How important is cognitive ability when adapting to changes?

A meta-analysis of the performance adaptation literature

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How important is cognitive ability when adapting to changes? A meta-analysis of the performance adaptation literature

The present meta-analysis was aimed at examining the role of individual differences in cognitive abilities in the context of performance adaptation (i.e. dealing with emergencies in the work or educational context). Another aim was to establish under which circumstances cognitive ability can predict performance adaptation particularly well. A three-level meta-analysis based on 133 correlations ($N = 37,963$) was conducted in order to estimate the mean strength of the relationship. Furthermore, several moderator analyses were carried out (e.g. task complexity, subjective vs objective assessment of performance adaptation) to explain the variability of the effect sizes. As expected, cognitive ability was positively related to performance adaptation ($r = .21$). However, the relationship was stronger when objective performance adaptation scores ($r = .25$) rather than subjective ratings were used ($r = .11$). Furthermore, cognitive ability seems to be particularly relevant for highly dynamic tasks ($r = .31$). Overall, cognitive ability can be a useful predictor of actual performance adaptation, which has implications for the selection context (e.g. selection of students or employees with high adaptability). Furthermore, cognitive ability seems to be more relevant than other personality-based predictors of performance adaptation that have been examined meta-analytically (Big Five and goal orientation).

Keywords: adaptive performance; adaptability; cognitive ability; performance adaptation; meta-analysis

Introduction

We are often exposed to educational and organizational challenges that require adaptive responses. Emergency landing, studying abroad, or using new software, all require behavioral adjustments. In such instances successful performance adaptation could save lives, increase the probability for having good grades, and benefit other entities (e.g. team, organization) by maintaining efficiency. Thus, it is not surprising that researchers have tried to establish predictors of performance adaptation. However, neither the Big Five personality traits (Huang, Ryan, Zabel, & Palmer, 2014; Woo, Chernyshenko, Stark, & Conz, 2014) nor the motivational aspects like goal orientation (Stasielowicz, 2019b) are strongly related to performance adaptation. It is not necessarily surprising, considering that performance is usually determined not solely by personality traits and motivation (van Yperen, Blaga, & Postmes, 2015) but also individual differences in abilities. In order to elucidate the role of abilities the evidence for the relationship between cognitive abilities and performance adaptation is synthesized in the present article.

In general, intelligence is considered one of the best predictors of job performance. This is evidenced by the magnitude of the meta-analytic correlations (Judge, Jackson, Shaw, Scott, & Rich, 2007; Lang, Kersting, Hülshager, & Lang, 2010; Schmidt & Hunter, 2004, 1998). However, job performance should not be equated with all kinds of performance. Accordingly, researchers distinguish between several performance constructs, i.e. personal initiative (Frese & Fay, 2001), organizational citizenship behavior (Organ, 1997), or counterproductive work behavior (Bennett & Robinson, 2000). Meta-analytic results indicate that not every type of performance can be predicted equally well by cognitive abilities. Specifically, for the relationship with organizational citizenship behavior (OCB), personal initiative, and complex problem solving small to medium effect sizes were found, and cognitive abilities seem to be unrelated to counterproductive work behavior (Gonzalez-Mulé,

Mount, & Oh, 2014; Stadler, Becker, Gödker, Leutner, & Greiff, 2015; Tornau & Frese, 2013).

The focus of the present article lies on another performance facet that has been examined thoroughly in the recent years - adaptive performance. Many daily activities involve facing unpredictability rather than relying on routines (Baard, Rench, & Kozlowski, 2014; Bohle Carbonell, Stalmeijer, Könings, Segers, & van Merriënboer, 2014). Most dramatic consequences of inadequate adaptation (i.e. loss of lives) are restricted to very specific situations, e.g. emergency landing, surgical emergency, or firefighting. Nevertheless, increasing adaptive performance in less dangerous situations is worth pursuing too. In the educational and organizational context adapting to changes successfully is important because it also affects general performance. Failure to adapt precludes from maintaining good overall performance level. It could not only have consequences for the specific person (i.e. bad grades, no promotion) but also for higher order entities (e.g. team, organization). To illustrate, an employee focusing on customers' needs and values while the company is restructuring could enhance organizational effectiveness (Dorsey, Cortina, & Luchman, 2010). Furthermore, adaptive performance of individuals could be beneficial to the financial performance of the organization (Bhattacharya, Gibson, & Doty, 2005). Considering the mentioned consequences, it is not surprising that researchers have acknowledged the increasing need for establishing predictors of adaptive performance that could be used in the selection context (Ryan & Ployhart, 2014). The current meta-analysis answers this call by systematically examining the role of cognitive ability, which has been described across several narrative reviews as a relevant predictor of performance adaptation (Baard et al., 2014; Bohle Carbonell et al., 2014; Jundt, Shoss, & Huang, 2015). The results of this quantitative synthesis will inform practitioners whether a measure of cognitive ability should be used in the selection context when looking for adaptable students or employees. The magnitude of the meta-analytic effect size will also have implications for the development of

potential trainings or interventions aimed at increasing performance adaptation. Specifically, it will reveal whether relatively low cognitive ability could be potentially compensated by aspects of personality that are more malleable and that could be honed through trainings, i.e. coping strategies, interpersonal skills, and values.

As mentioned in the preceding paragraphs several performance facets can be predicted well by cognitive abilities. However, it does not hold true for all kinds of performance, i.e. counterproductive work behaviour. Thus, one cannot automatically assume that intelligence promotes performance adaptation. Some researchers even argue that high cognitive abilities can have a detrimental effect on the performance (see Beier & Oswald, 2012 for a critique of this assertion). However, the available empirical findings seem to corroborate the assertion that high cognitive abilities are beneficial to performance adaptation. Nevertheless, the strength of the relationship varies a lot across studies (e.g. Allworth & Hesketh, 1999; LePine, Colquitt, & Erez, 2000) precluding from formulating practical recommendations, i.e. relevance for personnel selection. Therefore, the present meta-analysis aims at (1) estimating the practical importance of cognitive abilities in the context of performance adaptation, and (2) identifying conditions in which the role of cognitive abilities is particularly important. Before turning to those research questions a short overview of the performance adaptation research field is provided.

Performance Adaptation

Hitherto researchers used different names interchangeably when referring to performance adaptation, e.g. adaptive performance, adaptability, adaptive transfer, post-change performance. Following previous reviews (Baard et al., 2014; Stasielowicz, 2019b) *performance adaptation* will be used throughout the article as an umbrella term for all those names. Both the mentioned names and the examples provided in the introduction (i.e. studying abroad, emergency landing) indicate that dealing with changes is crucial to performance adaptation. Accordingly, Pulakos and colleagues (Pulakos, Arad, Donovan, &

Plamondon, 2000) defined performance adaptation as “altering behavior to meet the demands of a new situation, event, or set of circumstances” (p. 615). Depending on the context, adaptive performance may require multiple distinct behaviors. Pulakos and colleagues acknowledged the multifariousness of adaptive performance and postulated eight dimensions (Pulakos et al., 2002, 2000): (1) solving problems creatively, (2) dealing with uncertain or unpredictable work situations, (3) learning new tasks, technologies, and procedures, (4) demonstrating interpersonal adaptability, (5) demonstrating cultural adaptability, (6) demonstrating physically oriented adaptability, (7) handling work stress, and (8) handling emergencies or crisis situations.

Depending on how many dimensions and/or situations are considered by researchers, Baard and colleagues (2014) differentiate between domain general and domain specific research. Whereas the latter only refers to performance adaptation in specific situations, domain general research reflects aspects that can be shared across different activities or situations. This quest for examining generalizability across situations can manifest itself in assessing an amalgam of adaptive performance, skills, knowledge, preferences, and abilities. To illustrate, Ployhart & Bliese (2006) have developed a questionnaire (I-ADAPT) to measure the individual adaptability with items like “I quickly learn new methods to solve problems” or “It is important to me that I respect other’s culture”. The differences between the conceptualizations of performance adaptation (broad vs narrow) across studies will be considered in the current meta-analysis in an exploratory moderator analysis.

Many instruments developed to measure performance adaptation – including I-ADAPT - are based on the eight-dimensional structure introduced by Pulakos and colleagues. However, many researchers report a more parsimonious structure (Charbonnier-Voirin & Roussel, 2012; Griffin & Hesketh, 2003; Stokes, Schneider, & Lyons, 2010). The respective dimensions of performance adaptation can be assessed via two different methods, which differ at the methodological and conceptual level (Bohle Carbonell et al., 2014; Stokes et al.,

2010). In the present meta-analysis they are referred to as subjective ratings and objective scores. Whereas the former contains self-reports and peers' or supervisor's judgements, objective performance adaptation scores consist of more objective sources of information, i.e. task outcome.

In order to obtain objective performance adaptation scores people are usually confronted with unfamiliar (e.g. modified) situations. In many studies a so called task-change paradigm was adopted, where people are required to learn a task. However, after individuals complete some trials certain task characteristics are changed. Change usually leads to performance impairment (i.e. Howe, 2019; LePine et al., 2000), but after a certain period people tend to adapt to the new circumstances and their performance improves (Wheeler, 2012). Thereby, one can differentiate between a pre-change phase and a post-change phase. The extent of change varies between studies and the post-change phase can be "more difficult, complex, and dynamic" (Bell & Kozlowski, 2008, p. 302). The effective routine behaviors from the pre-change phase do not guarantee success in the post-change phase and their use can even be counterproductive. Objective scores are based on accuracy or adequacy (i.e. plausible solutions) in tasks like radar-tracing (Kozlowski et al., 2001), playing video games (Hardy, Imose, & Day, 2014; Schuelke et al., 2009), and reproducing presentation slides (Keith, Richter, & Naumann, 2010). Some researchers have also constructed situational judgement tests, which require participants to specify what would they do in specific situations (Chan & Schmitt, 2002; Grim, 2010).

However, using objective scores is not the only possibility to gauge performance adaptation. It can also be assessed through peer-ratings, supervisor-ratings or self-reports (Bohle Carbonell et al., 2014). In short: subjective ratings. They can be based on the mentioned instruments (Charbonnier-Voirin & Roussel, 2012; Pulakos et al., 2002, 2000; Stokes et al., 2010), which usually include several dimensions of performance adaptation.

Thus, they typically gauge more performance adaptation aspects than objective scores based on a single task.

Studies devoted to performance adaptation differ also with respect to the examined predictors. They include cognitive ability, goal orientation, conscientiousness, self-efficacy, training and learning strategies, transformational leadership, and experience (Bohle Carbonell et al., 2014; Jundt et al., 2015). Hitherto, three meta-analyses have been published where the relationship with individual performance adaptation is reported. In two meta-analyses the correlations with personality factors (e.g. Big Five) have been examined (Huang et al., 2014; Woo et al., 2014). Overall, the raw correlations with performance adaptation were small indicating that personality traits like Big Five are not pivotal when it comes to predicting performance adaptation. In another systematic review the role of motivational variables has been assessed (Stasielowicz, 2019b). Specifically, the dimensions of goal orientation were considered (learning goal orientation and performance goal orientation). However, non-negligible correlations were identified only for self-reported performance adaptation. Summing up, neither Big Five personality traits nor goal orientation can be recommended as predictors in the selection context when the goal is to predict objective performance adaptation. This, in turn, implies the necessity for systematic examination of the influence of other variables. In addition to personality traits (i.e. Big Five) and motivational variables (van Yperen et al., 2015) aspects like abilities can affect the performance. The present meta-analysis contributes to the literature by systematically examining the importance of cognitive abilities – reportedly one of the most important distal predictors of performance adaptation (Jundt et al., 2015). Does knowing cognitive abilities of individuals facilitate the identification of suitable people (employees, students) for activities requiring performance adaptation?

Cognitive Abilities and Performance Adaptation

Multiple definitions of intelligence indicate more or less explicitly that high intelligence

promotes adaptation (Friedman et al., 2006). In the context of performance adaptation multiple specific cognitive abilities could be relevant, depending on the situation. In the next paragraph it will be illustrated why specific abilities like processing speed, visuospatial abilities, memory, and reasoning can foster performance adaptation.

Increased information-processing is regarded as critical to performance adaptation (LePine et al., 2000). Handling emergencies requires people to register changes fast and accurately in order to act adaptively. Fast processing reduces or even averts potential costs, i.e. all lives can be saved or the damage of materials can be contained. The advantages of high processing speed are not restricted to task-oriented adaptation. Fast processing can also promote cultural adaptability as people can interpret social cues rapidly and refrain from breaching the norms.

Visuospatial abilities may also be important in certain contexts, i.e. sports or military. After all, athletes or soldiers are often confronted with dynamic environments, which require them to consider the actual and possible location and movement of team members or targets in order to reach given goals. Importantly, tasks like dynamic simulations or video games, which also require visuospatial abilities are often used in the performance adaptation research field (i.e. Hardy et al., 2014; Kozlowski et al., 2001).

Performance adaptation is sometimes based on solving problems creatively and learning new tasks, technologies, and procedures (Pulakos et al., 2000, 2002), which can benefit from another specific ability, namely good memory. The ability to retrieve previous experiences can make it easier to derive solutions to new tasks based on the acquired knowledge and the current situation. Furthermore, people with good memory may discover similarities between past and current events, which may prompt them to implement worked-out strategies. Reasoning – as another specific ability – may also contribute to creative solutions and efficient learning. The ability to think logically may enable one to identify patterns in the changed environment (i.e. relationships between the stimuli), which is

important if the old routines are not adequate anymore and new strategies need to be developed.

Summing up, multiple specific cognitive abilities can be theoretically connected to performance adaptation. In general, based on the skill acquisition literature (Beier & Oswald, 2012) one would expect that people with high abilities “will acquire more of the skill that is common across multiple tasks than lower-ability people” (p. 339). Accordingly, people with high abilities should be able to show better adaptive performance as the pre-change phase and the post-change phase share some common task characteristics. In general, the assertion that high cognitive abilities promote performance adaptation was corroborated in multiple empirical studies (e.g. Bell & Kozlowski, 2008; Carter & Beier, 2010; Morgan et al., 2013). Although in some studies the relevance of specific abilities has been examined - i.e. spatial abilities (Morgan et al., 2013), reasoning (Allworth & Hesketh, 1999) – researchers often use general intelligence scores rather than scores for specific abilities when examining the relationship with performance adaptation (Bell & Kozlowski, 2008; Carter & Beier, 2010; LePine et al., 2000). Alternatively, researchers use SAT/ACT scores or grade point average (GPA) as a measure of cognitive ability (Bell & Kozlowski, 2008; Kozlowski et al., 2001). Importantly, a positive relationship with performance adaptation was reported for all those measures of cognitive ability.

Based on the theoretical considerations and the mentioned empirical findings it can be assumed that cognitive abilities promote performance adaptation. However, the average strength of this relationship is unknown as the correlation varies a lot across studies (Holladay & Quiñones, 2003; Morgan et al., 2013). Therefore, the primary objective of the current meta-analysis was to synthesize the empirical evidence and compute the mean effect size across studies. This knowledge could then be used to make practical recommendations, i.e. whether cognitive ability could be a useful predictor in the selection context when searching for people (i.e. students, employees) able to deal with changing environments.

Hypothesis 1: Cognitive abilities are positively related to performance adaptation.

Considering that the effect sizes vary both between (Holladay & Quiñones, 2003; Morgan et al., 2013) and within studies (Frank & Kluge, 2017; Stasielowicz, 2019a) there is a need to explain the heterogeneity of the findings by identifying crucial differences between the studies, samples, situations or measures. Thus, the second goal of the present meta-analysis is to investigate under which circumstances the relationship between cognitive abilities and performance adaptation is the strongest. One potential contributing factor reflects the differences between assessment methods of performance adaptation that were described in the preceding sections (subjective ratings vs objective scores). Interestingly, in other research areas the relationship between cognitive abilities and performance facets is usually stronger when objective performance scores rather than subjective ratings are used (i.e. Conway, Lombardo, & Sanders, 2001). Also within the performance adaptation research field the two assessment methods (subjective and objective) are not interchangeable as indicated by the reported intercorrelations ranging from small ($r = .10$) to medium ($r = .43$) at best (Baumgartner, 2015; Stokes et al., 2010). The inequivalence may be attributed to the number of aspects gauged by each method. It was already mentioned that subjective ratings are usually assessed via multidimensional questionnaires and objective scores reflect the performance on specific tasks, which usually do not tap into many dimensions of adaptive performance. To illustrate, tasks usually require learning new technologies, and procedures, but participants are not necessarily required to show other aspects of performance adaptation like intercultural adaptive performance. The distinction between subjective ratings and objectives scores could already be identified as an important moderator in another meta-analysis devoted to performance adaptation (Stasielowicz, 2019b), where the aim was to assess the relationship with goal orientation. There is preliminary evidence, that this distinction could also be empirically relevant when examining the relationship with cognitive abilities. Specifically, individual effect sizes based on objective performance adaptation

scores (Carter & Beier, 2010; Morgan et al., 2013) seem to be larger than the effect sizes based on subjective ratings (Pulakos et al., 2002; Zorzie, 2012). Therefore, the assessment method of performance adaptation will be considered as a potential moderator in the current meta-analysis.

Hypothesis 2: Assessment method of performance adaptation (subjective ratings vs objective scores) moderates the relationship between cognitive abilities and performance adaptation.

Although the assessment method of performance adaptation is regarded as a crucial factor contributing to the heterogeneity of effect sizes, other systematic differences between studies, samples, situations or measures are possible. In order to rule out other explanations additional variables will be considered in the present meta-analysis, i.e. performance adaptation task type, and measure of cognitive ability (general, specific, SAT/ACT/GPA). All coded variables are described in the method section.

Method

Literature search. Initially, two databases (PsycINFO, Google Scholar) were used to locate work of interest. Keywords for the independent variable were: cognitive ability, intelligence, and general mental ability. The list for the dependent variable (performance adaptation) was longer due to the use of many different names in the extant literature, i.e. adaptive transfer or post-change performance (Jundt et al., 2015; Maynard, Kennedy, & Sommer, 2015). All keywords can be found in the supplementary materials. In addition to databases, reference sections of three reviews (Baard et al., 2014; Bohle Carbonell et al., 2014; Jundt et al., 2015) were examined to ensure, that studies identified by other researchers are also included in the present meta-analysis. The first literature search was conducted between May and September 2015. Two additional search waves were conducted in order to find more recent studies: (1) in January 2018, and (2) between June and July 2019. To check the relevance of a particular study both title and abstract were read. In case of uncertainty the full text was examined.

Inclusion criteria. Studies had to meet the following criteria in order to be considered for the current meta-analysis: (a) the relationship between cognitive ability and performance adaptation was assessed at the individual level, (b) cognitive ability was assessed via objective scores (i.e. intelligence scores, GPA/SAT scores), (c) samples sizes and the respective effect sizes or data enabling the computation of an effect size (i.e. *t*-value and group sizes) had to be reported, and (d) the report was written in English, German, Swedish or Polish. However, all of the relevant reports were written in English. Following the strategy of authors reviewing the field of performance adaptation (Huang et al., 2014; Maynard et al., 2015) gray literature (e.g. dissertations, working papers) was included in the present meta-analysis.

Several studies had to be excluded after examining the full text for the following reasons: (1) In some studies team adaptation rather than individual adaptation was examined. (2) If the relevant effect sizes could not be coded, then attempts were made to contact the authors. However, the authors either did not respond or no personal web profiles or e-mail addresses could be identified. (3) Some researchers used cognitive flexibility as a measure of cognitive ability. However, the relationship between cognitive flexibility and cognitive ability is weak (Good & Michel, 2013; Wheeler, 2012). Therefore, effect sizes based on cognitive flexibility were not considered in the present meta-analysis. The list of all excluded studies is provided in the supplementary materials. In a separate file the full references for the included studies are provided: https://osf.io/5y4km/?view_only=a09d6969fb32484db4e411de3e66da4e

Coding. Each report was coded twice (LS and KM/WS) and inconsistencies were resolved through discussions. Samples sizes and individual effect sizes from relevant reports were coded in order to estimate the mean effect size. In one relevant primary study identified for the present meta-analysis (Schunn & Reder, 2001) only significant correlations were reported. As the final dataset was not available anymore (personal communication, October 22, 2015) the missing effect sizes were considered as equal to zero.

In order to conduct the moderator analysis, the assessment method of performance adaptation (objective score vs subjective rating) was also coded for each effect size. Additionally, for each effect size based on subjective ratings it was coded whether self-reports or other ratings (peers, supervisors etc.) were used. Furthermore, the items or descriptions of questionnaires used to obtain subjective performance adaptation ratings were inspected in order to decide, whether a specific or broad definition of performance adaptation was utilized. Whereas the former focuses on the performance component, the latter (e.g. I-ADAPT measure) includes additional aspects (i.e. skills, preferences, values etc.). The inspection of items was necessary because terms like adaptive performance and adaptability are used interchangeably in the extant literature and one cannot rely on provided definitions.

For effect sizes based on objective scores the task type was coded (e.g. battle tank scenario, creating presentation slides). The full list of tasks is provided in the supplementary materials. In addition to task type, following the approach of Randall and colleagues (2014), task complexity was coded. Based on the framework proposed by Wood (1986) three aspects of task complexity were coded: component, coordinative, and dynamic complexity. Component complexity of a task is high when several distinct actions are needed to complete the task and/or multiple cues have to be processed (e.g. in simulations or video games). Coordinative complexity is high when there is interdependence between the task elements, i.e. a certain temporal order of actions is required (first do A, then do B etc.) and/or spatial aspects need to be considered (location or movement of the stimuli). Finally, the third aspect of task complexity – the dynamic complexity – reflects the changes in coordinative and component complexity that people encounter while completing the task, i.e. people suddenly receive a new kind of information (increase in component complexity) and/or need to carry out new steps (increase in coordinative complexity). After coding the three types of task complexity for the current meta-analysis, it became clear that almost all tasks are highly demanding with respect to component and coordinative complexity. This is due to the fact

that researchers often use simulations or scenarios in order to measure performance adaptation, i.e. firefighting, battle tanks (Good & Michel, 2013; Lang & Bliese, 2009). Thus, participants are required to process multiple cues (i.e. energy status of the tank, location of the enemy tanks, obstacles) and coordinate their actions (e.g. the tank needs to be recharged before moving further). Fortunately, there was some variability across the tasks with respect to the dynamic complexity. It enabled making a comparison between tasks where only coordinative complexity changed and tasks where both coordinative and component complexity changed. An additional comparison was made based on the general task type. Specifically, tasks were classified as simulation/scenario, situational judgment test, and other (i.e. creating presentation slides, Stroop task).

Additionally, information about the following variables was also extracted: publication year, country, sample type (i.e. students, employees), cognitive abilities measure (general intelligence vs specific ability), mean age of the sample, proportion of men in the sample, peer review, and financial support. The full data set can be accessed via https://osf.io/5y4km/?view_only=a09d6969fb32484db4e411de3e66da4e

Effect size. Correlation coefficient (r) was chosen as the effect size for the current meta-analysis. A positive effect size indicates that people with high cognitive abilities tend to show better performance adaptation than people with relatively low cognitive abilities. In some studies multiple relevant effect sizes were reported, i.e. one can use supervisor ratings and objective scores (e.g. error rate) to gauge performance adaptation. To avoid loss of information data dependency was accounted for by conducting a three-level meta-analysis in the present study (Cheung, 2014). For each level an equation can be specified:

$$\text{Level 1: } y_{ij} = \pi_{ij} + e_{ij}$$

$$\text{Level 2: } \pi_{ij} = \gamma_j + u_{ij}$$

$$\text{Level 3: } \gamma_j = b_0 + u_j$$

Alternatively, inserting the equations into each other results in a single equation:

$$y_{ij} = b_0 + u_{ij} + u_j + e_{ij}$$

According to the presented basic equations, individual effect sizes (y_{ij}) can deviate from the mean effect size (b_0) for several reasons: error (e_{ij}), true differences between samples (j) and true differences within samples (i , e.g. different measurement methods). The true differences can be modelled by including random effects (u) at level 3 and level 2. Variance of the random effects (= true variance, τ^2) may be explained in subsequent moderator analyses.

In contrast to a standard two-level meta-analysis, multiple effect sizes per sample may be included when using the three-level approach. When conducting a two-level meta-analysis one is forced to either (1) ignore the dependency of the effect sizes, (2) select one effect size per sample or (3) to compute an average effect size per sample. All three procedures can bias the results (Assink & Wibbelink, 2016; Hedges, Tipton, & Johnson, 2010). Importantly, it was hypothesized in the current meta-analysis that different assessment methods (subjective ratings vs objective scores), which can be also used within one study, would yield different correlations with cognitive abilities. Therefore, the three-level meta-analytic approach was chosen and all relevant effect sizes were included. R package *metafor* (version 2.1-0) was used to conduct the three-level meta-analysis (Viechtbauer, 2010). The true variance (τ^2) was estimated using restricted maximum likelihood estimation.

Heterogeneity analyses. In order to assess the heterogeneity of the effect sizes the Q and I^2 values were calculated. A statistically significant Q statistic means that the effect sizes are not homogeneous. However, I^2 values are easier to interpret. They indicate the proportion of true variance (τ^2) on the total variance ($\tau +$ sampling error). Conventionally, I^2 values of 25%, 50% and 75% correspond to the labels of low, moderate, and high proportion of true heterogeneity (Higgins, Thompson, Deeks, & Altman, 2003). In order to explain the heterogeneity moderator analyses were conducted.

Publication bias. When conducting meta-analyses it cannot be ruled out that certain

Analysis	<i>k</i>	<i>N</i>	<i>r</i>	CI	<i>Q</i>	<i>I</i> ²
Objective scores	39	6167	.25	[.20, .30]	569.68*	81.85
Subjective ratings	16	32723	.11	[.04, .19]	77.19*	91.13
Conceptualization (subjective ratings)						
Narrow	9	1319	.12	[.04, .20]	27.36*	57.27
Broad	8	31504	.06	[-.02, .15]	49.75*	95.45
Source (subjective ratings)						
Self-report	9	1323	.04	[-.04, .11]	34.97*	59.02
Peers/Supervisors	8	6167	.15	[.08, .23]	24.42*	94.98
Task type						
Simulation/video game	29	4875	.27	[.21, .33]	356.88*	77.74
SJT	3	448	0	[-.19, .19]	2.42	0
Other	7	844	.27	[.15, .40]	102.34*	90.61
Dynamic complexity						
Only coordinative change	14	1901	.19	[.10, .28]	141.55*	68.80
Component and coordinative change	20	3589	.31	[.23, .38]	237.88*	86.10
Cognitive ability measure						
General	22	2812	.21	[.14, .28]	294.43*	84.81
Specific	18	32775	.23	[.15, .30]	232.77*	94.66
ACT/SAT/GPA	10	2367	.21	[.12, .31]	246.16*	88.68
Country						
USA	36	6335	.23	[.17, .28]	716.11*	84.25
Other	11	31628	.17	[.07, .27]	72.85*	95.76
Sample						
Student sample	32	5805	.22	[.16, .28]	506.65*	81.99
Other sample	15	32158	.20	[.11, .29]	357.37*	97.08
Peer review						
Yes	31	4817	.24	[.18, .30]	376.52*	77.12
No	16	33146	.17	[.09, .25]	321.98*	96.81

Notes: *k* = number of independent samples; *N* = total sample size; *r* = weighted mean correlation; CI = confidence interval limits (95%); *Q* = *Q* statistic; *I*² = *I*² statistic.

* *p* < .05.

Table 1. Three-level meta-analytic results for the relationship between cognitive ability and performance adaptation.

Effect. The mean correlation between cognitive abilities and performance

adaptation was $r = .21$ ($p < .001$). As expected (Hypothesis 1), people with relatively high cognitive abilities showed on average better performance adaptation than people with relatively low cognitive abilities. However, individual effect sizes ranged from $r = -.36$ to $r = .65$ indicating heterogeneity ($Q = 904.67$, $df = 132$, $p < .001$, $I^2 = 92.90\%$). Variability was present both within the samples ($\tau^2 = 0.01$) and between the studies ($\tau^2 = 0.02$). Thus, conducting moderator analyses was suitable.

Moderator analyses. In order to explain the heterogeneity, moderator analyses were conducted. Table 1 contains the mean effect sizes for all considered subgroups. As expected (Hypothesis 2), the strength of the relationship between cognitive abilities and performance adaptation depended on the assessment method of performance adaptation. Specifically, the relationship was stronger when objective performance adaptation scores ($r = .25$) rather than subjective ratings ($r = .11$) were used and this difference was statistically significant ($p < .001$). The moderator could explain some of the heterogeneity within samples and between samples ($R^2 = .09$ and $R^2 = .18$ respectively). The differences between the two assessment methods are also illustrated in Figure 1. Due to the fact that residual heterogeneity was present in both subgroups, exploratory analyses were conducted within each group.

Figure 1. Violin plot that illustrates the distribution of individual effect sizes for the relationship between cognitive abilities and performance adaptation. The distributions are shown separately for the two assessment methods of performance adaptation (subjective ratings vs objective scores). The point in the middle corresponds to the median value. In general, the reported relationship was stronger when objective performance adaptation scores were used.

For subjective performance adaptation ratings two additional analyses were carried out. Specifically, the role of source of information (self vs peers/supervisors) and conceptualization of performance adaptation (narrow vs broad) was examined. The linear relationship with cognitive abilities was somewhat stronger when ratings from other people rather than self-reports were used ($r = .15$ vs $r = .04$, $p = .021$). Source of information could explain one third of the heterogeneity of effect sizes based on subjective ratings ($R^2 = .32$). In

contrast, the difference between the narrow and broad conceptualizations of performance adaptation was negligible ($r = .12$ vs $r = .06$, $p = .344$, $R^2 = 0$).

In order to explain the heterogeneity of effect sizes based on objective scores, the task characteristics were compared. Specifically, the role of dynamic complexity of the task and the task type was examined. With respect to task type a difference was found between situational judgment tests (SJT) and other tasks (i.e. simulations, video games). Whereas there was a lack of linear relationship with cognitive abilities for SJTs ($r = 0$), there was a moderate relationship when the objective performance adaptation scores were derived from other tasks ($r = .27$). Thus, differences between task types accounted for some heterogeneity of the effect sizes based on objective scores ($p = .028$, $R^2 = .17$). In a second analysis the tasks were compared with respect to their dynamic complexity. As mentioned in the preceding section, lack of studies with low dynamic complexity precluded from making all theoretically possible comparison. Only a single comparison was feasible. Whereas in some tasks only coordinative demands changed during task completion (i.e. changed order of required actions, new maps in video games), in many tasks component complexity changed too (e.g. other functions had to be considered in a spreadsheet program after the change). Interestingly, a stronger relationship between cognitive abilities and performance adaptation was found when both component and coordinative aspects of the task rather than only coordinative aspects changed ($r = .31$ vs $r = .19$, $p = .045$). Thus, dynamic complexity of the task could account for a certain proportion of heterogeneity between effect sizes based on objective scores ($R^2 = .11$).

In order to rule out the possibility that mentioned differences between objective scores and subjective ratings could be explained by other factors, exploratory moderator analyses were conducted where the role of cognitive ability measure (general, specific, ACT/SAT/GPA), country (USA vs other countries), and sample type (student samples vs other samples) was examined. However, the differences between respective subgroups were rather small (see Table 1) and statistically non-significant (all $ps \geq .344$).

Publication bias. Two analyses were carried out in order to address the publication bias.

Although somewhat larger effect sizes were reported for peer-reviewed articles than for reports that did not go through peer review (e.g. doctoral dissertations, working papers), the difference was rather small and statistically non-significant ($r = .24$ vs $r = .17$, $p = .190$).

Furthermore, the regression test for asymmetry indicated that there was no asymmetry in the distribution of effect sizes ($t = -0.58$, $p = .565$). Thus, no strong evidence for publication bias could be found in the present meta-analysis.

Discussion

Present meta-analysis was conducted in order to assess the relationship between cognitive abilities and performance adaptation. The main goal was to establish whether individual differences in cognitive ability are important in the selection context (i.e. college admission or personnel selection) when searching for individuals able to deal with changes. Another aim of the current meta-analysis was to examine which factors contribute to the heterogeneity of the findings. In particular, the role of assessment method of performance adaptation (subjective ratings vs objective scores) was investigated. Overall, the results of the meta-analysis indicate that cognitive abilities promote performance adaptation. However, the strength of the relationship varies a lot both between and within studies. Crucially, this variability could be partially explained by the proposed moderator (assessment method of performance adaptation). Specifically, stronger relationship was identified for effect sizes based on objective performance adaptation scores rather than subjective ratings. Additional moderator analyses revealed under which circumstances the predictive validity of cognitive ability seems to be particularly high. The main findings and their implications are discussed in the following paragraphs.

The decision to conduct the present quantitative synthesis was partially motivated by the growing relevance of adaptability in the dynamic world, where the learning and working environments can change rapidly. The need to establish predictors that could be used in the

selection context has been already acknowledged by other authors (Ryan & Ployhart, 2014). One objective of the current meta-analysis was to examine whether cognitive ability could be a more useful predictor than Big Five personality traits (Huang et al., 2014; Woo et al., 2014) and goal orientation (Stasielowicz, 2019b) as these predictors have been examined meta-analytically in the past. Superficially, examining the role of cognitive ability may seem trivial, since it has been established as a good performance predictor across different situations (Judge et al., 2007; Lang et al., 2010; Schmidt & Hunter, 2004, 1998). However, it cannot be assumed that cognitive ability is always relevant for performance-related constructs, e.g. no linear relationship with counterproductive work behaviour could be identified in one meta-analysis (Gonzalez-Mulé et al., 2014).

The magnitude of the mean effect size found in the present meta-analysis ($r = .21$) can be described as moderate. To put the findings into perspective, the raw correlation between cognitive abilities and job performance or training success usually varies between $r = .20$ and $r = .30$ (Bertua, Anderson, & Salgado, 2005; Lang et al., 2010). However, a stronger relationship ($r = .43$) has been reported for complex problem solving (Stadler et al., 2015) and a weak relationship ($r = .13$) was reported for OCB (Gonzalez-Mulé et al., 2014). In general, compared to other studies devoted to the relationship between abilities and performance (Bosco, Aguinis, Singh, Field, & Pierce, 2015), the mean effect sizes for objective performance adaptation scores would reside in the middle of the distribution. Nevertheless, when looking solely at the raw correlation one could argue that cognitive abilities can only account for 4% of the variance in performance adaptation. At the same time, cognitive abilities seem to be as important as in contexts where the use of cognitive ability measures during selection procedures is already recommended (i.e. job performance). Furthermore, none of the mean correlations from previous meta-analyses devoted to performance adaptation, where predictors like Big Five personality traits or goal orientation were used (Huang et al., 2014; Stasielowicz, 2019b; Woo et al., 2014), reached the level identified here

for cognitive abilities. Moreover, the heterogeneity of the effect sizes identified in the present meta-analysis indicates that there are circumstances where the predictive validity of cognitive abilities is somewhat higher than the mean effect size. The specific conditions are described in the following paragraphs.

As expected, differences between effect sizes could partially be explained by the assessment method of performance adaptation. A stronger relationship with cognitive abilities was found for objective performance adaptation scores than for subjective performance adaptation ratings ($r = .25$ vs $r = .11$). Furthermore, in an additional analysis a difference between subjective ratings based on self-reports and ratings based on other sources of information (peers/supervisors) was found ($r = .04$ vs $r = .15$). Using self-reports is not the perfect way to assess competencies or performance, because people tend to overestimate or underestimate their abilities (Heidemeier & Moser, 2009; Mabe & West, 1982). Thus, the very weak relationship between cognitive ability and self-reported performance adaptation identified in the present meta-analysis should not be problematic for practitioners, who favour more valid criteria. More generally, the pattern of results indicates that distinguishing between assessment methods of performance adaptation is important. This conclusion is in accordance with the results of previous meta-analyses devoted to individual or team performance adaptation where the strength of the relationship with predictors also depended on the assessment method of performance adaptation (Christian, Christian, Pearsall, & Long, 2017; Stasielowicz, 2019b). Thus, researchers should continue to make this distinction in the future meta-analyses of performance adaptation as it accounts for some differences between effect sizes in the extant literature.

One could argue that the identified differences between assessment methods reflect some other systematic differences between effect sizes. However, three other explanations could be ruled out in the present meta-analysis. Specifically, no substantial differences between cognitive ability measures (general, specific, ACT/SAT/GPA), countries (USA vs

other countries), and sample type (student samples vs other samples) were found. In addition, no strong evidence for publication bias was found in the present meta-analysis.

Although the assessment method of performance adaptation (objective scores vs subjective ratings) could account for a considerable amount of heterogeneity, the effect sizes based on the same method (i.e. objective scores) varied a lot too. Therefore, additional moderator analyses were conducted for the specific assessment methods. Distinguishing between narrow and broad conceptualization of performance adaptation ratings (performance only vs amalgam of performance, competences, abilities, values etc.) could not explain much of the heterogeneity.

With respect to objective performance adaptation scores, it was possible to identify conditions in which the relationship with cognitive ability is particularly strong. Specifically, based on the framework proposed by Wood (1986) preliminary evidence for the role of dynamic complexity of the task used to gauge performance adaptation was found. For tasks with high dynamic complexity, where both coordinative demands (i.e. new steps, new environments) and components of the task changed, the strongest relationship in the current meta-analysis was identified ($r = .31$). Thus, cognitive ability seems to be particularly relevant for dealing with complex dynamic environments. Similar findings were previously described in the context of job performance where the relationship with general mental ability is stronger for complex jobs than for less complex jobs (Schmidt & Hunter, 2004). Furthermore, the finding from the present meta-analysis corroborates the conjecture that the increased demands could result in stronger relationship between cognitive abilities and performance adaptation on complex tasks than on routine or simple tasks (LePine et al., 2000). After all, dynamic environments require people to process new cues, learn new procedures, identify new strategies. Thus, abilities like processing speed or reasoning may be particularly relevant in the context of adaptation.

In another analysis devoted to objective performance adaptation scores, differences between task types were examined. A profound difference was found between situational judgment tests and other types of task (i.e. video-based simulations, working with a spreadsheet program). Whereas the effect size for other tasks was of medium magnitude, there was lack of linear relationship for SJTs. One could wonder whether SJT responses could be used to predict actual performance adaptation rather than to serve as a criterion. After all, in some contexts SJTs can be useful when predicting performance (Whetzel & McDaniel, 2009). Unfortunately, in the primary studies identified for the present meta-analysis SJTs were never used together with other tasks. However, in one study ratings from other people were used in addition to SJT (Grim, 2010). The correlation between the two was moderate. Furthermore, the reliability of the SJTs used in the primary studies was generally low (i.e. Grim, 2010), with one exception (Chan & Schmitt, 2002). This pertains to many SJTs outside performance adaptation research field too (Kasten & Freund, 2016). Although it is possible that SJTs are multidimensional and the standard reliability coefficients (i.e. Cronbach's alpha) underestimate the reliability, researchers should use appropriate measures - e.g. McDonald's omega (Dunn, Baguley, & Brunson, 2014) - in order to account for the fact that they are measuring several dimensions. Thus, at present there is not much evidence for the utility of SJTs in the performance adaptation context and practitioners should refrain from utilizing it during selection procedures.

Due to lack of studies with certain characteristics one has to be cautious when generalizing some of the presented findings into applied contexts. In particular, more studies based on non-American and non-European samples are needed. Furthermore, there is lack of studies where social performance adaptation (i.e. cultural or interpersonal adaptation) or physically-oriented adaptation is gauged more objectively. In future studies one could examine the former by using observational methods and coding relevant behavior (i.e. contact attempts when studying abroad). The latter could be investigated with specific samples (i.e.

firefighters, athletes) during trainings. In addition, one could try to combine subjective ratings with objective scores and tailor the questionnaires to the task requirements. Such modifications could increase the correlation between subjective ratings and objective scores, which is currently small to medium (Baumgartner, 2015; Stokes et al., 2010).

In future studies one could also systematically examine whether some dimensions of performance adaptation can be predicted better than others. To illustrate, it is possible that aspects like learning new procedures or dealing with emergencies rather than interpersonal adaptation or physically-oriented adaptation can be predicted by cognitive abilities. In contrast, social skills may be more important for interpersonal or cultural adaptation than for task-oriented adaptation. Due to the fact that many researchers report overall scores rather than scores for each dimension it was not possible to carry out a respective moderator analysis in the current meta-analysis.

Finally, present findings indicate that while cognitive ability is important for performance adaptation, the relationship is not deterministic. Thus, performance adaptation seems to be malleable and one could try to identify variables that could be addressed in potential interventions to increase adaptive performance. To illustrate, researchers could investigate the mechanisms of performance adaptation by including state variables (i.e. motivation, mood) and assessing aspects like change awareness via questionnaires and process-tracing methods, e.g. thinking aloud, eye-tracking, EEG (Schulte-Mecklenbeck, Kühberger, & Ranyard, 2011). In addition, one could examine the importance of the fit between own interests and task requirements.

Conclusions

The current meta-analysis contributes to the literature by establishing that cognitive ability can be a useful predictor when seeking people (i.e. students or employees) able to deal with changes (e.g. dealing with new software, learning new procedures). Overall, cognitive ability seems to be superior to the previously meta-analytically examined predictors of performance

adaptation because the identified relationship was stronger than the ones reported for Big Five personality traits (Huang et al., 2014; Woo et al., 2014) and goal orientation (Stasielowicz, 2019b). According to the moderator analyses, actual performance adaptation can be predicted better than self-reported performance, which is important for practitioners as actual performance is a more valid criterion. Furthermore, performance adaptation on complex dynamic tasks can be predicted particularly well. This means that cognitive ability can be used in the selection context (i.e. education, work) when the goal is to find people, who can deal with complex changes (e.g. new environments, emergencies). Nevertheless, the strength of the relationship between cognitive ability and performance adaptation indicates that relatively low abilities could be compensated by other factors, which could be potentially fostered during trainings. In future studies researchers could investigate the role of state variables (e.g. motivation, mood) or the relevance of fit between interests and task characteristics.

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