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Review

How experts deal with novel situations: A review of adaptive expertise

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ABSTRACT

Adaptive expertise allows individuals to perform at a high level in the face of changing job tasks and work methods, setting it apart from routine expertise. Given the increased need for flexibility in the workplace, adaptive expertise is increasingly important for today's graduates and professionals. This review investigates which individual and environmental factors distinguish adaptive expertise from routine expertise and thus provides insights into how to facilitate adaptive expertise and its development. Key differences between routine and adaptive expertise are related to knowledge representation, cognitive and analogical problem solving abilities, and past experiences. Learning and working environments, which give individuals the responsibility to develop their own solution strategy and have supportive superiors benefit adaptive expertise. The results of our review also indicate that there is little consensus on the degree of adaptation adaptive expertise provides and the characteristics of a novel situation.

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1. Introduction

Today's work environments are characterized by increasing complexity due to higher levels of required knowledge and task volatility (Howard, 1995; Molloy & Noe, 2009; Tannenbaum, 2001). It is no longer sufficient to be an expert in one domain, but employees need to be able to combine different specializations (Pink, 2006), adapt to changes in their domain (Smith, Ford, & Kozlowski, 1996), and develop their expertise and become proficient in other domains (van der Heijden, 2002). In short, they must be able to deal effectively with novel situations and problems. Therefore, flexibility at the workplace becomes a critical ingredient for career success (van der Heijden, 2002). While some people quickly overcome changes in work requirements by inventing new procedures and using their expert knowledge in novel ways (Hatano & Inagaki, 1986; Holyoak, 1991), others do not possess this ability and find themselves thrown back performing as a novice. This ability to quickly get accustomed to change has been called adaptive expertise (Hatano & Inagaki, 1986).

Adaptive expertise is generally seen as important, but its characteristics and development are ill understood. Achieving a better understanding of the concept of adaptive expertise is necessary to design learning activities that contribute to its development. Therefore, the aim of this systematic review is to establish what the characteristics of adaptive expertise are and with which training and task characteristics it flourishes. By analyzing the characteristics that distinguish adaptive expertise from routine expertise, it will become possible to deduct what learning activities lead to it.

Hatano and Inagaki (1986) first coined the term adaptive expertise and contrast it with routine expertise. They conceptualize that both types of expertise comprise the same *extent* of domain knowledge and the ability to perform flawless in familiar situations. However, the difference becomes apparent once confronted with an unfamiliar situation: A situation in which the task, method or desired results are not known in advance (Ellström, 2001). While individuals with routine expertise struggle with the new demands, adaptive expertise allows for easily overcoming the novelty and quickly regaining a high level of performance thanks to a knowledge representation which allows for flexibility (Schwartz, Bransford, & Sears, 2005). In contrast to routine expertise, individuals with adaptive expertise possess the knowledge of why and under which conditions certain methods have to be used or new methods have to be devised.

Various authors studying adaptive expertise have provided numerous descriptions with features that fall apart in three groups. First, adaptive expertise entails all the basic components of routine expertise (e.g., Fisher & Peterson, 2001; Hatano & Oura, 2003; Martin, Rivale, & Diller, 2007; Mylopoulos & Woods, 2009; Varpio, Schryer, & Lingard, 2009). Second, adaptive expertise is marked by better developed meta-cognitive skills than routine expertise (e.g., Crawford, Schlager, Toyama, Riel, & Vahey, 2005; Martin, Petrosino, Rivale, & Diller, 2006). Third, adaptive expertise is set apart through abilities such as flexibility, ability to innovate, continuous learning, seeking out challenges, and creativity (e.g., Barnett & Koslowski, 2002; Crawford et al., 2005; Hatano & Oura, 2003; Martin et al., 2006, 2007; Mylopoulos & Scardamalia, 2008; Varpio et al., 2009). These characteristics point to two important facets of adaptive expertise. Firstly, it develops out of routine expertise. This is based on the first characteristic and implies that both forms of expertise are observable through accurate and efficient performance on domain-relevant and familiar tasks. It is postulated that individuals with routine expertise maintain their performance but halt their learning (Chi, 2011) and thus do not further develop into the stage of adaptive expertise. Secondly, Hatano and Inagaki (1986) suggest that adaptive expertise is after all domain-dependent because it is through accumulated experiences that adaptive expertise develops. In line with this conceptualization, researchers typically define the situation in which adaptive expertise is beneficial over routine expertise as changes in work and/or job task requirements (Allworth & Hesketh, 1999; Blickle et al., 2011; Griffin & Hesketh, 2003), changes in the complexity of situations (Chen, Thomas, & Wallace, 2005), changes from usual to unusual situations (Joung, Hesketh, & Neal, 2006), or changes from common to exceptional situations (Neal et al., 2006).

The focus on 'change' distinguishes research on adaptive expertise from research on expert performance. The latter type of research tries to identify individuals who perform on a superior level on tasks representative for their domain (Ericsson, 2007; Ericsson & Towne, 2010). Through analysis of their performance on *standardized* tasks it is possible to identify abilities of experts within a domain. In contrast to expert performance research, the tasks with which to analyze adaptive expertise are not standardized tasks within the experts' domain, but *novel* tasks within or even outside their domain. Research on adaptive expertise should thus not be placed within the research tradition of expert performance research. While this research is moving away from its classical focus on chess players, musicians and sportsmen, it still focuses on analyzing the performance of individuals who have achieved a sustainable and observable streak of top performance on standardized tasks within their domain.

Research on professional expertise distinguishes itself from traditional expertise research by perceiving expertise as a developmental process observable through the problem-solving skills of individuals (Tynjälä, Nuutinen, Eteläpelto,

Kirjonen, & Remes, 1997). Another important difference is its strong focus on the social environment as a place in which learning happens. This is included in the dimensions of social recognition and growth and flexibility of professional expertise (Van Der Heijden, 2000). These two dimensions, a focus on development and the social environment, pinpoint the differences between expert performance and professional expertise. Adaptive expertise narrows the operationalizing lens further down by only looking at the developmental dimension of professional expertise. These differences between expert performance and adaptive expertise result in a number of characteristics of adaptive expertise research. Firstly, studied tasks need not be standardized nor representative for the domain; however, they need to represent a realistic problem. Secondly, participants are not selected for their track record of superior performance in their domain, but they should also not be novices. Ideally, they have some years of work experience. Thirdly, performance should be measured based on speed, accuracy and feasibility of proposed solutions to unfamiliar problems.

Starting from our preliminary description of adaptive expertise and how research on adaptive expertise differs from expert performance research, a systematic literature review was conducted to detail characteristics of adaptive expertise and the environments in which individuals with a high level of adaptive expertise excel. We aim to answer four research questions. To create a well-founded conceptual understanding of adaptive expertise, the aim of the first two questions is to pinpoint which learning and personality-related factors are characteristic for adaptive expertise and not for routine expertise:

1. What learner characteristics (knowledge, skills, regulation processes, and past experience) influence adaptive expertise?
2. What personality factors influence adaptive expertise?

   The goal of the latter questions is to discover which environmental factors benefit behaviors indicating adaptive expertise:
3. What task and training characteristics (e.g., instruction, task complexity) influence adaptive expertise?
4. What characteristics of the learning climate (e.g., tolerance of mistakes, supervision) influence adaptive expertise?

2. Method

To answer the research questions a systematic review has been done. This method has been chosen for its transparency and reproducible process (Cook, Mulrow, & Haynes, 1997). A systematic review allows to discover the consistency and variation within studies in one field (Davies, 2000) and thus to provide an exhaustive summary on the relevant studies for the research questions. To retrieve the necessary studies, the databases of Business source premier, CINAHL, Emerald Insights, Eric, MedLine, PsycArticles, and Social Sciences Citation Index were consulted. Those databases were chosen for their access to articles in the field of educational science. Articles using the term "adaptive expertise", "adaptive expert" or "adaptive performance" published between 1991 and 2012 were retrieved. The term adaptive performance was included, because it is the outcome of an individual trying to overcome the discrepancies between his or her behavior and the new demands created by changes in the work environment (Chan, 2000). As through adaptive expertise individuals overcome these discrepancies, they should demonstrate adaptive performance. In the remainder of the article, adaptive expertise will be used to describe both terms. Articles which had one of the terms in the abstract or keywords were selected. The search resulted in an output of 124 unique articles.

The abstracts of the complete set of articles were scanned for exclusion criteria. Of the retrieved articles, 53 did not deal with the topic of adaptive expertise or adaptive performance or did not describe how it was measured. Those articles discussed topics such as adaptive expert systems, adaptive market/company performance, or performance judgments. Other exclusion criteria were: Lack of realistic work or learning environment as these did not provide accurate task and training characteristics (3), conceptual paper (26) as these did not provide empirical evidence for characteristics of adaptive expertise or its development, suggestion of adaptive expertise as an explanation of reported findings but not as the object of study (3), and studied outcomes of adaptive expertise but not antecedents (5). Excluded were also book reviews, conference and symposium abstracts (6), and articles in languages other than English (2). Four articles could not be accessed and one article contained the same data set as discussed in another article. Of the 124 articles originally retrieved 21 eventually matched the inclusion criteria.

3. Results

3.1. Sample descriptive

In the articles the dependent variable was defined as adaptive expert or adaptive expertise (5), adaptive performance (15), and adaptive transfer (1). Two articles were published before 2000, 12 before 2010, and 7 after 2010. Quantitative studies were conducted 14 times and seven studies used a mixed-method approach. Ten studies were conducted at the workplace, six in an educational context, and five were simulation studies. Workplace studies were conducted in several industries (hospitality = 2; military = 1; aerospace = 1; electric power utility company = 1, and government agency = 1) and also across industries (4). The studies conducted in educational contexts dealt with experienced firefighters (2) and engineering pupils/students (4). Table 1 provides an overview of the research questions.

Adaptive expertise has been measured through different methods. These methods are summarized in Table 2 as performance data (objective and subjective ratings of performance) and self and peer assessment instruments.

Table 1
Overview of research questions addressed per study.

Study	Context	Learner	Personality	Task	Environment
Allworth & Hesketh, 1999	Workplace	X	X	X	
Barnett & Koslowski, 2002	Workplace	X			
Bell & Kozlowski, 2008	Simulation	X		X	
Blickle et al., 2011	Workplace	X	X		
Charbonnier-Voirin et al., 2010	Workplace				X
Chen et al., 2005	Simulation	X			
Griffin & Hesketh, 2003	Workplace	X	X	X	X
Han & Williams, 2008	Workplace	X			X
Hughes et al., 2013	Simulation	X		X	
Joung et al., 2006	Training			X	
Martin et al., 2006	Education		X	X	
Martin et al., 2005	Education			X	
Neal et al., 2006	Training			X	
Neal et al., 2012	Workplace		X		
Pandy et al., 2004	Education			X	
Pulakos et al., 2002	Workplace	X	X		
Rayne et al., 2006	Education	X			
Reder & Schunn, 1999	Simulation	X			
Schraub et al., 2011	Workplace	X	X	X	
Stokes et al., 2010	Simulation	X	X		
Zhang et al., 2012	Workplace		X		
Total: 21 studies					

A common measurement method is to rate the performance of individuals on a new task by increasing the component and/or coordinative complexity compared to the trained task (Wood, 1986). Component complexity refers to the number of information cues and acts involved in a task, and coordinative complexity describes the relationship between information cues, acts and performance. Studies on instructional designs typically measure adaptive expertise through performance on an unfamiliar problem that was not discussed in class. Apart from Bell and Kozlowski (2008) other studies do not use a framework to guide their decision in designing the adaptive expertise task.

For peer and self-assessment the instrument assessing adaptive performance developed by Pulakos, Arad, Donovan, and Plamondon (2000) was used prominently. This instrument measures eight dimension of behavior: (1) handling emergencies, (2) handling work stress, (3) solving problems creatively, (4) dealing with uncertain situations, (5) learning new tasks, technologies, and procedures, (6) interpersonal adaptability, (7) cultural adaptability, and (8) physically oriented adaptability. Other instruments refer to job relevant behaviors, which demonstrate adaptation to changes such as emergencies, interruptions, unforeseen events and innovations. In those studies change is conceptualized as any situation, which does not fit the job description and thus does not fall in the category of contextual and task performance. The number of items varies between 6 and 24, and reliability scores are between .76 and .97.

3.2. What learner characteristics influence adaptive expertise?

The learner characteristics identified in the reviewed articles refer to four categories: domain knowledge, skills, regulation processes, and past experience. Table 3 presents a summary of the studies.

3.2.1. Domain specific knowledge and skills

Domain knowledge refers to declarative knowledge (knowing that), procedural knowledge (knowing how) and conditional knowledge (knowing when and where) individuals need to possess in order to perform in a specific domain (Alexander, 1992). Experts and novices have different knowledge representation (extent, organization, abstraction, and consolidation) which influence how they retrieve information (Chi, 2006) and thus solve problems (Schwartz et al., 2005).

Chen et al. (2005) and Hughes et al. (2013) investigated whether the extent of someone's knowledge base has an influence on adaptive expertise. Knowledge was measured through multiple-choice questions, thus only assessing the extent of knowledge and no other characteristics of knowledge representation, such as abstraction or organization (Chi, 2006). They reported a positive correlation between the extent of the knowledge base and adaptive expertise ($r = .41$, $p < .01$, $d = .89$ in the study by Chen et al., and $r = .46$, $p < .01$, $d = 1.03$ in the study by Hughes et al.). Both studies used a simulation exercise in which the adaptive expertise task was more complex than the training tasks.

Rayne et al. (2006) investigated the effect of an active learning method (star.legacy cycle) on the development of adaptive expertise in novices and experts. They used four groups of students (high school, first year, second year, and third year university students). These groups had different levels of prior knowledge and thus differed in the extent, organization, abstraction, and consolidation of their domain knowledge. While third year university students had a greater extent of domain knowledge, their level of abstraction, organization and consolidation are influenced by the most common situation in which

Table 2
Measurement methods of dependent variable.

Study	Measurement	
	Instrument	Reliability
Performance data: objective performance		
Bell & Kozlowski, 2008	Scores on transfer trial which was more difficult and complex than training trials	n.a.
Hughes et al., 2013	Performance during a transfer trial which was more difficult and novel than the training tasks	n.a.
Reder & Schunn, 1999	Performance on a more complex air traffic controller task.	n.a.
Stokes et al., 2010	Performance score of a more complex tasks than during training trials	n.a.
Performance data: subjective performance		
Barnett & Koslowski, 2002	Case answers of participants compared to the answers of 2 "super expert" (professors with a focus on restaurant management and with restaurant management experience)	Interrater reliability = .82
Chen et al., 2005	External raters scored performance during trials	Interrater reliability for roles within simulation r_{wg} = .94 and .89
Joung et al., 2006	Spotting errors made during the emergency situation and providing viable solution	Inter-rater reliability Cohen's kappa > .80 for the different scenarios
Martin et al., 2005	Answer to a novel (transfer) question on course exam. Points given for partially correct answer (1) and for reasonable and justified answer (2). Points also given if the student considered multiple perspectives in his/her answer (1).	Interrater reliability = .93
Martin et al., 2006	Test scores on adaptive expertise problems (transfer problems which students have not learned how to solve). Points given for factual knowledge and "innovation" (correct identification of possible solutions steps and information needed)	Not reported
Neal et al., 2006	Test scores on cases presented after the training session. Answers coded regarding classification accuracy, classification reaction time and confidence of response.	Not reported
Pandy et al., 2004	Amount of factual, conceptual and transfer of knowledge on questions. Answers were coded as novice (only factual knowledge), proficient (factual and conceptual knowledge) and expert (factual, conceptual and transfer knowledge). Adaptive expertise scores were given based on a weighted score of each form of knowledge	Not reported
Rayne et al., 2006	Score on transfer problem. 0 for not using multiple perspective and 1 for using multiple perspective	Interrater reliability > .9
Peer/supervisor/self-assessment instrument		
Allworth & Hesketh, 1999	Supervisor rating Graphical Distributional Performance Rating	Alpha = .93
Blickle et al., 2011	Peer-assessment Instrument developed by authors	Alpha = .86
Charbonnier-Voirin et al., 2010	Self-assessment Instrument developed by Pulakos et al. (2000); 19 items	Alpha = .87
Griffin & Hesketh, 2003	Supervisor rating Instrument developed by Pulakos et al. (2000); 20 items	Alpha for Organization A = .97 Alpha for Organization B = .98
Han & Williams, 2008	Supervisor rating Instrument developed by Pulakos et al. (2000); 12 items	Alpha = .96
Neal et al., 2012	Supervisor rating Instrument developed by Griffin et al. (2007)	Alpha = .93
Pulakos et al., 2002	Supervisor rating Instrument developed by Pulakos et al. (2000); 24 items	Alpha = .97
Schraub et al., 2011	Self-assessment Instrument developed by Pulakos et al. (2000); 6 items	Alpha = .76
Zhang et al., 2012	Self-assessment Instrument developed by Schmitt, Cortina, Ingerick, and Wiechmann (2003); 6 items	Alpha = .54

Table 3
Research question 1: What learner characteristics (knowledge, skills, regulation processes, and past experience) influence adaptive expertise?

	Domain knowledge	Skill	Regulation process	Past experiences
Allworth & Hesketh, 1999		Abstract reasoning ($r = .33$, $p < .005$) Clerical speed and accuracy ($r = .25$, $p < .005$) Numerical reasoning ($r = .17$, $p < .05$)	Goal setting/effort (n.s.) Self-efficacy (n.s.)	Experience of change ($r = .14$, $p < .05$) Customer service experience (n.s.) Experience with people (n.s.) Experience dealing with change (n.s.)
Barnett & Koslowski, 2002	Education (n.s.) Business education (n.s.) Business consulting experience ($F(1, 28) = 4.2$, $p < .05$)	Deep/theory based reasoning ($F(1, 28) = 13$, $p = .001$)		
Bell & Kozlowski, 2008	Basic knowledge ($r = .50$, $p < .01$) Strategic knowledge ($r = .38$, $p < .01$)	Cognitive ability ($r = .49$, $p < .01$) Analogical transfer ($r = .60$, $p < .01$)	Self-efficacy ($r = .29$, $p < .01$)	
Blickle et al., 2011		GMA (n.s.) political skills ($r = .32$, $p < .01$)		
Chen et al., 2005	Knowledge ($r = .41$, $p < .01$)	Skills ($r = .62$, $p < .01$)	Goal choice activities ($r = .13$, $p < .05$) Goal striving activities ($r = .31$, $p < .01$) Self-efficacy ($r = .30$, $p < .01$)	
Griffin & Hesketh, 2003		Cognitive flexibility (n.s.; n.s.[a])	Self-efficacy (n.s.; $r = .38$, $p < .01$)	
Han & Williams, 2008				Experience with learning activities ($r = .23$, $p < .01$)
Hughes et al., 2013	Knowledge ($r = .46$, $p < .01$)	GMA ($r = .35$, $p < .01$)	Self-efficacy ($r = .19$, $p < .05$)	
Pulakos et al., 2002		AFQT (armed forces qualification test) ($r = .14$, $p < .05$)	Achievement motivation ($r = .31$, $p < .05$)	Emergencies – experience (n.s.) Stress – experience (n.s.) Problem-solving – experience ($r = .11$, $p < .05$) Change – experience ($r = .16$, $p < .05$) Learning – experience ($r = .24$, $p < .05$) Interpersonal experience (n.s.) Cultural experience ($r = .15$, $p < .05$) Physical experience ($r = .17$, $p < .05$)
Rayne et al., 2006	Prior knowledge × Time ($X^2(3, N = 106) = 10.1$, $p < .05$.			
Reder & Schunn, 1999		Inductive reasoning ($r = .46$, $p < .003$)		
Schraub et al., 2011			Psychological strain ($r = -.36$, $p < .01$)	
Stokes et al., 2010		Cognitive ability ($r = .25$; $p < .01$)	Self-efficacy ($r = .24$, $p < .01$)	

Notes: Unless stated otherwise, all correlation values are reported with post-test measurements.
[a] Results are reported for the two analyzed organization individually. The first number refers to Organization A, and the second to Organization B.

they were asked to retrieve information. If such situations mainly include common problems in a typical drill-and-practice format, their knowledge representation favors routine problem solving over novel problem solving (Schwartz et al., 2005). Adaptive expertise was measured in the final exam through a question addressing a problem not discussed in class. Students were labeled as having 'adaptive expertise' if they used multiple perspectives when solving the problem. The authors report less development for students with more prior knowledge ($X^2(3, N = 106) = 10.1$, $p < .05$). They argue that this is due to the knowledge representations of students with more prior knowledge. The standard situations in which students had to apply their knowledge have favored an *organization* of the knowledge, which is detrimental for problems requiring the use of multiple perspectives. The prior education of students consisted of traditional drill-and practice format, which taught students to recognize key characteristics of the situation and apply one solution method to it. The adaptive expertise question in the final exam did not provided those recognizable characteristics, thus students were not able to select the solution method. In addition, their prior training has discouraged the use of multiple solution paths, thus creating a strict knowledge organization

without links between multiple concepts. While the authors did not mention other representational characteristics the same argument can be applied to the abstraction and consolidation of knowledge. Thus the negative impact of prior knowledge on adaptive expertise described above can also be applied to the abstraction and consolidation of domain knowledge.

Bell and Kozlowski (2008) differentiate between declarative knowledge and contextual knowledge. In their simulation exercise they reported that declarative knowledge relates more strongly to adaptive expertise than contextual knowledge ($r = .50$, $d = 1.15$ and $r = .38$, $d = .82$ respectively, $p < .01$). It could be that the declarative knowledge can be easier applied to new situation, as it is more abstract than contextual knowledge.

Lastly, Barnett and Koslowski (2002) compared the importance of domain-specific knowledge from two different fields for adaptive expertise. They compared whether knowledge in restaurant management is more important than knowledge in business consulting to solve a novel problem in the domain of restaurant management. Through think-aloud protocols the performance of business consultants, restaurant managers, and business students was compared with the answer given by two experts (professors who specialize and have experience in restaurant management in addition to broader business experience). The results reveal that business-consulting experience predicted overall performance ($F(1, 28) = 4.2$, $p < .05$). The authors suggest that business consultants, by working on a variety of problems, have achieved high levels of abstraction in their knowledge representation, allowing them to apply their knowledge flexible and deal with novel problems.

Chen et al. (2005) researched the impact of flight-simulation skills (pilot and gunner skills) on adaptive expertise. In addition to measuring domain specific knowledge, the authors also investigated the impact of domain specific skills on adaptive expertise. Domain experts rated the performance of pilots and gunners. The authors reported a positive relation between domain specific skills and adaptive expertise ($r = .62$, $p < .01$, $d = 1.57$), measured by the participants' performance during the more complex adaptive expertise session.

The following conclusions regarding domain specific knowledge and skills can be made: Firstly, knowledge extent is important for adaptive expertise. Secondly, the manner in which this body of knowledge is organized plays an even greater role for adaptive expertise. Adaptive expertise results in the organization of knowledge, which makes it easy to be applied to various situations. Thus the knowledge representation, in terms of organization, abstraction, and consolidation, is de-contextualization, weakening the link between situation and solution. Through this, it is easier for individuals to apply a known solution to a new situation. Therefore, declarative knowledge has a stronger impact on adaptive expertise than contextual knowledge.

3.2.2. Domain-independent skills

Several studies report on domain-independent skills such as cognitive flexibility and analogical problem solving. Griffin and Hesketh (2003) analyzed the impact of cognitive flexibility, measured by a test for change in problem-solving strategies in a multinational IT company (organization A) and a large public service organization (organization B). The authors define cognitive flexibility as the ability to change one's response in accordance with changes in the environment by disregarding the previous response pattern and creating a new one. No significant relationship between cognitive flexibility and adaptive expertise was reported; however, the authors stipulate that this may be due to the low variance in cognitive flexibility, which reduced the strength of the correlation.

This argument for the absence of significant result is supported by the findings of Bell and Kozlowski (2008), who investigated the impact of analogical problem solving (i.e., the ability to transfer skills to a context which differs on surface characteristics but shares the same deeper characteristics) on adaptive expertise. The results of their simulation study show that being able to draw analogies between situations relates to adaptive expertise ($r = .60$, $p < .01$, $d = 1.50$). This is further supported by the findings of Barnett and Koslowski (2002) who showed that performance level could be traced back to the amount of deep/theory based reasoning ($F(1, 28) = 13$, $p < .01$), mediating the impact of consulting experience on adaptive expertise. Thus the higher performance of business consultants was not due to their experience in business consulting, but due to their reasoning skills.

Researchers use various terms to refer to a general set of cognitive abilities, for example, analytical skills and inductive reasoning skills. Blickle et al. (2011) studied cognitive abilities and adaptive expertise at the workplace, but could not find a significant relation between these two variables. The authors cite a possible ceiling effect for their non-significant results, as their participants were part of the top 17% of the US population with regard to cognitive abilities. In contrast, other studies report a positive relationship between adaptive expertise and various measures of cognitive abilities: The armed forces qualification test, an entry test for armed forces measuring general cognitive abilities ($r = .14$, $p < .05$, $d = .28$; Pulakos et al. 2002), general math, verbal, and analytical skills ($r = .25$, $p < .01$, $d = .51$; Stokes, Schneider, & Lyons, 2010), abstract reasoning ($r = .33$, $p < .005$, $d = .70$; Allworth & Hesketh, 1999), clerical speed and accuracy measuring the ability to perceive detail ($r = .25$, $p < .005$, $d = .51$; Allworth & Hesketh, 1999), numerical reasoning ($r = .17$, $p < .05$, $d = .34$; Allworth & Hesketh, 1999), inductive reasoning ($r = .46$, $p < .003$, $d = 1.02$; Reder & Schunn, 1999), general cognitive abilities as measured by the SAT or ACT test ($r = .49$, $p < .01$, $d = 1.12$; Bell and Kozlowski, 2008), and general mental abilities as measured by the Raven Advanced Progressive Matrices ($r = .35$, $p < .01$, $d = .74$; Hughes et al., 2013).

Blickle et al. (2011) investigated the influence of political skills, that is, the ability to use ones knowledge about others' work to influence their action for achieving personal and/or organizational goals, on adaptive expertise. The authors reported a positive correlation ($r = .32$, $p < .01$, $d = .67$) of political skills with adaptive expertise.

The findings presented in the above section supports the hypothesis that analogical problem solving skills and abstract reasoning skills positive relate to adaptive expertise. The ability to represent problems in such a way that analogies between

domains can be made makes it possible to find solutions for novel problems. In addition, general cognitive abilities as measured through various instruments relate to adaptive expertise. The role of domain-dependent skills and political skills has only been investigated in one study, making it difficult to generalize from the results.

3.2.3. Regulation processes

Regulation encompasses cognitive, affective and behavioral processes through which learners monitor their learning processes and the progress they make (Cannon-Bowers & Bowers, 2009). The investigated regulation processes in the context of adaptive expertise are self-efficacy, goal-setting and goal achievement, and regulation of emotions.

3.2.3.1. Self-efficacy. Two different measures of self-efficacy were reported: Self-efficacy for the task (confidence in the ability to perform the required task) and self-efficacy for dealing with change (confidence in the ability to deal with changes). Bell and Kozlowski (2008), Chen et al. (2005), Hughes et al. (2013), and Stokes et al. (2010) measured self-efficacy for performing a simulation task after the training period and report a moderately positive correlation between self-efficacy and adaptive expertise (in order, $r = .29$, $p < .01$, $d = 1.31$; $r = .30$, $p < .01$, $d = .63$; $r = .19$, $p < .05$, $d = .38$; $r = .24$, $p < .01$, $d = .49$). Regarding self-efficacy for change a positive and significant correlation is only reported for organization B in the study of Griffin and Hesketh (2003; $r = .38$, $p < .01$, $d = .81$). As participants of organization B had tenure for a period of only 7 months, compared to tenure of more than 5 years for participants in organization A, it is possible that a relationship between self-efficacy for change and adaptive expertise is only present when participants are still in a stage of transition. Allworth and Hesketh (1999) also investigated self-efficacy for change, but they reported a non-significant correlation with adaptive expertise. The authors do not further elaborate on this finding.

3.2.3.2. Goal-setting and goal achievement. Allworth and Hesketh (1999) collected self-assessment scores of hospitality employees' ability to set goals and the effort to reach them in three different contexts (work; school, university or college; home, leisure or community). They report a non-significant relationship between goal-setting and adaptive expertise. By combining these three contexts in one instrument the effect of goal-setting on adaptive expertise in the work context may have been blurred. Other studies have taken care of using only one context in their measurement instrument. Chen et al. (2005) focused their measurement of goal choice (an individual's decision of how to allocate effort to various team goals) and goal striving (an individual's effort to reaching various team goals) on the work contexts and reported a positive correlation with adaptive expertise ($r = .13$, $p < .05$, $d = .26$ for goal choice, and $r = .31$, $p < .01$, $d = .65$ for goal striving). Pulakos et al. (2002) measured achievement motivation (the desire to master tasks beyond the expectations of others), and reported a positive relationship between achievement motivation and adaptive expertise ($r = .31$, $p < .05$, $d = .65$).

3.2.3.3. Emotional regulation. One study focused on regulating emotions, which interfere with solving novel problems. Schraub, Stegmaier, and Sonntag (2011) analyzed the impact of not being able to deal with possible negative emotions related to change. They reported a negative correlation between psychological strain (i.e., cognitive and emotional irritation as a result of changes in the workplace) and adaptive expertise ($r = -.36$, $p < .01$, $d = .77$).

The reviewed studies provide evidence that a number of regulation processes are important for adaptive expertise. Self-efficacy for the task as well as goal-setting and achievement seem to have a positive impact on the ability to deal with novel problems. Emotional regulation needs to be further researched before the results can be generalized.

3.2.4. Past experience

Pulakos et al. (2002) and Alloworth and Hesketh (1999) analyzed amongst other things the relation of experience with change (past experiences with unpredictable situation) and interpersonal experience (prior experience with dealing with other people and their viewpoints) on adaptive expertise. Experience with change was positively and significantly correlated in both studies ($r = .16$, $p < .05$, $d = .32$; Pulakos et al., 2002, and $r = .14$, $p < .05$, $d = .28$; Allworth and Hesketh (1999), and interpersonal experience had no significant relationship with adaptive expertise in both studies.

Pulakos et al. (2002) and Han and Williams (2008) analyzed how experience with various learning activities relates to adaptive expertise. Both report a positive correlation between past experience with learning activities and adaptive expertise ($r = .24$, $p < .05$, $d = .49$ and $r = .23$, $p < .01$, $d = .47$ respectively).

Pulakos et al. (2002) also studied other types of experiences and reported the following correlations with adaptive expertise: Experience with problem-solving ($r = .11$, $p < .05$, $d = .22$), experience with different cultures ($r = .15$, $p < .05$, $d = .30$), experience with physical-oriented adaptability (experiences with extreme heats/colds, strenuous or physically demanding tasks, etc.) ($r = .17$, $p < .05$, $d = .34$), experience with emergencies (non-significant), and experience with stress (non-significant).

Allworth and Hesketh (1999) also analyzed other experience: Dealing with change (positive and negative copying strategies and finding support to deal with the change) and job related experience (customer service). None of them correlated with adaptive expertise.

The results regarding past experience indicate that unpredictable situations and experience with learning activities are beneficial for adaptive expertise, whereas experience with other people do not influence adaptive expertise. Other forms of experiences have not been sufficiently studied to draw conclusions.

Table 4
Research question 2: What personality factors influence adaptive expertise?

	Personality characteristics
Allworth & Hesketh, 1999	Agreeableness (n.s.) Conscientiousness (n.s.) Extroversion (n.s.) Openness to experience (n.s.) Emotional stability (n.s.)
Blickle et al., 2011	Agreeableness (n.s.) Conscientiousness (n.s.) Extroversion ($r = .28$, $p \leqslant .01$) Neuroticism (n.s.) Openness to experience (n.s.)
Griffin & Hesketh, 2003[a]	Openness to experience (n.s.; $r = .28$, $p < .05$) Change receptivity (n.s.; $r = .30$, $p < .05$) Conscientiousness (n.s.; n.s.)
Martin et al., 2006	Adaptive beliefs – Exam 1 ($r = .27$, $p = .04$) Adaptive beliefs – adaptive expertise development ($r = -.30$, $p = .03$)
Neal et al., 2012	Openness to experience (n.s.) Agreeableness (n.s.) Extraversion (n.s.) Conscientiousness ($r = .09$, $p < .01$) Neuroticism (n.s.)
Pulakos et al., 2002	Openness to experience (n.s.) Emotional stability ($r = .18$, $p < .05$)
Schraub et al., 2011	Emotional stability ($r = .40$, $p < .01$)
Stokes et al., 2010	Conscientiousness (n.s.) Neuroticism (n.s.) Openness to experience (n.s.)
Zhang et al., 2012	Conscientiousness ($r = .17$, $p < .05$)

Notes: Unless stated otherwise, all correlations are reported with post-test measurements.
[a] Results are reported for the two analyzed organization individually. The first number refers to Organization A, and the second to Organization B.

Table 5
Characteristics of studies analyzing personality factors. 2011

Study	Context	Predictor Variable	Dependent Variable
Allworth & Hesketh (1999)	Hotel industry	Goldberg's adjective checklist	Supervisor rating Graphical Distributional Performance Rating
Blickle et al., 2011	Various industries	NEO-FFI; German Version	Peer-assessment Instrument developed by authors
Griffin & Hesketh, 2003	IT and public service companies	IPIP	Supervisor rating Instrument developed by Pulakos et al. (2000)
Neal et al., 2012	Government agency	IPIP	Supervisor rating Instrument developed by Griffin et al. (2007)
Pulakos et al., 2002	Military	Own instrument	Supervisor rating Instrument developed by Pulakos et al. (2000)
Schraub et al., 2011	Various industries	TIPI-G; German version	Self-assessment Instrument developed by Pulakos et al. (2000)
Stokes et al., 2010	Simulation study	IPIP	Performance score of a more complex tasks than during training trials
Zhang et al., 2012	Various Chinese business	Based on 3 subscales of the CPAI-2	Self-assessment Instrument developed by Schmitt et al. (2003)

3.3. What personality factors influence adaptive expertise?

Personality factors are widely researched in the job performance field. These consist of the Big Five factors (agreeableness, conscientiousness, extraversion, emotional stability/neuroticism, and openness to experience) and adaptive beliefs. Table 4 provides the summary of the results.

The Big Five personality factors are (1) agreeableness, (2) conscientiousness, (3) extraversion, (4) emotional stability/neuroticism, and (5) openness to experience (Goldberg, 1990). Of these factors only agreeableness (described by adjectives such as good-natured and cooperative) had consistent non-significant effects on adaptive expertise in three studies (Allworth & Hesketh, 1999; Blickle et al., 2011; Neal, Yeo, Koy, & Xiao, 2012).

Neal et al. (2012) and Zhang, Zhou, Zhang, and Chen (2012) are the only two studies which reported a positive correlation between conscientiousness (understood as people who are organized, careful and practical) and adaptive expertise ($r = .09$,

$p < .01$, $d = .18$ and $r = .17$, $p < .05$, $d = .34$ respectively). Allworth and Hesketh (1999), Blickle et al. (2011), Griffin and Hesketh (2003), and Stokes et al. (2010) report a non-significant correlation. The studies differ in various aspects as summarized in Table 5.

Neal et al. (2012) conducted their research with a governmental sample whose work context may have posed a greater need for conscientiousness than in the other studies done in a western work setting. The positive correlation between conscientiousness and adaptive expertise may thus be context and culturally dependent.

The contextual and cultural argument for divergent results could also be applied to the reported findings for extraversion (being talkative, outgoing and assertive). While Allworth and Hesketh (1999) and Neal et al. (2012) reported non-significant correlations, Blickle et al. (2011) reported a positive relation between extraversion and adaptive expertise ($r = .28$, $p < .01$, $d = .58$). The participants were alumni of a German business school who graduated at least 5 years earlier. It could be that in their work environment extraversion was particularly important, which is demonstrated through the positive significant correlation.

Regarding openness to experience (the desire to experience new situations), a positive and significant correlation was only reported by Griffin and Hesketh (2003) for organization B in which participants has tenure for less than one year ($r = .28$, $p < .05$, $d = .58$). Murphy (1989) suggests that the impact of personality factors on performance differs between transition stages and maintenance stages. Transition stages are characterized by adoption to new environments or rules, whereas employees can focus on their daily tasks during the maintenance stages. Therefore, this effect may not have been present in the other studies showing non-significant correlations (Allworth & Hesketh, 1999; Blickle et al., 2011; Neal et al., 2012; Pulakos et al., 2002; Stokes et al., 2010).

Lastly, for emotional stability/ neuroticism (the ability to stay calm when confronted with difficult situations) most studies report a non-significant correlation (Allworth & Hesketh, 1999; Blickle et al., 2011; Neal et al., 2012; Stokes et al., 2010). Only Pulakos et al. (2002) and Schraub et al. (2011) report a positive correlation ($r = .18$, $p < .05$, $d = .37$ and $r = .40$, $p < .01$, $d = .87$ respectively). As described in Table 5, these two studies do not share similar contextual features. Also the argument of tenure suggested by Griffin and Hesketh (2003) does not apply, as participants in all studies were in the maintenance stage.

While the Big Five are often included in job performance studies, the presented results demonstrate that their influence on adaptive expertise is not straightforward. Le et al. (2011) demonstrate that a curvilinear relationship between personality factors and job performance exist. It is possible that this non-linearity also applies to the relation of personality to adaptive expertise, but this has not yet been researched.

Griffin and Hesketh (2003) proposed a more narrowly defined concept of change-receptivity (enjoying working in an environment which is characterized by change) as a better indicator for an individual's affinity for unfamiliar situations than openness to experience. Their results show a positive correlation in one of the studied organizations ($r = .30$, $p < .05$, $d = .62$). However, the authors argue that this relation only holds if the person is in a transition stage, as tenure can moderate the influence certain variables have on performance (Murphy, 1989). However, as discussed above, this argument needs further research to ascertain its validity.

Martin et al. (2006) investigated the impact of adaptive beliefs, the belief that expertise is dynamic and not stable, on the development of adaptive expertise. Development of adaptive expertise was measured at the beginning, middle and end of the course through the difference in examination scores on the 'adaptive expertise question', a domain specific problem not discussed in class. Martin et al. (2006) reported that adaptive beliefs were related to the adaptive expertise score during the first assessment ($r = .27$, $p = .04$, $d = .55$), and that students with the lowest adaptive beliefs showed the largest improvement in adaptive expertise ($r = -.30$, $p = .03$, $d = .62$). The authors argue that this development is due to the active learning format of the course, which moderates the impact of adaptive beliefs on adaptive expertise. The students with the highest adaptive beliefs already had high scores on the adaptive expertise task, thus limiting the amount they could develop.

The second research question dealt with personality factors related to adaptive expertise. The results show that the influence of personality characteristics is not clear. Possible reasons could be the contextual differences between studies, the difference in measurement instruments or a curvilinear relationship between personality and adaptive expertise. Regarding the impact of adaptive beliefs, as only one study investigated this variable, conclusion cannot be made.

3.4. What task and training characteristics influence adaptive expertise?

The following task and training characteristics will be described in this section: star.legacy cycle, error training, exception training, exploratory learning, error framing, and emotional-control strategy, autonomy, work requirements, complexity and task interdependence. Table 6 summarizes the results.

3.4.1. Training characteristics

Different instructional methods were analyzed for their impact on adaptive expertise. The common thread in these methods is that students are stimulated to explore and discover. Martin, Rayne, Kemp, Hart, and Diller (2005), Martin et al. (2006), Pandy, Petrosino, Austin, and Barr (2004), and Bell and Kozlowski (2008) studied instructional methods that focus on self-directed learning. Martin et al. (2005, 2006) and Pandy et al. (2004) analyzed the influence of a new course design (star.legacy) on adaptive expertise. This format uses an active learning approach in which students are given a problem for which they have to find a solution and present it to class. Adaptive expertise was measured through a weighted formula consisting of students' score on the factual (10%), conceptual (40%) and transfer (50%) assessment rubric. Pandy et al. (2004) report that

Table 6
Research question 3: What task and training characteristics (e.g., instruction, task complexity) influence adaptive expertise?

	Task characteristics
Bell & Kozlowski, 2008	Unguided exploratory learning ($F(1, 342) = 8.88$, $p < .01$) Error encouragement frame ($F(1, 342) = 3.19$, $p < .10$) Emotional control strategy (n.s.)
Griffin & Hesketh, 2003[a]	Work requirements (n.s.; $r = .34$, $p < .01$) Autonomy (n.s.; n.s.) Complexity ($r = .34$, $p < .01$; not measured)
Hughes et al., 2013	Error encouragement frame (n.s.) Error discouragement frame (n.s.) Practice difficulty ($r < .46$, $p < .01$)
Joung et al., 2006	Learning from errors ($F(1, 57) = 7.44$, $p < .05$)
Martin et al., 2005	HPL course design ($X^2(1, 30) = 4.82$, $p = .03$)
Martin et al., 2006	Problem type ($F(3, 169) = 33.5$, $p < .001$)
Neal et al., 2006	Instruction × Exception type ($F(1,87) = 9.83$, $p < .05$)
Pandy et al., 2004	HPL course design ($t = 1.962$, $p < .05$ one-tailed p-value)
Schraub et al., 2011	Autonomy ($r = .28$, $p < .01$) Task interdependence ($r = .22$, $p = .01$)

Notes: Unless stated otherwise, all correlation values are reported with post-test measurements.
[a] Results are reported for the two analyzed organizations individually. The first number refers to Organization A, and the second to Organization B.

the new course design led to significantly higher test scores on the adaptive expertise question than the traditional teaching format ($t = 1.96$, $p < .05$, $d = .82$).

Martin et al. (2005) also report that the new course design led to an increase in adaptive expertise, measured through the increased use of multiple perspectives when solving unfamiliar problems ($X^2(1, 30) = 4.83$, $p = .03$, $d = .85$). Martin et al. (2006) investigated students' performance on three types of problems assessed at the beginning, middle and end of the course: A knowledge problem to measure students' factual knowledge, an innovation problem to measure the effort a student put into solving a novel problem, and an adaptive expertise problem which looked at the accuracy of the solution in addition to effort. The authors reported an interaction effect between problem type and time: Scores on knowledge and innovation problems improved from the beginning to the middle of the course, followed by an increase in adaptive expertise from midway of the course toward the end ($F(3,169) = 33.5$, $p < .001$). These findings suggest that adaptive expertise can only develop once the factual knowledge (as measured by the knowledge problem) and the motivation to solve new problems (as measured by the innovation problem) is present.

Bell and Kozlowski (2008) used a simulation game to analyze the impact of different instructional methods on adaptive expertise. Two forms of exploratory instruction were investigated: Unguided exploration (participants were asked to explore and experiment to discover the best strategy for solving the problem) and proceduralized instructions (detailed step-by-step instructions were given to participants on how to perform the task). Unguided exploration yielded higher performance than proceduralized instructions on the adaptive expertise task, a task more complicated than the training task ($F(1, 342) = 8.88$, $p < .01$, $d = 1.27$). Next to exploratory training, the authors also investigated the impact of emotional-control instructions (participants were given training on how to deal with anxiety and frustration). However, no effects of emotional-control instructions on adaptive expertise were found.

Learning by errors was investigated as another instructional method. Hughes et al. (2013) used a combat simulation task and compared error-encouragement with error-avoidance instructions. They report non-significant correlations between the two framing conditions and adaptive expertise. Bell and Kozlowski (2008) used the same two error-learning condition (error-encouragement and error-avoidance), however participants received information on how their errors relate to the knowledge and skills being practiced. Only participants in the error-encouragement conditions showed marginally significant higher adaptive expertise ($F(1,342) = 3.19$, $p < .10$, $d = .76$).

Joung et al. (2006) also compared the effect of error training and non-error training on adaptive expertise. Like Bell and Kozlowski (2008) they provided participants with information on how errors relate to practiced knowledge and skills. In contrast to Hughes et al. (2013) and Bell and Kozlowski (2008), they did not frame errors as being good or bad for learning, but simply included errors in one training condition. Error-training consisted of case studies in which the protagonist made errors in fire incident management. The authors reported a positive effect of error training on adaptive expertise during case study assessment ($F(1, 57) = 7.44$, $p < .05$, $d = .71$).

Neal et al. (2006) researched the influence of exception training. This form of training is similar to error training in that participants are instructed to recognize situational cues in which applying standardized procedures results in errors. Thus, the goal is to avoid errors by recognizing non-routine situations. The authors examined whether exception training (alerting trainees to exceptions to the rules of fire behavior and management) results in better performance on near and far exception exercise items. Near exception items contained similar features as presented during the training session, whereas far exception items presented a new situation to the participants with no familiar features. The results showed that trainees receiving the exception training performed better on near exception items, whereas trainees in the control group performed better on

far exception items ($F(1, 87) = 9.83$, $p < .05$, $d = .51$). The authors suggest that the exception training may force participants to focus on conditions, which signal exceptional situations. These conditions were easily recognizable in the near exception items but not in the far exception items. The far exception items may have triggered control group participants to elaborate on the differences between training and performance cases and thus recognize the unusual situation.

The different instructional methods presented in this section demonstrate that adaptive expertise benefits from training situations in which participants are responsible for building their knowledge, as in the star.legacy course design format or in unguided exploration. The studies using error-training demonstrated that the benefits of making errors lies in getting a better understanding of the domain by connecting the errors to the to-be-learned knowledge and skills. The benefits of error-training is limited if participants are provided with guidelines for recognizing situation when the to-be-learned knowledge and skills is insufficient, as shown in the exception training study.

3.4.2. Task characteristics

Griffin and Hesketh researched task complexity (how complicated task and work decisions are) and reported a positive correlation between complexity and adaptive expertise ($r = .34$, $p < .01$, $d = .72$). Schraub et al. (2011) looked into task interdependence (the degree to which employees have to work closely together with colleagues to reach their goals) and reported a moderately positive correlation with adaptive expertise ($r = .22$, $p < .01$, $d = .45$).

Hughes et al. (2013) analyzed task difficulty. The authors let participants decide on the difficulty level of the combat simulation exercise during practice trials and reported a positive correlation between practice difficulty and adaptive expertise ($r = .46$, $p < .01$, $d = 1.03$).

Next to task complexity, autonomy (i.e., the degree to which participants are allowed to decide how to accomplish tasks and change the status quo) was studied. Schraub et al. (2011) report a moderately positive correlation between autonomy and adaptive expertise ($r = .28$, $p < .01$, $d = .58$), whereas Griffin and Hesketh (2003) report a non-significant correlation. It is unclear why the two studies report divergent results: In both cases, the sample is diverse and both studies make use of the instrument developed by Pulakos et al. (2000). However, Pulakos et al. (2000) do not publish the instrument; only provide definition for the various dimensions. As a result, researchers using this instrument develop their own items and chose which dimensions they want to include. This reduces the ability to compare studies using the instrument. In this case, the different focus of the two studies (Schraub et al. (2011) studying psychological strain and Griffin and Hesketh (2003) career adjustment) directed the authors to transform the instrument to suit their research interest.

Lastly, Griffin and Hesketh (2003) also studied the relation of job requirements (i.e., the extent to which the job requires to be adaptive) on adaptive expertise. The authors report a non-significant correlation between level of job requirements and adaptive expertise for organization A, but a positive correlation for organization B ($r = .34$, $p < .01$, $d = .72$). They suggest that the extent that a job requires to be adaptive is only associated with adaptive expertise in transition stages. Given that no other studies in this review investigated the impact of work requirements and, no clear support for or against the authors' claim can be provided.

The third research question looked at task and training characteristics influencing adaptive expertise. Task exploration and error-encouragement have a positive relation with adaptive expertise. A common denominator of the task characteristics is a higher chance of making errors. Those factors could thus have a positive relation to adaptive expertise, if errors are connected to domain knowledge. No conclusion is being made regarding the characteristic of task interdependence as not enough evidence is presented.

3.5. What characteristics of the learning climate influence adaptive expertise?

A learning climate reflects the norms and behaviors of individuals and their supervisors who work in the same setting (Pirola-Merlo, Härtel, Mann, & Hirst, 2002). The findings are summarized in Table 7.

Learning activities of professionals can be divided into formal and informal learning activities. Informal learning activities can further be divided into activities with the explicit goal of learning (deliberate learning) and those without the explicit goal of learning (implicit learning; Eraut, 2000). Han and Williams (2008) investigated the relation of team learning climate (openness to change and new ideas, tolerance of mistakes, expectations of high performance/accountability) with adaptive expertise. The wording of the survey items suggests that they perceived team learning to promote deliberate learning. They report a moderately positive correlation between team learning climate and adaptive expertise ($r = .20$, $p < .01$, $d = .41$). Charbonnier-Voirin, El Akremi, and Vandenberghe (2010) analyzed the impact of implicit learning measured by the climate for innovation (stimulation of employees to develop new solutions and work methods). They report a non-significant correlation between climate for innovation and adaptive expertise.

Two factors related to supervisor behavior – management support and transformational leadership – were studied. Both factors deal with superiors' characteristics of creating a supportive work environment in which employees feel valued. Griffin and Hesketh (2003) report a moderately positive correlation between available management support (approachable, encourages people, organizes help) and adaptive expertise ($r = .20$, $p < .01$, $d = .41$). Thus higher managers' support is related to higher levels of adaptive expertise. Charbonnier-Voirin et al. (2010) studied whether transformational leadership is related to adaptive expertise. Transformational leaders value employees' interests and opinions for the development of the vision and direction of the work unit and support their professional development. Their findings indicate that transformational leadership is also positively related to adaptive expertise ($r = .44$, $p < .01$, $d = .97$).

Table 7
Research question 4: What characteristics of the learning climate (e.g., tolerance of mistakes, supervision) influence adaptive expertise?

	Environment
	Team climate
Charbonnier-Voirin et al., 2010	Climate for innovation (n.s.)
Han & Williams, 2008	Learning climate ($r = .20$, $p < .01$)
	People
Charbonnier-Voirin et al., 2010	Transformational leadership ($r = .44$, $p < .01$)
Griffin & Hesketh, 2003[a]	Management support ($r = .20$, $p < .01$; not measured)

Notes: Unless stated otherwise, all correlation values are reported with post-test measurements.
[a] Results are reported for the two analyzed organization individually. The first number refers to Organization A, and the second to Organization B.

While the limited amount of studies on learner behaviors and adaptive expertise makes it difficult to generalize the presented findings, regarding supervisor behavior it is suggested that employees whose managers value them and support their work and development have higher levels of adaptive expertise. No conclusion is made about learning climate as more evidence is needed to make sense of the results.

4. Discussion

The frequent changes in the current work environment driven by task and knowledge volatility (Howard, 1995; Molloy & Noe, 2009; Tannenbaum, 2001) calls for experts who possess the required domain expertise and can quickly overcome changes. Such experts are known as possessing adaptive expertise (Hatano & Inagaki, 1986). To further the understanding of the concept, this review set out to synthesize the findings about adaptive expertise in terms of its characteristics (research questions 1 and 2) and development (research questions 3 and 4). Twenty-one studies conducted in various settings were included. The original conceptualization of adaptive expertise can be refined in the following point, addressed by the first two research questions: Adaptive expertise has similar, but not the same, basic components than routine expertise. They share the same *extent* of domain knowledge and skills, but differ in their knowledge representation. These representational differences have been shown to lie within the organization and abstraction of knowledge. Only partial support could be found for the other two points, higher meta-cognitive skills and specific abilities, mentioned in the definition of adaptive expertise: Some regulative processes have been addressed, but apart from self-efficacy to perform a task, no other factors has shown consistent result or researched often enough to allow generalization. Regarding specific abilities, the review has shown that general cognitive abilities and analogical problem solving are important elements of adaptive expertise. New characteristics of adaptive expertise not mentioned previously are the importance of being confronted with novel situations and learning new tasks. Past experience related to dealing with other people and their viewpoints does not relate to adaptive expertise.

Research questions 3 and 4 dealt with task, training, and environmental factors relevant for adaptive expertise. The review provides clear evidence that adaptive expertise is related to asking individuals to develop their own solution strategy. This may take the form of unguided exploration or other forms of active learning styles. In such learning formats the possibilities for making errors is great, which further benefits adaptive expertise if a link is made between the errors and the to-be-learned knowledge. Establishing this link leads to deeper understanding of the domain, resulting in a knowledge representation beneficial for adaptive expertise. Lastly, the findings indicate that adaptive expertise is related to supportive supervisors.

Some of the findings presented conflicting results, which could not in all cases be traced back to differences in conceptualization or operationalization of the variables. Firstly, the relation of personality factors on adaptive expertise remains unclear. Two suggestions for this inconsistency are presented: In the job performance research a curvilinear relationship between personality factors and performance exists (Le et al., 2011). It is suggested that this also holds for adaptive expertise. Another possibility is that specific work setting factors mediate the relationship between personality and adaptive expertise. Secondly, regarding autonomy at work no straightforward conclusions could be drawn. The inconsistent results could be due to the different focus (psychological strain and work adjustments), which guided the selection and wording of measurement instrument. Thirdly, the studies on learner behavior seem to suggest that deliberate learning is related to adaptive expertise, but not implicit learning. However, this suggestion is only based on the wording of the survey items and needs further research to support it.

While analyzing the studies, it became clear that adaptive and routine expertise should be related to different knowledge representations. These differences in representation result in the superior performance in novel situations. Routine expertise is limited by its lack of awareness of the context-specificity of its knowledge. In addition, they may lack cognitive and/or analogical problem solving abilities. This results in individuals with routine expertise not knowing how to deal with novel situations. This assumption is supported by the evidence presented in the third research question on task and training characteristics. Activities should stimulate learners to explore the topic and encourages errors. This allows individuals to try out different solution methods and thus gain a better understanding of the domain (Hatano & Inagaki, 1986). Variety in practice

aids the creation of a flexible knowledge base and is thus related to adaptive expertise (Hatano & Inagaki, 1986; Van Merriënboer, Jelsma, & Paas, 1992). In the same manner, a work environment which provides a variety of tasks also leads to a flexible knowledge base.

4.1. Limitations

The review faces some limitations. Firstly, studies which use the concept of adaptive expertise to make sense of their findings have been excluded. The authors made this choice to limit variance in conceptual frameworks of the reviewed studies. If adaptive expertise is used to explain findings of a study, it was not designed to measure adaptive expertise. This decision could have led that some characteristics of adaptive expertise are not included. Secondly, the various ways adaptive expertise is measured could have distorted results. Where possible these differences were taken into account. Nevertheless, some differences in result could be due to the measurement instrument. Finally, conclusions about causality cannot be made due to the lack of experimental studies using a pre-post design with control groups. While it seems logical to assume that the mentioned environmental characteristics lead to adaptive expertise, the empirical evidence only shows a relation, not a cause and effect.

4.2. Future research

In relation to the definition of adaptive expertise used by numerous authors more research is needed to verify that adaptive expertise contains higher meta-cognitive skills than routine expertise. The present review only includes limited evidence as this aspect has been largely neglected. More importantly, the knowledge representation of adaptive expertise should be further researched, as this seems to be a key difference between adaptive and routine expertise.

The literature review revealed an important conceptual gap within the field: The dimensionality of adaptive expertise. Based on a study of critical incidents in various jobs Pulakos et al. (2000) defined eight different dimensions of adaptive performance, the visible behavior from adaptive expertise. Some are closely related to the knowledge domain (e.g., learning new tasks) whereas others could be labeled 'every day' adaption (e.g., interpersonal adaption, adaption to stressful situation) as the adaption does not require domain knowledge. To further the field of adaptive expertise and keeping in line with the assumption made above on adaptive expertise's knowledge representation, the dimensions of adaption related to the knowledge domain should be focused on.

Another aspect which needs more research is the degree of adaptability one might expect from adaptive expertise. The definitions of adaptive expertise refer to "coping with change", "dealing with uncertain situations", "transfer learning as job demands vary", or "transfer expertise to novel problems", but no article describes how large the change has to be in order to demonstrate adaptive expertise and when the situation is so novel that even an individual with adaptive expertise cannot handle it. Thus, future research needs to address the domain-specificity of adaptive expertise. For example, has a medical doctor who is also a successful medical teacher adaptive expertise? Or a medical doctor who becomes a medical lawyer? Thus how strong does the link between the new and the old domain of expertise have to be in order for adaptive expertise to be manifest? While this is an important question, it is also difficult to answer: To be able to measure adaptive expertise, it is needed to clearly define the characteristics. However, to do this it is necessary to know how much difference there needs to be between the old and the new situation for adaptive expertise to become manifest.

Lastly, the development of adaptive expertise deserves further attention. This is especially important for the educational field, as it will provide further insights in how to design learning environments and tasks that support the growth of adaptive expertise. However, this need is difficult to address properly if neither the dimensions of adaptive expertise nor its degree of adaption are fully understood.

4.3. Implication

Given the current state of research on adaptive expertise the following recommendations can be made for training professionals. In formal learning settings, novelty in the form of unfamiliar tasks can be introduced after an initial level of efficiency in the domain has been achieved. Learners should be stimulated to explore these tasks, solve them with limited scaffolding, and reflect on their errors. Such novel tasks should re-occur at irregular intervals and "...create occasional *impasses* which confront the learners with situations where the [learned] routines do not work and which train them to switch from an automatic to a problem-solving mode" (van Merriënboer & Kirschner, 2013, p. 265). The trainer should pay attention to creating a risk free and supportive environment. Summative assessment should be minimalized to strengthen a positive learning climate. In informal learning settings, it is important to create a learning climate through supportive superiors and peers and to stimulate professionals to take on new tasks outside of their current job descriptions.

5. Conclusion

In this review we have synthesized the research on individual and environmental characteristics related to adaptive expertise. This advances the field by offering an empirical basis for characteristics of adaptive expertise and how they differ

from routine expertise. By establishing these characteristics, research into its development can pick up, as a concept is better rooted in evidence. The review also unearthed areas, which need further research, most importantly the knowledge representation characteristic for adaptive expertise and its degree of adaptability.

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