed only small effects of extraversion on intelligence (Wolf & Ackerman, 2005) suggesting that larger sample sizes may be required to detect mediation effects of extraversion on reasoning.

Apart from considerations on statistical power, potential reasons for the differences in obtained effect sizes could also be found in the different test administrations: On the CPS test, each item had a time limit, whereas the reasoning test had only an overall time limit. The former might be a more valid reflection of working style as it prevents extreme response latencies. Another explanation for the diverging pattern of results is that different tests and different test-taking situations trigger different behaviors in extraverts and introverts. This explanation is in line with Eysenck's (1994) cortical arousal theory of extraversion. Arguably, the complex and interactive CPS test puts extraverts at a pleasant level of cortical arousal, whereas introverts might suffer from over-arousal due to the demanding test situation. This is then reflected by extraverts spending more time on-task (i.e., higher response latencies) and showing a higher ratio of interventions (i.e., higher action orientation). The reasoning test, on the other hand, provides less external arousal and, therefore, the mediation effect is less pronounced. Obviously, this interpretation is post hoc, and the link to the cortical arousal theory must remain speculative. Remarkably, Doerfler and Hornke (2010) claimed that extraverts suffer from low cortical arousal during reasoning tests, which could be brought in line with our finding that the mediation effect is stronger for CPS than for reasoning performance. However, in contradiction to Doerfler and Hornke who found that extraverts are characterized by lower reasoning test performance, our results provide some evidence that extraversion is positively related to cognitive ability. In particular, our findings support the notion that extraversion is related to specific test-taking behavior (Eysenck, 1994) and that this behavior mediates the relation between extraversion and overall performance. In their metaanalysis on the relation between cognitive ability and personality, Wolf & Ackerman (2005) found a positive average correlation, however, the estimated effect size between extraversion and intelligence for studies conducted in the year 2000 and later was negative, indicating that not only had the magnitude of the correlation decreased, but also that the direction of the correlation had changed from positive to slightly negative. The authors argue that the use of different measures most likely lead to this seemingly confusing pattern of results. In line with this argument, Rammstedt, Lechner, and Danner (2018) found substantial differences in the relation between personality and cognitive ability depending on the facets of personality measured. For extraversion, they found the facet of sociability to be related most strongly (and negatively) to cognitive ability, whereas assertiveness was related less strongly but positively. A more comprehensive measure of extraversion that includes several of its facets may therefore be needed to fully understand the results presented in this paper.

Regarding the general implications of our findings, Doerfler and Hornke (2010), who also found a mediating effect of working style for the relation between extraversion and cognitive ability, argue for separate norms for extraverts and introverts. We respectfully disagree with this position and think that such a step would be premature. In fact, if differences in test-taking behavior and working style between extraverts and introverts are indicative of actual behavioral differences outside the testing situation, these differences in test-taking behavior have high diagnostic relevance for real-world selection decisions. Given the potential of overt test-taking behavior for illuminating the underlying mechanisms and providing a direct link between extraversion and cognitive ability, we hope this field of research will receive further attention in the near future.

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