Dynamic performance

DYNAMIC PERFORMANCE:

THE ROLE OF TASK AND INDIVIDUAL CHARACTERISTICS

Alicia L.T. Walkowiak

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I feel the change, I see the vicious circle
Finally turned into a virtuous one
Timelessness

From: “Vacuity”, Gojira (2008)

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GENERAL INTRODUCTION

GENERAL INTRODUCTION

July 1, 2002, Überlingen, Germany. Bashkirian Airlines Flight 2937 (Tupolev Tu-154 passenger jet) and DHL Flight 611 (Boeing 757) collided in mid-air, killing all 69 passengers and crew in the Tupolev and the two crew members of the Boeing. The working conditions for the air traffic controller (ATCo) on duty at time of the crash were stressful and the situation was not comparable to a normal nightshift duty (German Federal Bureau of Aircraft Accidents Investigation, 2004). Reports of the crash (German Federal Bureau of Aircraft Accidents Investigation, 2004; Johnson, 2004) describe several factors leading to this crash, one being the fact that ATCo did not notice in time that the two aircraft were not sufficiently separated. The ATCo was working alone at the time of the crash, which is not according to regulations. The other ATCo on duty was resting; although it was against the rules, it was common practice during nightshifts and tolerated by the management. Furthermore, there was a delayed aircraft that needed to land at an airport nearby, obviously this approach also required the attention of the ATCo. When the second ATCo decided to rest for the night, neither of them was aware that they also still needed to handle this delayed flight. This was thus yet another unforeseen aspect in their work that night. Also, maintenance work was being carried out on the radar system, and because of this the ATCo had to use a fallback system that misses some of the aids that the normal system contains. In itself this is not a problem, but combined with all the other factors that played a role in causing the collision, the fallback system probably made it more difficult for the ATCo to work as effectively as he would have normally done. If the normal system would have been working at the time of the collision, then the ATCo would have received a warning by the optical collision warning system a few minutes before the crash. Another warning system did give a warning approximately 30 seconds before the collision, but this warning was not heard by anyone, probably because of the fact that not all open workstations were continuously staffed by ATCos.

Another main cause that is mentioned in the report (German Federal Bureau of Aircraft Accidents Investigation, 2004) is the fact that the crew members ignored the advice that their TCAS system gave, but followed the instructions of the ATCo instead. The TCAS is the on-board aircraft collision avoidance system, which was relatively new at that time. This might be the reason why the crew members ignored it and followed the ATCo's instructions: regulations and instruction concerning the TCAS system were not standardized, incomplete and partially contradictory (German Federal Bureau of Aircraft Accidents Investigation, 2004; Johnson, 2004). In the end, this concurrence of circumstances, some that were completely unforeseen, led to the collision between the Tupolev and the Boeing in the airspace above Überlingen, with fatal consequences.

The above example emphasizes the importance of dynamic performance. Air traffic controllers have to be able to quickly respond to their dynamic environment. Their job is dynamic in nature: ATCos have to process new information all the time, they have to communicate with different parties and via different media. Especially in stressful situations, when they are confronted with one or more unforeseen factors, as in the example of the Überlingen collision, it is highly important that ATCos can deal with unforeseen changes in an effective way. Obviously, in most of the cases ATCos are able to do so: in by far most of the cases when there are unforeseen circumstances no incidents happen during an ATCo's shift. However, it is important to study if and how the work environment of an ATCo can be further improved so that ATCos are able to cope with their increasing workload. Therefore, in this thesis I will focus on dynamic performance and I will describe the influence of both individual and task characteristics on dynamic performance.

Of course, dynamic performance is not only relevant in the setting of aviation or air traffic control (ATC); dealing with changes in work is relevant in almost every occupation. Nowadays, in the fast changing world of work, organizations face many changes such as globalization, tighter economic resources and technological changes, that require employees to be adaptive (Cascio, 2003; Ployhart & Bliese, 2006). Employees need to stay up to date to be able to cope with these rather unpredictable circumstances in their work. In work, employees need to be able to adapt, they need to be dynamic. They face changes in their work or in the organizations and they need to be able to respond properly to these changes in order to perform well at the job. Dynamic performance can be seen as a specific type of performance that changes over time, and this change can be caused by either external causes (for example an interruption or a training) or by internal causes (for example self-regulation of performance or learning processes) (Sonnentag & Frese, 2009). Performance can vary between persons, for example because of differences in learning capabilities or aging, but also within persons, for example because of differences in people's fatigue levels (Sonnentag & Frese, 2009). For employees, it is relevant to keep up to pace when being confronted with a changing work environment, for example to prevent high levels of stress or even burnout. For organizations, it is relevant to make sure that employees are able to be flexible in their work, to ensure high levels of performance. This dynamic component in work also has its consequences for selection procedures. There used to be the assumption that performance is stable (see for an overview: Sonnentag & Frese, 2009), which would be convenient since it implies that you can measure a trait in a selection procedure and the validity of that procedure would remain stable over time. However, when performance is a dynamic construct, a trait that might be predictive at first might lose its predictive value over time. Of course, this is important information for work and organizational psychologists, and that is why the topic of dynamic performance has gained more and more attention in the scientific literature, yet there are many issues still to be answered, which I will indicate later in this introduction. Of course, there are also characteristics of the job itself that might influence dynamic performance, for example task complexity (Ackerman, 1992), and these task characteristics might even interact with individual difference characteristics. Therefore, the focus of this thesis will be on the influence of both, individual and task characteristics on dynamic performance. Specifically, I will address the following question: How do characteristics of the individual and of the task influence dynamic performance? In doing so, I will give an overview of the literature on dynamic performance (chapter 2), I will describe an experiment in which I focused on skill acquisition (chapter 3) and I will describe two experiments in which I focused on a more specific form of dynamic performance, namely adaptive performance (chapters 4 and 5).

DYNAMIC PERFORMANCE

Performance can be seen as either a process by which people are working towards a goal, or as the congruence between the goal and the outcome of that process (Roe, 1999). Performance is hence a dynamic construct: How performance is dynamic over time, or changes over time, is crucial (Roe, 1999). Dynamic performance can thus be seen as a specific type of performance in which the focus is on how performance changes over time. The changes in performance are not per se a direct result of external factors, but changes take place over time, for example because of changing task characteristics or because of changes within the individual (Sonnentag & Frese, 2009). Or, as Sonnentag and Frese (2009, p.549) state: “we should hasten to add that time per se is not the important variable – rather there are processes within time that produce the effects of dynamic performance”.

ADAPTIVE PERFORMANCE

A more specific form of dynamic performance is adaptive performance, in which the focus is on how individuals respond to unforeseen changes in their work. Individuals differ in the degree to which they are able to do so and hence adaptability can be seen as the individual characteristic that predicts how well individuals respond to unforeseen changes. Ployhart and Bliese (2006) gave an overview of the role of adaptability in modern work. In their chapter they describe several forces that led to the fact that adaptability is nowadays an even more important skill than it used to be in the past. One of these factors is the technological changes that have taken place the past decades. Nowadays, employees need to work with computers in almost every job, and, although the current generation is growing up with computers, the pace at which for example software changes makes it inevitable that employees have to keep on learning new software or new systems. Another important factor is knowledge-based nature of work. It is expected that employees keep their knowledge up to date and that they not only are aware of the specific knowledge for their job. However, also broader knowledge and skills are often required, for example because people need to be able to work in large project teams and hence need to be able to work with people with different expertise and different cultural background (Ployhart & Bliese, 2006). Also, organizational competition has been growing over the last decades. Organizations merge or form alliances with other organizations, which might lead to e.g. changes in policies and procedures. Somewhat related, organizations work together internationally or expand to foreign markets. As most of these changes took place during the past 30 years, the field of research on adaptive performance is a relatively new field of inquiry (Baard, Rench, & Kozlowski, 2014; Ployart & Bliese, 2006).

Although adaptive performance is also relevant in team settings (see e.g. Burke, Stagl, Salas, Pierce, & Kendall, 2006), the focus of this thesis will be on individual adaptive performance. Adaptive job performance can be seen as a multifaceted construct and there are many types of behavior that are part of it (Pulakos, Arad, Donovan, & Plamondon, 2000). The past few years, a model of adaptive performance dimensions has been developed (Pulakos et al., 2002). The first dimension in this model is solving problems creatively, which is the aspect of adaptive performance that is related to solving ill-defined or complex problems. Although creativity can be seen as a component of adaptive performance, they are two conceptually distinct constructs. Important for adaptive performance is that solving problems creatively is just one of the components (Pulakos et al., 2000), adaptive performance is thus more than solving a problem in a creative manner. The second dimension is dealing with uncertain or unpredictable work situations. People have to be able to deal with unexpected changes in their work. Third, they distinguish learning new tasks, technologies, and procedures: Employees have to be able and willing to learn new skills for their current and for a possible future job. Fourth, people need to be able to demonstrate interpersonal adaptability: Teamwork is important for adaptive performance and employees have to be able to work together with many different types of individuals. A fifth dimension is cultural adaptability. Because many organizations work globally, employees have to be able to work together with people from different cultures and to work effectively with new traditions. The sixth dimension is physically oriented adaptability: In some jobs, employees have to be able to adapt to changes in the physical environment, such as noise. Seventh, employees have to be able to handle work stress. They have to be able to remain calm in stressful situations. The eight and last dimension is handling emergencies or crisis situations. This involves reacting to very dangerous situations.

The eight above mentioned dimensions can be seen as subdimensions of individual adaptability (see e.g. Ployhart & Bliese, 2006) and adaptability can be defined as “an individual’s ability, skill, disposition, willingness, and/or motivation, to change or fit different task, social, and environmental features” (Ployhart & Bliese, 2006, p. 13). This means that adaptability is a characteristic of the person and is not specific to just one situation, although it is influenced by specific situations. Adaptability is hence different from adaptive performance: Adaptability is a trait or characteristic of the person, while adaptive performance is the behavior that a person shows.

ADAPTABILITY IN AIR TRAFFIC CONTROL (ATC)

The trait of adaptability is especially important in highly dynamic jobs, such as the job of an Air Traffic Controller (ATCo). ATCos have to process a lot of information, for example the radar and radio communication with pilots and it is of vital importance that they can respond effectively if something changes, for example if the weather conditions suddenly change and a different runway has to be used. The ATCo has to be able to form a mental picture of the current aircraft, their main characteristics and the plan of how to handle the traffic (Niessen & Eyferth, 2001). He has to be constantly aware of this information, so that he is able to direct the aircraft to the correct runway or airport in the safest and most efficient way. The Überlingen collision, described previously in this chapter, makes clear that there can be large consequences if an ATCo is not able to deal with unforeseen factors. Of course, in by far most of the cases an ATCo will not make any mistakes and will be able to maintain her situation awareness, but more research is needed to specify which factors enable people to perform dynamically. Because of the relevance of dynamic performance in air traffic control (ATC), the studies described in this thesis focus on dynamic performance in an ATC setting.

As stated before, the fact that performance is seen as a dynamic construct has consequences for selection procedures. Therefore, it is important to know which individual difference characteristics can predict dynamic job performance, so that these can be applied in selection procedures as well as for developmental purposes in a performance management system. Of course, not only the characteristics of an individual play a role when it comes to predicting levels of job performance. Task characteristics are also relevant and might even interact with individual level characteristics. Air Traffic Controllers (ATCos) have to work in a complex and dynamic environment in which they have to safely and efficiently control air traffic. In the past decades, the amount of air traffic has steeply increased, which led to a growing work load for ATCos, so the task characteristics that influence the work of an ATCo has changed over the years. It is therefore important to think of ways how air traffic can be organized in such a way that ATCOs are able to deal with the increase of air traffic in a safe way.

SESAR AND NEXTGEN

To make sure that ATCos can continue to perform as safely and efficiently as possible, to prevent delays and to furthermore take into account the environment, several programs

have been developed to change the current system of Air Traffic Management (ATM). These include the Single European Skye ATM Research (SESAR) project in Europe and the NextGen project in the United States of America (see e.g. Brooker, 2008).

Focusing on the situation in Europe, the SESAR project aims at creating a single European sky, compared to the current situation in which the sky is fragmented and different countries are responsible for different parts of the European sky. In Europe, the airspace is very busy and there are many airports, often relatively close to each other. In 2012, there were 9.5 million flights controlled in Europe and 0.7 billion passengers. The forecast is that in 2035 there will be 14.4 million flights per year and 1.4 billion passengers (SESAR, 2018). However, these numbers were calculated before the Covid-19 crisis. Due to Covid-19, there were 81.7 % fewer flights in week 24 of this year, compared to that same week in 2019 (Eurocontrol, 2020). Schiphol Airport reports 89.9 % fewer flights and 96.8 % fewer passengers in May 2020 compared to May 2019 (Schiphol, 2020). At this point, it is not clear yet how this will develop in the near future. Eurocontrol (2020) expects that in February 2021, there will still be 15 % fewer flights compared to the year before, but of course this percentage depends on how the virus will develop in the coming months. For now, I will focus on the situation before the Covid-19 crisis.

In the current situation, the ATM systems are fragmented; the sky is divided in smaller pieces of airspace. To make the system more efficient and to reduce workload for ATCos, the idea of SESAR was born. One of the aspects of the SESAR project is to implement more new technologies to make the system more efficient. This could have implications for the job of an ATCo, because levels of automation could increase even more. If this is the case, this would mean that the job of ATCo will consist of more passive tasks, compared to the very active role that she has in the current situation. Nowadays, ATCos have an active role in communicating with other ATCos and pilots and redirecting aircraft, while in the future some of these tasks may be fulfilled by computer systems. However, the ATCo still has to be able to respond if there would be a system failure. This implicates that adaptability will become an even more important characteristic for ATCos as it is already at this moment. However, not much is known about how ATCos respond to unforeseen changes if their role in the process becomes more passive. There is some evidence suggesting that conflict detection is much more difficult when ATCos have to work with high density traffic and under passive control (Metzger & Parasuraman, 2001) and that issues as stress and boredom of ATCos will become more salient in such a situation (Langan-Fox, Sankey, & Canty, 2010). None of these studies focused on the effect of unforeseen changes on performance and the relevant cognitive processes, while this information is required to keep selection and training procedures up-to-date. Also, it is necessary to gain more insights into the influence of characteristics of the tasks, and how these interact with individual characteristics in predicting adaptive performance. To date, these questions have remained unaddressed in the literature.

THIS THESIS

As stated before, the focus of the current thesis is the influence of individual and task characteristics on dynamic performance in an ATC setting. Research on dynamic performance has mainly focused on the relevant factors at the individual level, such as conscientiousness, openness, general mental ability, self-efficacy and goal orientation (e.g. Chen, Thomas, & Wallace, 2005; Chen, 2005; Kozlowski et al., 2001; Lang & Bliese, 2009; Yeo & Neal, 2006). However, not much is known about the influence of task characteristics, although research has shown the effect of task characteristics, such as complexity and consistency, on general performance and skill acquisition (Ackerman, 1988, 2007; Ackerman & Cianciolo, 2002; Farrell & McDaniel, 2001). Therefore, in this thesis I will try to answer the following question: What are the effects of individual and task characteristics on dynamic performance, and more specifically, on skill acquisition and adaptive performance?

Chapter 2 is a theoretical overview on the topic of dynamic performance. It will highlight previous findings and important theories in the field of dynamic performance, incorporating both skill acquisition and adaptive performance. Also, I will elaborate on the definition of dynamic and adaptive performance. In this chapter I will show that there are different types of adaptive performance and I will elaborate on the different individual and task characteristics' that have an influence on adaptive performance. Also, I will stress the fact that in studies on dynamic performance the concepts 'tasks' and 'task characteristics' are often not clearly defined and I will indicate how I will define these in my following empirical chapters.

Chapter 3 describes an empirical study in which an ATC simulator was used. In this first study, we wanted to see if people show a learning curve using this task, hence focusing on skill acquisition. In this complex computer task, participants needed to detect conflicts between aircrafts, i.e. they had to predict and prevent colliding aircraft. More specifically, we studied the interaction effect of time, task complexity and general mental ability on task performance. We know from previous research (Ackerman, 1988; Ackerman & Cianciolo, 2002; Farrell & McDaniel, 2001; Lang & Bliese, 2009) that these task complexity and general mental ablity can each impact the level of performance and we were hence interested to see their combined effect on dynamic performance, since previous research stresses the interaction effect of individual and task characteristics on performance (e.g. Howe, 2019).

Chapter 4 is an empirical study in which we focused on the role of another task characteristic, namely task consistency, in the different types of adaptive performance, again using an ATC computer task. Task consistency involves the predictability of the task (Voelkle et al., 2006); A consistent task can be performed automatically, without attention (Ackerman, 1988). Ackerman (1988; 1992) showed that the consistency of a task has a different effect on the skill acquisition of an individual than task complexity and in this chapter we focused on the effect of adaptive performance. We used a slightly different version of the computer task in this study; the task of the participant was no longer to detect conflicting aircraft, but to direct aircraft to their corresponding airport. Again, we distinguished two different types of the task, in this case a consistent and an inconsistent version.

Chapter 5 describes the influence of task complexity on adaptive performance. We studied the effect of task complexity on different types of adaptation using the same ATC simulator task as in the previous study. Task complexity involves the amount of information that is available for the individual, the memory load, and the number of subtasks that a person has to do (Ackerman, 1988; Ackerman & Cianciolo, 2002). Again, participants were asked to detect and solve conflicts between aircraft and we developed two different versions of the task, namely a complex and a non-complex version. This enabled us to study the effect of task complexity on two different types of adaptive performance. By defining different types of adaption, we define adaptive performance in a more specific way and we can show performance trajectories over time. Statistical analyses for chapters 3 and 5 were done using the same dataset. In chapter 3, we only focused on skill acquisition (i.e. the phase before the unforeseen change), while in chapter 5 we were interested in the phase after the unforeseen change was introduced. Therefore, an overview of the intercorrelations of the study variables of those chapters can be found in table 1.1.

Table 1.1 *Intercorrelations of the Study Variables of Chapters 3 and 5; n = 135.*

	1.	2.	3.	4.
Noncomplex condition				
1. Prechange performance noncomplex condition	-			
2. Postchange performance noncomplex condition	.76*	-		
3. Education level	.05	.18	-	
4. General mental ability	.04	.13	-.03	-
	5.	6.	7.	8.
Complex condition				
5. Prechange performance complex condition	-			
6. Postchange performance complex condition	.85*	-		
7. Education level	.07	-.07	-	
8. General mental ability	.19	.17	-.17	-

* *p* < .01

Lastly, chapter 6 will provide an overview of the key findings and I will discuss the theoretical and practical implications of my studies. I will briefly summarize the previous chapters and I will give suggestions for future research. Lastly, I will give a general conclusion of this thesis. See Figure 1.1 for an overview of the main constructs and their relationships that will be discussed in this thesis. As mentioned before, this figure is included because for Chapter 3 and 5 the same dataset was used.

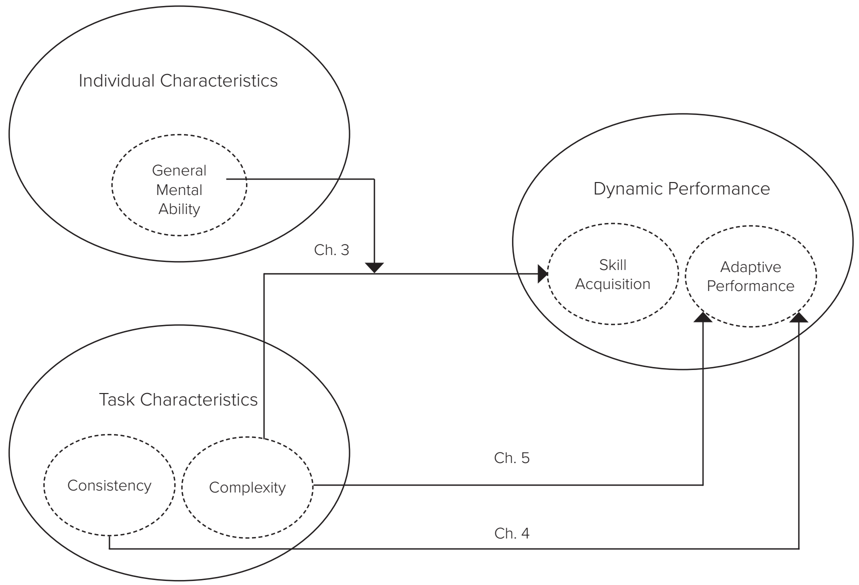

Figure 1.1. Overall model of the different constructs in this thesis.

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DYNAMIC PERFORMANCE AT WORK: A THEORETICAL REVIEW

ABSTRACT

In many jobs it is important that people are able to respond to unforeseen changes. The topic of dynamic performance has received increasing attention over the past few years. There are several related research areas that are relevant: research on skill acquisition, task switching, interruptions and adaptability are all closely related to dynamic performance. In this review, I will give an overview of the most important findings in these four research areas and indicate what the differences and overlap between these areas are. A clear definition of dynamic performance is missing in the literature so far. I will define dynamic performance and adaptive performance, a more specific type of dynamic performance. In this review I will highlight the importance of taking into account personal and task characteristics in studying dynamic performance, and the task-change paradigm will be proposed as a useful research paradigm in this respect.

DYNAMIC PERFORMANCE AT WORK: A THEORETICAL REVIEW

Previously, scholars assumed that cognitive ability is the most important predictor of job performance and that the relationship between abilities and performance is stable over time (Schmidt, Hunter, & Outerbridge, 1986). This implies that when cognitive ability is measured only once, namely during the selection procedure, this would be predictive of job performance over the whole course of a career. Murphy (1989), however, disagreed with the idea that only one measurement point of an ability would be sufficient to predict job performance both in the short term, and also in the long term and he proposed that early appraisal alone, such as measuring a personality trait only once during a selection procedure, does not give a valid representation of an ability or skill. Job performance changes over time and it is not a stable factor (Farrell & McDaniel, 2001; Miner & Glomb, 2010). The same applies to the relationship between abilities and performance: This relationship is dynamic and will fluctuate over time (Ackerman, 1992; Farrell & McDaniel, 2001). Individuals develop over time, they acquire new knowledge and skills, their job characteristics might change over time: These are just a few examples of factors that affect the dynamics of job performance and the relationship between abilities and performance.

Performance can be seen as either a process by which people are working towards a goal, or as the congruence between the goal and the outcome of that process (Roe, 1999). From this definition it is clear that the concept of time is crucial (Roe, 1999): Performance is a process, in which individuals work towards a specific goal. However, this aspect is often overlooked by scholars (Roe, 1999, 2008). In this thesis I will use the term *dynamic performance*, because it emphasizes the importance of the process. Dynamic performance can thus be seen as a specific type of performance in which the focus is on how performance changes over time. This change can be caused by either external causes (for example an interruption or a training), or by internal causes (for example self-regulation of performance or learning processes) (Sonnentag & Frese, 2009). In the literature, different terms related to dynamic performance can be found, and although they are highly related, they are treated as different concepts. In this theoretical review I will discuss the concept of dynamic performance and I will explain how concepts such as skill acquisition, interruptions, task switching and adaptability fit into the overarching concept of dynamic performance, how they overlap and differ from each other. Furthermore, I will highlight which gaps still exist in this field of research and by doing so, this thesis extends previous research by filling in at least some of these gaps, namely by focusing on the influence of both individual and task characteristics on dynamic performance.

SKILL ACQUISITION

Job performance can be seen as a form of skill acquisition, because people will continuously learn at the job and job performance is hence not stable (Murphy, 1989). One example is the so-called honeymoon effect (Murphy, 1989): during the first three months, often higher level of job performance are visible, because employees are highly motivated at their new job and experience their job as novel and challenging. Performance can be depicted in a learning curve, showing that at first, people acquire a task rather quickly, after which the learning process slows down. This process of skill acquisition can be divided into different phases (Ackerman, 1988, 1992, 2007; Fitts & Posner, 1967; Murphy, 1989; Shiffrin & Schneider, 1977). Both Ackerman (1988, 1992, 2007) and Murphy (1989) describe the process of skill acquisition in different phases, and these phases overlap to some extent, as will be explained in the next paragraph. Both theories can be seen as the basis of dynamic performance; they both describe how performance levels will fluctuate over time.

Ackerman's theory is based on the work by Schiffrin and Schneider (1977). When individuals are confronted with a novel task, they need time to get acquainted with the task and task performance will be rather slow. This is what has been called controlled processing (Shiffrin & Schneider, 1977). However, after a while individuals know which strategies to use and they will be able to perform more rapidly and without conscious attention, which is described as automatic processing. Ackerman (1988, 1992) builds upon this work and distinguishes three different phases: the cognitive phase, the association phase and the autonomous phase. Firstly, the cognitive phase is characterized by high cognitive load. The learner has to understand task instructions, to familiarize with task goals, to formulate strategies, etcetera. This phase is primarily based on controlled processing. Secondly, in the associative phase, task strategies will be proceduralized. Processing will be more and more automatic and because of this, individuals will be able to increase their pace and fewer errors will be made. Thirdly, in the autonomous phase, skills will be automatized, so that the learner can perform the task with hardly any attention. In this latter phase, individuals will use automatic processing.

Murphy builds upon Ackerman's theory, but argues that there are only two phases in job performance: the transitional phase and the maintenance phase. Murphy's phases are more specifically linked to actual job performance, while Ackerman based his theory mainly on his work in the lab. In the transitional phase, people are starting to learn the task and skills develop more and more in this phase. The transition phase takes place when an employee is new to the job or when major tasks or duties have changed. This is comparable to Ackerman's cognitive and associative phase. In Murphy's maintenance phase, the skill is completely learned by the employee and can be performed with almost no effort. In this phase, employees only have to apply well-learned procedures and they do not have to deal with novel or unpredictable information. This is comparable to Ackerman's autonomous phase. In Murphy's model it is possible to switch between stages, for example when an employee gets new responsibilities, he will return to the transitional stage.

During the early phases of skill acquisition, employees rely heavily on cognitive ability (Ackerman, 1988, 1992, 2007; Keil & Cortina, 2001; Murphy, 1989). This is a basic ability that is necessary to perform many different activities (e.g. understanding instructions, formulating strategies). Depending on the content of the task, also more task specific abilities might play a role, for example verbal abilities in a semantic task. According to Ackerman, the second phase can be associated with perceptual speed ability. The focus in this phase is on making performance quicker, which thus has a clear link to perceptual speed ability: how fast can strategies be developed and implemented? The third and last phase can be associated with psychomotor ability. This mainly refers to how fast someone can respond when there are no cognitive processing demands: performing a skill automatically. Murphy adds to this that during the later phase of skill acquisition, performance relies more on motivation and personality. Research has shown that indeed personality, and particularly conscientiousness, has an influence on job performance, especially in the later phases of skill acquisition (Lievens, Ones, & Dilchert, 2009; Thoresen, Bradley, Bliese, & Thoresen, 2004). Hence, this stream of research shows that differences in individual characteristics are important and that it depends on the stage of skill acquisition which characteristic is the most important at that point in time.

Besides the individual difference variables general ability, perceptual speed and psychomotor ability, two other variables have a moderating influence on the process of skill acquisition (Ackerman, 1988; Ackerman & Cianciolo, 2002; Farrell & McDaniel, 2001). The first factor is task complexity. A task that is more complex will demand more attention. Learners will make more mistakes and need more time to perform the task.

The second moderating variable is consistency. To define consistency, Ackerman (1988) refers to the classical work by Schiffrin and Schneider (1977). They conducted an experiment in which participants had to memorize several letters or numbers, i.e. the memory set. After that, the participants were confronted with a number of frames that contained items from the memory set, but also several distractors. They manipulated the relationship between the memory set and the distractors. In their consistent mapping condition, distractors were never of the same type as the items from the memory set. For example, if the memory set consisted of letters, then the distractors were always numbers. Participants in this condition found it rather easy to distinguish items from the memory set from the distractors, because they could simply apply the same rule in every trial: If they had memorized letters, they knew after a few trials that they could simply ignore the numbers, because these were always the distractors. In the varied mapping condition (i.e. the inconsistent condition), the distractors could be both letters and numbers, which made it more difficult for participants to find the letters/numbers that they had to memorize. In this condition, participants used controlled and thus slower processing of the items, as opposed to the consistent mapping condition. They concluded that individuals in a consistent mapping condition use automatic processing, which is much faster and less error prone compared to the performance of the individuals in the varied mapping condition, who were forced to use controlled processing.

Following Schiffrin and Schneider (1977), Ackerman (1988; 1992) distinguished consistent tasks from inconsistent tasks. An inconsistent task (cf. varied mapping according to Schiffrin & Schneider, 1977) needs controlled processing, which means that it is not possible to complete all three phases of skill acquisition: An inconsistent task will stay cognitively demanding. This means that task characteristics can have a profound impact on the process of skill acquisition, which is also visible in the individual learning curves. Especially for task consistency a clear impact is visible: For an inconsistent task, the learning curve looks less steep and there is more variability if performance across people is compared. Ackerman furthermore acknowledges that, except for complexity and consistency, also other variables may have a moderating influence on skill acquisition, including motivation, efficacy and abilities. Farrell and McDaniel (2001) showed, using an existing job database, that task consistency indeed shapes the learning curve of employees as Ackerman proposes in his studies. They confirmed that when a job is consistent, job performance improves faster than in an inconsistent job, and that furthermore the asymptote is reached sooner than in an inconsistent job. Also, cognitive ability appeared to be the best predictor for job performance in the early phase of skill acquisition, while psychomotor abilities were more important in a later phase. For inconsistent tasks, cognitive ability is the best predictor for performance overall. This is in line with Ackerman's theory, since he claims that in an inconsistent task, people will only reach the first phase of skill acquisition, in which cognitive ability is the most important predictor.

For this thesis, I would like to extend research on skill acquisition, by focusing on the interaction effect of individual and task characteristics on dynamic performance (see chapter 3). Previous research (Le et al., 2011) has suggested that job complexity moderates the relationship between individual characteristics and task performance, so in chapter 3 I focus on the interaction effect of task complexity and general mental ability on task performance. Also, suggestions have been given to incorporate recently developed methods of analysis, such as growth modeling analysis, into the field of skill acquisition (Voelkle, Wittmann, & Ackerman, 2006). Voelkle and colleagues (2006) explain that growth curve modeling has the advantage that interindividual differences in performance can be directly predicted and it is a convenient way to study the relationship between abilities and performance over time. Hence, in this thesis, I will use growth modeling analysis to analyze the data and in this way extend previous studies on dynamic performance.

INTERRUPTIONS

During work people normally face many interruptions: receiving an e-mail, the phone that rings, a colleague that has an urgent question, etcetera. These interruptions can be seen as an (unforeseen) change: An employee suddenly has to change to another task. Studies on interruptions are related to adaptive performance, since an interruption can be seen as a specific type of adaptive performance, but the main difference between these two research fields is that studies on interruptions in general do not focus on performance over time. However, since an interruption requires an employee to adapt her performance, it is relevant to discuss this topic here.

One might assume that interruptions have a negative impact on performance and this is also what many studies found: Interrupting people can lead to a slower performance, more errors and it can make people more annoyed (Bailey & Konstan, 2006; Eyrolle & Cellier, 2000). However, a study by Zijlstra and colleagues (1999) showed no decline in performance after an interruption, because they changed their performance strategy. In their study participants compensated for this deterioration by a change in speed, and because of this, there was an increase in effort expenditure. The interruption posed higher demands on the resources of the participants, because they needed to invest more inform to keep their task performance at the same level. Actually, there was overcompensation: The main task was performed faster while the quality did not change. The authors propose that when interrupted people realized that the main task would take too much time, they adjusted their working plan. The quality of performance did not change, but the interruptions did have a negative impact on the emotions and wellbeing of the participants. This means that people can react efficiently to an interruption, but that the interruption still has an impact on their emotional state.

A distinction can be made between four types of interruption (Jett & George, 2003): intrusions, breaks, distractions, and discrepancies. When the flow and continuity of an employee's work are unexpectedly interrupted by another person, this has been called an intrusion. Breaks on the other hand are not unexpected: They are initiated by the employee himself. A distraction is an interruption in the work that is caused by a psychological reaction to secondary activities or stimuli. For example, when an employee is working with the window open and suddenly hears a strange sound outside; this interrupts his attention to the task. Discrepancies can be described as the difference between what the employee expects to happen and what is actually happening. This leads to a shift in attention to the perceived change that took place. Those four types of interruptions obviously have negative consequences: Employees might experience more time pressure and might get annoyed by the interruption. However, interruptions can also have positive consequences (Jett &

George, 2003). Being interrupted might lead to information sharing, which is especially applicable to intrusions. Also, a break might give the opportunity to take some rest and it might be a welcome variety when the task is boring and a discrepancy might lead to effortful processing.

Jett and George (2003) mention that a discrepancy is a form of interruption that is not widely recognized. However, in the light of the concept of adaptability this is probably the most relevant form of interruption: People are faced with an inconsistency in their task, namely an unexpected change to which they have to react efficiently. Following Jett and George's line of reasoning this means that an unforeseen change both can result in positive and negative consequences. When people suppress or deny the change, this will lead to negative emotional reactions: People will get frustrated since they can no longer perform on the same level. However, when people do recognize the need for a change in strategy they will experience positive emotions. Factors that influence the reaction to a perceived discrepancy include the adeptness at handling unforeseen changes, openness to new experiences, personal relevance of the change, stage of development and flexibility of the person (Jett & George, 2003).

Of course, it is also important to know what can be done to improve performance when people are interrupted. Several studies looked at the effect of giving participants informative cues about the interruption (e.g. Hameed, Ferris, Jayaraman, & Sarter, 2009; Ho, Nikolic, Waters, & Sarter, 2004). Cues such as giving information about the importance of the interruption indeed improved performance in those studies. However, those are all experimental studies and it remains unclear how to implement those cues in a real life setting. Interruptions or changes in the task often appear unexpectedly; thus far it is not clear how this could be implemented.

In our research, we were also interested in the effect of an unforeseen change on performance (chapters 4 and 5). In the field of interruptions, often the duration of task performance is measured, to see how much time is added to the task execution when an interruption takes place, or the number of errors made during task execution is measured. However, the focus there is not on dynamic performance: The performance trajectory itself is not measured. In our research we are interested to measure performance over time, so that we can specifically focus on how performance changes when a person is confronted with an unforeseen event. To do so, we will use a specific research paradigm that is often used in studies on adaptive performance (e.g. Chen et al., 2005a; Lang & Bliese, 2009; LePine, Colquitt, & Erez, 2000; LePine, 2003, 2005), which has been developed in task switching research.

TASK SWITCHING

In current studies on dynamic performance the task-change paradigm is often used (e.g. Bröder & Schiffer, 2006; Chen, 2005; Chen, Gully, Whiteman, & Kilcullen, 2000; Johnson, et al., 2006; Lang & Bliese, 2009; LePine, 2003, 2005; LePine, et al., 2000). In this (pseudo-) experimental research paradigm, participants have to perform a rather complex and, to them, new (computer) task. Halfway through the experiment, after first acquiring the skills that are needed for the task, an unforeseen change is introduced which makes it necessary for participants to change their strategies to adapt to this change and to remain effective in their performance. The paradigm has its origins in the task switching literature and can be seen as a variation there of. The invention of this paradigm dates back to 1927, a study by Jersild (as described in Monsell, 2003). In a task-switching experiment (see for example Meier, Woodward, Rey-Mermet, & Graf, 2009; Meiran, et al., 2000; Monsell, 2003; Yehene & Meiran, 2007) participants are first trained on two or more tasks that require attention. Then a certain stimulus is presented that indicates which of two tasks should be performed. Which task this is depends per trial. In the task change paradigm there is only one change in the task: Participants learn a task until a certain level of performance is achieved, then a change in the task occurs and the participant has to adapt her strategies to perform well on this changed task. In the task switching paradigm the task can switch to the other task several times during the experiment. A general finding in those experiments is the 'switch cost': It takes longer to initiate the task on a switch trial than on a non-switch trial (Monsell, 2003).

Performance in the task switching paradigm can be improved if the participants can prepare for the task switch (Gade & Koch, 2007; Mayr & Kliegl, 2003; Meiran, et al., 2000; Meiran & Daichman, 2005; Rubin & Koch, 2006; Yehene & Meiran, 2007). Preparation means that participants receive some kind of cue that indicates that in several moments the task will switch. Disadvantage of this line of research is that it is not clear whether findings can be generalized to a real world setting. In task switching research, often simple computer tasks are being used (see for example Meier, Woodward, Rey-Mermet, & Graf, 2009; Meiran, et al., 2000; Yehene & Meiran, 2007) while in the real world people often have to switch between complex tasks. It might also be difficult to give cues in the real world, since changes often appear unexpectedly. However, it is important to further investigate ways of facilitating switching performance of people in a realistic setting.

ADAPTIVE PERFORMANCE

A relatively new stream of research has focused on adaptability: the degree to which individuals are able to respond effectively to changes in a complex environment. Two definitions of adaptability have been given earlier. Interestingly, Ployhart and Bliese (2006) incorporated the eight dimensions of Pulakos and colleagues (2000) in their I-ADAPT theory. They state that overall adaptability can be subdivided in eight dimensions: crisis, work stress, creativity, uncertainty, learning, interpersonal, cultural and physical, which are the keywords from Pulakos et al.'s dimensions. Ployhart and Bliese (2006) explain how these eight dimensions can be seen as underlying latent constructs, which are all related to overall adaptability. This means that adaptability can occur in multiple ways and in multiple dimensions, i.e. task, social and environment (Ployhart & Bliese, 2006). They furthermore acknowledge that there are several knowledge, skills, abilities and other characteristics (KSAOs) that have an influence on these sub-dimensions. The KSAOs can be weighted to each sub-dimension and overall adaptability is the weighted total of the eight sub-dimensions. Adaptability is thus a multifaceted concept and it can be influenced by several individual difference variables. Recently, it was also concluded that there are many different definitions of adaptability, but that " a common theme of each definition is that they explain the flexible and responsive work behaviors needed to adapt to changing conditions and demands" (Park & Park, 2019, p. 312). Furthermore, Jundt, Shoss, and Huang (2015) acknowledge that pursuing clarity about the construct of adaptability is one of the key challenges to overcome in this research field.

Baard and colleagues distinguished four approaches of research on adaptive performance (Baard, Rench, & Kozlowski, 2013): a performance construct approach, an individual difference construct approach, a change in performance approach and a process approach. In the performance construct approach, scholars define adaptation as a set of performance dimensions that enable the individual to effectively respond to an unforeseen change, in which some scholars (e.g. Borman & Motowidlo, 1993) see it as being part of traditional job performance dimensions, while others (e.g. Pulakos et al., 2000) argue that it is a distinct type of performance. In the individual difference construct approach, adaptability is defined as a set of characteristics of the individual that enables people to respond to unforeseen changes under different conditions (Baard et al., 2013). It is assumed that adaptability is a trait that can be used to predict whether an individual will be successful in dealing with unforeseen changes. In the performance change approach, adaptation is simply seen as a response to a change in the environment. Scholars in this approach see performance as a process and it is often investigated over time (e.g. Chen, 2005; Lang & Bliese, 2009; LePine et al., 2000; LePine, 2003, 2005). Lastly, the process approach sees adaptation as a process on its own. Adaptation is not just about recognizing that a task has changed, but also about understanding how your strategy has to change to remain effective in your performance. It is assumed that this process can be measured, which is not the case in the performance change approach. In the performance change approach, adaptation is defined as the criterion, so as the outcome of the process, while in the process approach adaptation

is seen as the process itself. The authors argue for a better integration and definition of adaptive performance and they propose a multilevel architecture for adaptation. This proposed architecture consists of three dimensions. The first one is the changes in the task features. The authors argue that for this dimension a distinction can be made between component complexity, coordinative complexity and dynamic complexity (Wood, 1986). Component complexity represents the number of actions that are related to the task, the task difficulty. Coordinative complexity is related to the linkages between cues and actions and their sequence, if-then statements. Dynamic complexity is about the change in cues and actions, for example changes in the number of cues that are given.

The second dimension focuses on the level of analysis, which can be individual, team or unit. The third dimension is the underlying adaptation process, which can be cognitive (e.g. attention, learning), affective/motivational (goal orientation, self-efficacy), or behavioral (skilled actions). In this thesis I will use the performance change approach, which means that adaptation is defined as the outcome of the adaptation process. In the empirical chapters in this thesis, I also focus on the process of adaptation, by measuring adaptive performance over time. However, since I measure the outcome of this process and not the process itself, I define adaptation according to the performance change approach: When a change in a task is introduced, there is an underlying process occurring which results in adaptive performance (Baard et al., 2013). This means that we do not actually test the underlying process, but these processes are meant to guide our hypotheses.

TYPES OF ADAPTATION

In previous research (Lang & Bliese, 2009) a framework has been proposed to make a distinction between 2 types of adaptation and 2 common performance components. The two performance components are: basal level of task performance and rate of skill acquisition. Basal task performance refers to "mean differences in the overall level of performance across a specified period of time" (Lang & Bliese, 2009, p.414). The mean score of performance will differ between individuals, i.e. basal task performance can be seen as mean-level performance. Skill acquisition refers to the learning process of individuals. An individual that has a higher rate of skill acquisition will learn quicker, both before and after the change. The learning curve will thus be steeper for this individual.

The two adaptation types are transition adaptation and reacquisition adaptation. Lang and Bliese (2009) mention three aspects of transition adaptation: transition adaptation occurs immediately after the change, it is a flexible reaction that leads to a minimal decrease of performance and it is measured relative to the level of performance and the learning rate before the change. Basically, transition adaptation is the immediate relapse of performance. Reacquisition adaptation is different from transition adaptation in the sense that reacquisition adaptation is about the process of recovering after the unforeseen change. Unlike transition adaptation, it refers to the learning behavior that is necessary to understand the changed task so that performance can return to the pre-change level.

INDIVIDUAL LEVEL ADAPTIVE PERFORMANCE

Although most studies focus on individual level adaptive performance, adaptive performance can of course also take place on the team level. Since the focus of this thesis is on individual level adaptive performance, I will not include studies on the team level in this review. Studies focusing on the individual level of adaptability mainly investigated the influence of individual characteristics on adaptive performance. Especially cognitive ability and personality received much attention, while a few studies also looked at the influence of goal orientations and self-efficacy.

General mental ability

Intuitively one would expect that cognitive ability has a strong positive effect on adaptive performance, since it also influences (the first phase of) skill acquisition. However, results are mixed. On the one hand, studies show that GMA predicts performance (LePine et al., 2000; Schmidt & Hunter, 1998, Stasielowicz, 2019). For example LePine and colleagues (2000) found that general mental ability predicted performance before the unforeseen change in the task was introduced, and this relationship increased strongly after the change in the task. Those authors follow the line of reasoning that people with high GMA have more cognitive resources to adequately monitor and perform a task, and are thus more equipped to adapt to an unforeseen change (Lang & Bliese, 2009). Stasielowicz (2019) distinguished between transition and reacquisition adaptation and found that cognitive abilities were positively related to both types of adaptive performance.

On the other hand, there are studies that show the opposite effect: a negative relationship between GMA and adaptability. Lang and Bliese (2009) found that individuals with a high level of GMA show a larger decline of performance immediately after the change occurred, but they acknowledge that this negative effect only refers to the relative change in performance of the individual across time. The performance of those individuals was actually better, so a distinction should be made between actual overall performance and adaptability. There are two possible explanations for those findings (Lang & Bliese, 2009). The first one is that individuals with a high level of GMA learn more when performing the task. Their performance after a change declines stronger because they have more knowledge to lose. A second explanation is that individuals with high GMA levels reached automaticity in the task, while other individuals did not. Previous research (Beilock & Carr, 2001) shows that if knowledge is proceduralized, and hence automaticity is reached, it will be more difficult for experts to switch to another strategy, compared to novices that use a more step-by-step way of processing.

Personality

Several studies looked at the relationship between personality and adaptability (see e.g. Huang, Ryan, Zabel, & Palmer, 2014). Most attention has been given to the Big Five personality characteristics conscientiousness and openness to experience. Conscientiousness has been found to be positively related to job performance (Schmidt & Hunter, 1998), and hence it is plausible to also expect a positive relationship with adaptability. One has to be motivated and committed to the task to develop new strategies after an unforeseen change. However, results are mixed (LePine, et al., 2000): In some occasions conscientiousness is negatively related to adaptive performance. A plausible explanation mentioned in the literature is that the two components of conscientiousness, dependability and volition, do not have the same impact on performance. Dependability reflects the degree to which a person works in a very orderly, cautious and dutiful way, while volition reflects one's will to achieve and self-motivation (Barrick & Mount, 1991; Costa & McCrae, 1992; Costa, McCrae, & Dye, 1991; LePine et al., 2000). LePine et al. (2000) found that dependability was negatively related to adaptability, but not volition. This means that being highly self-disciplined and striving for high achievement will lead to a better adaptive performance, while being orderly, organized and dutiful can have a negative impact on the performance. The latter group might be less flexible, since those individuals work in a very deliberate and orderly way.

Openness to experience includes being willing to engage in new experiences, to be curious, broad minded and creative. As LePine and colleagues (2000) acknowledge, for adaptability it is very important to be creative and to focus attention on areas that others do not consider, since individuals have to develop new strategies as the task suddenly changes. Indeed, studies (LePine, 2003; LePine et al., 2000) have shown that openness to experience is positively related to adaptability. Huang and colleagues (2014) only found a significant effect of emotional stability in their analysis, but not for conscientiousness and openness to experience, which might be due to the fact that they did not take subfacets of these personality traits into consideration. Emotional stability is an important predictor for adaptive performance, because individuals those individuals stay calm and level-headed when confronted with an unforeseen change, will have less difficulties with handling this change (Pulakos, et al., 2002; Huang, et al., 2014).

Finally, there is some evidence that extraversion is positively related to adaptive performance, but only under certain circumstances (Wihler, Meurs, Wiesman, Troll, & Blickle, 2017). It was found that the relationship between extraversion and adaptive performance is moderated by social competency and trait activation. If an individual is an extravert, is socially competent and works in a climate for personal initiative, then the individual will perform well when she is confronted with an unforeseen change in the work (Wihler, et al., 2017). This is in line with the meta-analysis by Huang and colleagues (2014) who showed a positive effect of ambition, an aspect of extraversion, on adaptive performance.

Goal orientation and self-efficacy

The influence of goal orientation and self-efficacy on performance is quite straightforward: Results so far are comparable with studies on the influence of these concepts on common performance, namely that especially a learning goal orientation and high self-efficacy are beneficial (Kozlowski et al., 2001; LePine, 2005; Porter, Webb, & Gogus, 2010). More specifically, it has been shown that learning goal orientation and self-efficacy are also related: A high learning orientation leads to higher self-efficacy which then again is positively related to adaptive performance (Kozlowski et al., 2001). Also, the type of goal used in the training phase (learning versus mastery oriented) influenced self-efficacy, in such a way that a mastery oriented training had a positive impact on the level of self-efficacy. Another study showed that when the goals, that a team has to fulfill, are difficult, a learning goal orientation is even more beneficial, while goal difficulty did not have an independent effect on team adaptive performance (LePine, 2005). Team members with a high performance orientation did not share relevant information when confronted with an unforeseen change in a difficult task, since they did not focus on developing new strategies to remain effective in their performance.

More recently, Howe (2019) showed that goal orientations can act as moderator on the relationship between GMA and performance. Often it is assumed that GMA is positively related to performance, but this is not always the case. Howe builds upon the work from Beilock (Beilock & Carr, 2001; Beilock & DeCaro, 2007) who showed that if individuals have to perform a complex task or a task in which they experience high levels of pressure, that individuals with high GMA choke under pressure: Their performance advantage disappears. Howe showed that the type of goal orientation plays a role in this relationship. Individuals that were assigned a do-your-best goal, a learning goal or a performance goal while performing a stock market exercise. The relationship between GMA and performance was positive for those who were assigned a do-your-best or learning goal, but this effect was nullified for individuals with a performance goal. This study shows that the relationship between GMA and performance is not always that straightforward; that it depends on situational factors. In Chapter 3, I will focus on this relationship in more detail.

TASK CHARACTERISTICS

Until now hardly any studies looked at how characteristics of the task or how the change itself influences the (adaptive) performance on the task (see e.g Jundt, Shoss, & Huang, 2015; Park & Park, 2019). Gillie and Broadbent (1989) conducted four experiments on characteristics

of interruptions. They did not mention the task-change paradigm or adaptability, their focus was on interruptions. Nevertheless, this study informs the adaptability literature. They found that when people are interrupted when performing a computer task, the length of the interruption and the opportunity to control the specific moment at which the primary task is stopped and the secondary task (the interruption) is started are not important in determining whether an interruption is disruptive. However, the nature of the interruption is important in determining the level of disruptiveness. The nature of the interruption is comparable to the characteristics of the change in the task-change paradigm. When the interruption is very similar to the main task and when the interruption is very complex people will experience the interruption as highly disruptive (Gillie & Broadbent, 1989). In those experiments complexity was defined as the amount of processing or memory storage that was required. The aspect of similarity is difficult to transfer to characteristics of the change, since in the Gillie and Broadbent (1989) experiment the interruption is a whole new task (an arithmetic task when performing a memory task), while in the task-change paradigm the participant is performing one task, in which an unforeseen change takes place. However, the aspect of complexity is applicable to adaptability: The more complex the task after the change, the more difficult it will be to perform the task.

Zijlstra and colleagues (Zijlstra, Roe, Leonova, & Krediet, 1999) also took complexity into account in their study. They found that task complexity sometimes had a positive effect on performance, while sometimes the effect was negative. Their explanation is that when people experience a task as rather dull, they might find an interruption challenging, which lead to an increase of positive feelings. When people already have troubles performing the task, and a complex interruption is introduced this leads to the opposite effect: a decrease of positive feelings. This is in line with Jett and George (2003): An interruption can both have positive and negative effects, depending on the characteristics of the task at hand.

Johnson and colleagues (2006) studied characteristics of a change in a more realistic setting. They studied adaptation at the team level and looked at a change in the reward system of the team. A distinction has been made between a cooperative reward structure and a competitive reward structure. In a cooperative reward structure team members support each other and share information they know or learn. In this way, all members can profit from each other's knowledge and experience. On the other hand in a competitive structure team members do not share knowledge and experiences: There is competitiveness within the team. Results of this study (Johnson, et al., 2006) show that teams that shifted from a cooperative structure to a competitive structure were able to manage this change, while changing from a competitive to a cooperative structure was much more difficult. Those teams were very competitive after the change, which led to low information sharing and low accuracy of performance. Those teams were in a state that has been called 'cutthroat cooperation' (Johnson, et al., 2006): They are likely to perform in a way that is consistent with the competitive structure, although the current reward structure is a cooperative one. The authors explain these findings by stating that it takes longer to create trust than to undermine it.

The Johnson et al. (2006) study is an example of a very specific kind of change, namely a change in reward structure, which is especially applicable for organizations that are facing a merger. However, it is quite striking that there is lack of attention to task characteristics that could influence adaptive performance. For example Burke, Stagl, Salas, Pierce, and Kendall (2006) propose an input – throughput – output model of team adaptation. They acknowledge that several individual characteristics influence the process of adaptation, but they do not mention task characteristics at all. It was stated earlier that the field of adaptability relies on the field of skill acquisition. For skill acquisition, several studies looked into the impact of task characteristics on performance (Ackerman, 1988, 1992; Ackerman & Cianciolo, 2002). It is surprising that none of the studies on adaptive performance examined the influence of for example task complexity and task consistency on adaptive performance.

When comparing studies that used the task-change paradigm, it is quite striking that, although they all use a very similar research paradigm, the type of change that is introduced in the experimental task can differ. For example, when looking at team adaptability a problem in the communication between team members can be used (LePine, 2003, 2005), but also a change in difficulty and complexity (Chen et al., 2005). At the individual level also different types of manipulations have been used, for example a change in the amount of information that needs to be processed (e.g. Lang & Bliese, 2009) or a change in the rule that has to be applied to make a correct decision (e.g. LePine, Colquitt, & Erez, 2000). Chen (2005) studied adaptive performance in a real life setting: He examined the effect of a newcomer in teams of knowledge workers. Although the before mentioned approaches are very different from one another, they all use different types of unforeseen changes and use different definitions of adaptive performance. In the current thesis, we will use the task-change paradigm, which enables us to distinguish between different components of performance: skill acquisition, transition adaptation, and reacquisition adaptation (Lang & Bliese, 2009). By focusing on transition and reacquisition adaptation, we zoom in on the process of adaptive performance, which enables us to discuss adaptive performance in a more specific way.

CONCLUSION

The aim of this review paper was to give an overview of the literature on adaptive performance and to indicate gaps and possibilities in this field. Besides the relative new literature on adaptability, there has already been an interest in how people acquire a skill and handle

unforeseen changes in a task or a job, which is clear when looking at the related fields that are described in this review. Research on skill acquisition, interruptions and task switching already learned us about the influence of personal and environmental characteristics on how people respond to unforeseen changes. However, most of these studies have been conducted in a different field than Industrial and Organizational (I/O) psychology; they stem mainly from experimental psychology. In I/O Psychology, the adaptability research applied and extended this knowledge from experimental psychology, focusing on the influence of characteristics of the individual on adaptive performance.

A commonality of most existing studies on adaptability is that they use the task-change paradigm. This, of course, makes it easier to compare between studies. However, as stated earlier, besides the fact that a similar research paradigm has been used, these studies differ substantially from each other, not only in the type of task that has been used, but also in the type of manipulation of the unforeseen change that has been used. One might question if a system failure in the communication channel leads to the same type of adaptive performance as an increase of difficulty and complexity in the task. It is difficult to draw any conclusions about this issue, since none of the studies for example compared different types of unforeseen change. Baard and colleagues proposed an architecture that could be used as a starting point for this (Baard et al., 2013), since they proposed to make a distinction between 1) the type of change that is used in the task, 2) the level of analysis that is used, and 3) the underlying process. As mentioned before, in the current thesis, we used the task-change paradigm, which enables us to distinguish different types of performance over time: skill acquisition, transition adaptation, and reacquisition adaptation (Lang & Bliese, 2009). Looking at the architecture proposed by Baard and colleagues (2013), this paradigm enables us to both focus on the between person and within person level of analysis, and furthermore, we zoom in on the process of adaptive performance by distinguishing transition adaptation from re-acquisition.

In this thesis, chapters 4 and 5 focus on adaptive performance. In these chapters, I describe two laboratory studies that relied on the task-change paradigm, focusing on the influence of task consistency and task complexity, respectively. Recently, Park & Park (2019) also acknowledge in their review that the influence of task characteristics on adaptive performance is one of key issues that should be studied by future research. Our studies are the first studies to our knowledge that focus on the influence of task characteristics on adaptive performance. We furthermore extend previous research by using a framework (Lang & Bliese, 2009) to distinguish two types of adaptive performance, namely transition and reacquisition adaptation, from basal task performance and skill acquisition. Using this framework, we measured performance over time, which will give us more insights into how individuals deal with unforeseen changes, answering not only the question “does performance change after an unforeseen change?", but also the question "*how* does performance change over time after an unforeseen change?" (Roe, 2008).

Another aspect that has been mainly neglected in the field of adaptability is the influence of task characteristics (Jundt, et al., 2015; Park & Park, 2019). Although many studies focused on the influence of individual difference characteristics such as GMA, conscientiousness, openness to experience, and goal orientation, there are no studies in which task characteristics as such are examined, while this topic deserved a lot of attention in the skill acquisition, interruption and task switching field. Therefore, in chapter 3, 4 and 5 I will describe the influence of task characteristics complexity and consistency on dynamic performance in an air traffic control setting.

A final issue that has to be raised is how adaptive performance is operationalized and measured when using the task-change paradigm (see Baard, et al., 2013, Jundt, et al., 2015, Park & Park, 2019). In many studies the authors calculated a mean score of performance on the task after an unforeseen change has been introduced, some then controlled for the performance before the change. However, when using this approach, the aspect of performance over time is neglected, although time is crucial in understanding adaptive performance (see for example Roe, 2008). The framework that Lang and Bliese (2009) proposed and that distinguishes between an immediate response to an unforeseen change (i.e. transition adaptation) and a re-learning phase after the change (i.e. reacquisition adaptation) could serve as a handle in this respect and will be used in this thesis.

In conclusion, although many studies have been performed on the topic of adaptive performance, there still remain questions to be answered. The task-change paradigm is an excellent research paradigm to study adaptive performance in the lab, especially when taking into account how performance changes over time, and the architecture given by Baard and colleagues seems to be a useful starting point for future research (Baard et al., 2013). When focusing not only on individual difference characteristics and paying attention to the specific manipulations of the unforeseen change in the paradigm, this can lead to new insights into how people actually respond to unforeseen changes, which will be necessary for work and organizational psychologists to improve selection and training methods.

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3

DYNAMIC PERFORMANCE AND TASK COMPLEXITY: THE MODERATING EFFECT OF GENERAL MENTAL ABILITY

ABSTRACT

General mental ability (GMA) is often seen as an excellent predictor of job performance. In this study, we investigated whether task complexity and GMA have an interactive effect on dynamic performance, which we operationalized as skill acquisition. We expected that the difference between individuals with high versus low GMA is especially profound when performing a less complex task than when performing a very complex task. In our experiment, 135 participants filled out several questionnaires and participated in an air traffic control (ATC) computer simulator task. Growth modeling analyses revealed a three-way interaction between Time, Complexity and GMA. The performance trajectories of individuals high and low on GMA were significantly different. Specifically, the performance advantage of high GMA individuals compared with low GMA individuals was smaller when performing a complex task. These findings emphasize the importance of taking into account both individual and task characteristics in selection and training procedures.

SKILL ACQUISITION AND TASK COMPLEXITY: THE MODERATING ROLE OF GENERAL MENTAL ABILITY

Predicting job performance in selection procedures is an important research topic for industrial and organizational psychologists. On the one hand, job performance is influenced by characteristics of the individual and individual questionnaires are hence often used in selection procedures (Schmidt & Hunter, 1998). One factor that is often seen as an important predictor of job performance is general mental ability (GMA) (Schmidt & Hunter, 1998). On the other hand, characteristics of the job also have an influence on job performance (Ackerman & Cianciolo, 2002; Farrell & McDaniel, 2001) and research has shown that task complexity has a negative effect on job performance (Farrell & McDaniel, 2001). Moreover, recent research shows that task characteristics such as task complexity can have a moderating influence on the relationship between individual characteristics and job performance (Le et al., 2011). In the present study we will shed light on the interaction effect of task complexity and general mental ability (GMA) and its influence on performance over time. Task complexity and GMA can both have an effect on the level of task performance (see for example Ackerman, 1988, 1992; Farrell & McDaniel, 2001). Ackerman already acknowledged in his early work (Ackerman, 1988, 1992) that the correlation between an ability such as GMA and performance partly depends on the specific task characteristics, however it still remains unknown if GMA and task complexity have an interactive effect on task performance. Using an experimental design, we add to the existing literature by studying the mechanisms that lead to dynamic performance of individuals. We advance existing literature by focusing on the interactive effect of GMA and task complexity on performance, and, more specifically, we focus on *dynamic* performance by studying skill acquisition. This enables us to get a complete overview of the performance trajectory of our participants (cf. Voelkle et al., 2006), which enables us to identify dynamic features of phenomena (Roe, 2008).

JOB PERFORMANCE AS A DYNAMIC CONSTRUCT

In 1989, Murphy was one of the first to acknowledge that job performance is a dynamic construct and that the relationship between predictors of job performance and job performance itself can also fluctuate over time (Murphy, 1989). He distinguished two stages in job performance: a transitional stage and a maintenance stage. In the transitional stage, employees are still learning their task and they need a lot of attention and effort to perform well. After a while, they reach the maintenance stage, in which performance is mainly automatic and employees are no longer confronted with novel or unpredictable information. However, if an element in their job changes, for example they receive new responsibilities, employees will return to the transitional stage until performance becomes more automatic again, and hence employees will then continue in the maintenance stage. Job performance is hence a dynamic construct, which is similar to what Ackerman proposed in his theory on skill acquisition (Ackerman, 1988, 2007). In this theory it is assumed that people need time to learn a task and that the process of skill acquisition is quadratic: Individuals will first rapidly increase their performance, after which the learning will slow down. This results in a typical learning curve. The process of skill acquisition can be divided into three phases (Ackerman, 1988, 2007; Fitts & Posner, 1967): 1. a cognitive phase: This phase is characterized by high cognitive load. The learner has to understand task instructions, to familiarize with task goals, to formulate strategies, etcetera. This phase is primarily based on controlled processing (Shiffrin & Schneider, 1977); 2. An associative phase: In this phase task strategies will be proceduralized, making task completion faster and reducing errors. Processing will be more and more automatic; 3. An autonomous phase. In this phase skills will be automatized, so that the learner can perform the task with hardly any attention. These phases overlap with the stages that Murphy proposed, in the sense that the transitional stage is comparable with the first two phases by Ackerman (cognitive and associative), since performance is not yet proceduralized, employees need attention and effort to perform. The maintenance stage is comparable to the autonomous phase, since skills will be automatized then.

The first phase of skill acquisition can be associated with general intelligence/ability (Ackerman, 1988, 2007; Farrell & McDaniel, 2001; Murphy, 1989). General ability is a construct that is necessary to perform different activities (e.g. understanding instructions, formulating strategies). Ackerman also takes into account that depending on the content of the task, also more task specific abilities might play a role, for example verbal abilities in a semantic task. However, general intelligence is the most important construct in this first phase of skill acquisition. The second phase can be associated with perceptual speed ability. The focus in this phase is on making performance quicker, which thus has a clear link to perceptual speed ability: how fast can strategies be implemented and compiled? The third and last phase can be associated with psychomotor ability. This mainly refers to how fast someone can respond when no cognitive processing demands are required and the task is a routine: performing a skill automatically. To conclude, in our study we focus on skill acquisition as a form of dynamic performance. We followed the approach of Ackerman in measuring performance over time and in this way establishing individuals' skill acquisition trajectories.

THE INTERACTION OF INDIVIDUAL CHARACTERISTICS AND TASK CHARACTERISTICS

Task complexity can have a profound effect on skill acquisition and job performance (Ackerman, 1988, 2007; Farrell & McDaniel, 2001). A complex task is a task in which individuals need to process a lot of information and hence complex tasks demand more

attention from individuals than non-complex tasks. As a result, individuals will make more mistakes and need more time to perform a complex task. A task that has a high level of task complexity is a task that is difficult to perform, because individuals will need all their attention while performing and they will need time to acquire the skill. We therefore expect that task complexity negatively affects performance trajectories such that skill acquisition (i.e., increase in performance) is lower for complex compared to non-complex tasks.

Hypothesis 1: Task complexity will have a negative effect on the performance trajectories of individuals, i.e. skill acquisition.

Focusing on skill acquisition, Kanfer and Ackerman (1989, p. 664) already acknowledged that "dynamic changes in performance [can be conceptualized] as a function of abilities, motivation, and task characteristics". Ackerman (1988, 1992, 2007) showed in a series of studies the influence of general mental ability (GMA) on the different phases of skill acquisition, especially in the first phase of skill acquisition. During this first phase, the cognitive phase, people rely heavily on working memory. They have to understand the instructions of the task that they have to perform, then they have to familiarize with the task goals, subsequently they have to come up with strategies on how to accomplish the task (Ackerman, 1988). GMA is often seen as an important predictor of job performance (Schmidt & Hunter, 1998) and of adaptive performance (Stasielowicz, 2020), however, there is also research showing a negative relation between GMA and performance (Beilock & Carr, 2001; Beilock & DeCaro, 2007). Beilock and colleagues studied the influence of working memory on task performance in several experiments in which they manipulated work pressure or complexity of the task. Working memory is closely related to GMA. In their studies, they used different types of tasks, including different math problem-solving tasks and a laboratory golf putting task. Results revealed that when people are under pressure, for example because of high attentional and cognitive processing demands, it is much more difficult for people with high GMA to perform as well as before, since now they opt for less advanced strategies and hence they lose their performance advantage. Beilock and colleagues refer to this phenomenon as choking under pressure. An explanation is that people with high GMA rely heavily on rule based processing and less on associative processing (Beilock & Carr, 2001; Beilock & DeCaro, 2007). The difference between rule based and associative processing stems from dual process theories (Petty & Cacioppo, 1986; Rydell, Mcconnell, Mackie, & Strain, 2006). When people use rule based processing, they process information relatively slowly and consciously, requiring a lot of attention and effort. They use explicit knowledge to apply rules while performing a task, while in associative processing people rely on previously learned associations. In associative processing, processing is relatively fast and unconscious.

Based on the studies by Beilock (Beilock & Carr, 2001; Beilock & DeCaro, 2007), Howe (2019) also discusses why GMA is not always beneficial for performance. He indicates that choking under pressure mainly happens when the individuals experience high pressure to perform or a high level of task complexity. In his study he focused on goal type and it is concluded that goal type is one of the boundary conditions for the relationship between GMA and performance. In the study, participants either received the instruction to do their best, to reach a specific performance goal in the task, or a learning goal that directed them to use strategies to facilitate performance (Howe, 2019). When individuals were assigned a learning goal or a do-your-best goal, this led to better performance for people high on GMA than when they were assigned a performance goal. The author argues that when individuals were assigned a performance goal, they felt more pressured which led to a lower performance in the high GMA group. This indicates that indeed individuals high on GMA lose their performance advantage if they are confronted with a complex task, that makes them feel under pressure.

The studies by Beilock and colleagues show that people high on GMA rely more on rule based processing than on associative processing, while it is the other way around for people low on GMA: They rely more on associative processing. When people experience high pressure, rule based processing is no longer the optimal way of performing, because it is slower and hence leads to worse performance. This means that the high pressure that people experience while executing a highly complex task can make it more difficult for people with a high GMA to prevail their performance advantage. That is why we expected that GMA would moderate the relationship between task complexity and performance trajectories, such that people high on GMA would have more difficulties to perform well over time in the high complexity task condition, i.e. we expect them to have a flatter learning curve than individuals low on GMA. People with high GMA will use more rule based processing, which makes it more difficult for them to perform a complex task (Beilock & Carr, 2001; Beilock & DeCaro, 2007), because they will learn the task at a slower pace, leading to a flatter learning curve. This leads to our second hypothesis:

Hypothesis 2: There will be a three-way interaction between GMA, task complexity and time on the task performance of individuals. Specifically, the performance trajectory of individuals with high GMA will be stronger influenced by the level of task complexity than the performance of individuals with low GMA. We expect that the learning curve of individuals with high GMA will be flatter than the curve of people with low GMA when confronted with a complex task.

METHOD

In this experiment we used an air traffic control (ATC) simulator (Fothergill, Loft, & Neal, 2009), which is a realistic computer task that can be used with both ATC novices and

experts. The task itself is complex, including a lot of information that needs to be processed by the participant. In the current experiment we developed two versions of the task, a complex version of it and a non-complex version.

PARTICIPANTS AND PROCEDURE

In this study 135 students (60 males) with a mean age of 21.82 years (*SD* = 4.27, range = 17 – 49) participated voluntarily. All participants provided informed consent and received a written debriefing after participating. Participants were rewarded with either course credit or a gift coupon.

When participants entered the lab, they received information about the study and after having signed the informed consent form, they started with a questionnaire on demographics and the GMA test. Next, participants were randomly assigned to one of two conditions: An experimental group (n = 76) that performed a task with a high level of complexity and a control group who performed a task with a low level of complexity (n = 59). In this study an air traffic control task was used, which was based on Yeo and Neal's conflict recognition task (2004, 2006, 2008), using the ATC-lab Advanced program (Fothergill, Loft, & Neal, 2009). In this computer task people in the complex condition had to handle 18 aircraft in each trial. In the non-complex condition there were 15 aircraft. Furthermore, in the complex condition there were 4 pairs of conflicting aircraft present in each trial, in the non-complex condition 3 pairs. Pretesting of the computer task made clear that this difference between the number of aircraft and conflicts would significantly impact the performance of the participants.

3

Some of the aircraft were in conflict with each other at certain points in the trial, that is, the distance between aircraft was less than 5 kilometers, which corresponds to approximately 1 centimeter on the screen. It was chosen to use kilometers instead of nautical miles, which is the usual unit of measurement in air traffic control, since our participants are not familiar with this term. The main aim of the ATC task was for the participant to indicate which pairs of aircraft will become a conflict. In the complex condition each trial contained 4 pairs of conflicting aircraft; in the non-complex condition there were 3 pairs. If participants recognized a conflict, they had to take action: They could change the speed and altitude of the aircraft to prevent conflicts.

Due to technical problems, data of 9 participants were not saved, and thus lost. This led to a total number of 69 participants in the complex condition and 57 in the non-complex condition. Participants in the non-complex condition were confronted with a smaller number of aircraft, conflicts and aircraft that had to be accepted.

The experiment took place in a laboratory. In each session 1 – 8 participants were tested.

Every participant in one session was in the same experimental condition: high or low complexity. First, participants completed the questionnaire about background information. Next, they received a manual with the instruction for the ATC task and the experimenter went through this manual together with the participant. After this, the participants could start with the computer task. This task involved 20 3-minute trials.

MEASURES

Before starting with the ATC computer task, participants had to fill in a questionnaire about background information, including sex, age and education level. Next, participants had to perform a short GMA test, which consisted of two subscales of the Groninger Intelligence Test (GIT, Luteijn & Van der Ploeg, 1983), namely the Matrijzen scale, which measures verbal GMA, and the Legkaarten scale, which measures nonverbal GMA.

Task performance was measured as the number of correctly solved conflicts in the ATC task.

STATISTICAL ANALYSES

We performed growth modeling analyses using the open source software R, following the approach by Bliese and Ployhart (2002). More specifically, we used the nlme package (linear and nonlinear mixed effect models; Pinheiro, Bates, DebRoy, & Sarkar, 2011) in the open source software R and restricted maximum likelihood estimation (RMLE). Growth modeling analyses is a statistical technique that can be used to study growth trajectories of individuals' performance over time (Bliese & Ployhart, 2002). It can be seen as a specific type of multilevel analysis which makes it possible to study performance over time. In growth modeling analyses, the level 1 variable is the variable 'time' and the level 2 variable is the variable at the individual level. In all our analyses we controlled for educational level of the participant, since we tested individuals with different types of background. First, we only tested growth models at level 1, and then we entered our two level-2 variables condition and GMA. For condition, we dummy coded the condition in which we randomly placed our participants by using 0 and 1, for GMA we first summed the two subscales and then z-standardized this total score of GMA.

RESULTS

First, we inspected the means and correlations of the main study variables (see Table 3.1 and 2). According to Bliese and Ployhart (2002) the first step in growth modeling analysis is the calculation of the intraclass coefficient (ICC). The ICC indicates the proportion of variance in the dependent variable that can be explained by between-person differences. Our analyses

revealed an ICC of .26, which indicated that between-person variance explained 26 % of the variance in performance, suggesting that there are sufficient individual differences in performance across time.

Table 3.1. Means, Standard Deviations, and Correlations of the Study Variables.

Variable	*M*	*SD*	1.	2.	3.
1. Condition	.56	.49	-		
2. GMA	22.86	4.83	.13	-	
3. Performance	55.87	18.18	-.18*	.11	-

Note. *N* = 126. Condition coded as 0 = non-complex condition, 1 = complex condition

Table 3.2. Means and Standard Deviations per Condition

Variable	M	SD
Control condition		
1. GMA	22.13	4.25
2. Performance	59.64	16.73
Complex condition		
1. GMA	23.43	5.19
2. Performance	52.75	18.84

Note. *N* = 57 in the control condition; *N* = 69 in the complex condition.

Next, we calculated the model in which we tested whether time had a linear relationship with our dependent variable (i.e. performance on the ATC task) and we added a random slope for time to our model. We found a significant effect of time on performance [estimate (2141) = 2.85, p < .01], see Table 3.3, Model 1. Since in skill acquisition one would rather expect a quadratic effect of time, we tested whether time had a quadratic relationship with performance and added the quadratic term to the model. We indeed found the expected effect [estimate (2140) = -335.10, p < .01], see Model 2 in Table 3.3. Analyses revealed that the linear model (Model 1 in table 3.3), in which slopes can vary, fitted the data better than the previous model with only fixed effects [χ2diff(6) = 161.63, p < .01]. In the next step we compared the quadratic model with random slope with the previous linear model and the quadratic model fitted the data better [χ2diff(7) = 187.12, p < .01]. In the last step of our level-1 model, we assessed whether the model improves by incorporating a correlated error structure and the analyses revealed that this was the case [χ2diff(7) = 83.19, p < .01].

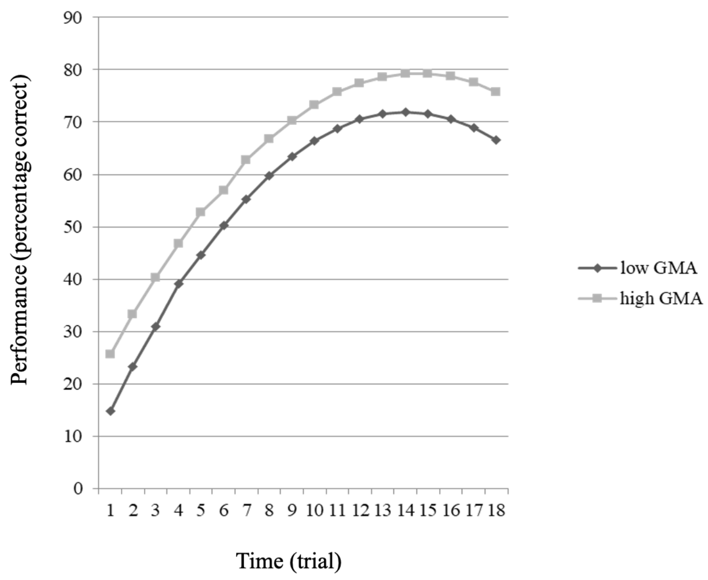

Figure 3.1. Performance trajectory for the control condition (predicted values based on the final quadratic level 2 model)

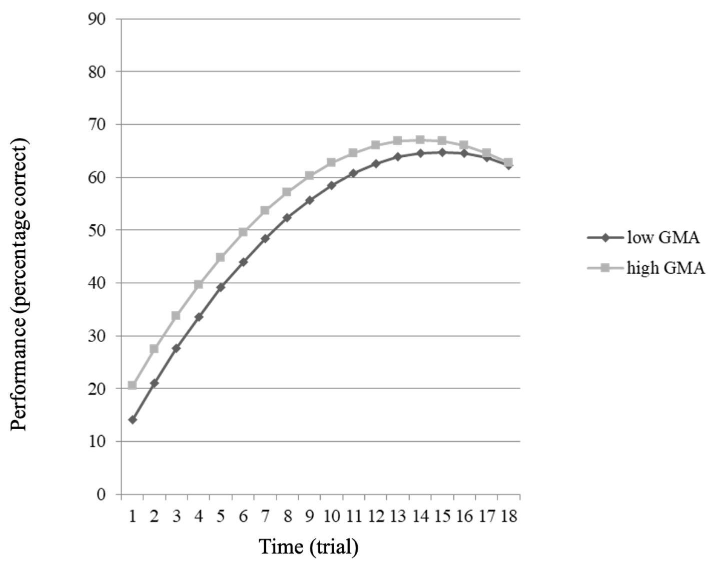

Figure 3.2. Performance trajectory for the complex condition (predicted values based on the final quadratic level 2 model)

We continued with the level 2 analyses and added the interaction terms Condition*GMA and the Time(quadratic)*Condition to our model as fixed effects. We did this first for the linear model (Model 3 in Table 3.3) and also for the quadratic model (Model 4). Results showed, as expected, a significant main effect for condition [estimate (61) = -9.07, $p < .01$], but no significant interaction Time(quadratic)*Condition [estimate (1199) = 34.48, $p = .47$] (see Table 3.3, Model 4). This means that our first hypothesis was not confirmed: Individuals in the complex condition did not perform worse than individuals in the non-complex condition.

To test hypothesis 2, we also added the three-way interaction Time*Condition*GMA to the model, which we did both for the linear and the quadratic model. As can be seen in Table 3.3, this effect was significant in our final quadratic model, Model 4 [estimate (1199) = -100.07, $p < .01$]. The graphs of the predicted values of our final model (see figure 3.1 and 3.2) confirmed that in the non-complex condition, participants low versus high in GMA showed a different learning curve than participants in the complex condition. In the complex condition, the difference between the performance trajectories of individuals high and low on GMA was smaller and more specifically, the difference in their trajectories completely disappeared towards the end of the task. According to hypothesis 2, we expected a flatter learning curve, which is not the case here, but we found that there is no difference in the performance trajectory towards the end instead.

Table 3.3. Growth Models Predicting Performance as a Function of Task Consistency and General Mental Ability

	Model 1			Model 2			Model 3			Model 4		
Variable	Coef.	Coef. SE	*t*	Coef.	Coef. SE	*t*	Coef.	Coef. SE	*t*	Coef.	Coef. SE	*t*
Level 1												
Intercept	31.18	1.48	21.11**	55.86	1.61	34.67**	59.70	16.62	3.59**	59.70	16.62	3.59**
Time (linear)	2.85	0.17	16.60**	697.15	42.74	16.31**	556.56	67.05	8.30**	556.56	67.05	8.30**
Time (quadratic)				-335.10	25.57	-13.11**				-258.21	35.62	-7.24**
Level 2												
Condition							-9.07	4.21	-2.16*	-9.07	4.21	-2.16*
GMA							1.55	3.09	.50	1.55	3.09	.50
Condition*GMA							3.42	4.25	.80	3.42	4.25	.80
Time (linear)*GMA							48.14	64.27	.75	48.14	64.27	.75
Time (linear)*Condition							-86.91	90.29	-.96	-86.91	90.29	-.96
Time (linear)*Condition*GMA							10.75	89.88	.12	10.75	89.88	.12
Time (quadratic)*GMA										58.07	34.15	1.70
Time (quadratic)*Condition										34.48	47.98	.72
Time (quadratic)*Condition*GMA										-100.07	47.75	-2.09*
	SD	Correlation 1	Correlation 2	*SD*	Correlation 1	Correlation 2	*SD*	Correlation 1	Correlation 2	*SD*	Correlation 1	Correlation 2
Random effects												
1. Intercept	9.41	–	–	11.72	–	–	14.92	–	–	15.29	–	–
2. Time	1.37	.21	–	1.54	-.07	–	1.67	-.42	–	1.70	-.44	–
Residual	24.79			23.19			24.58			23.43		

Note. * $p < .05$; ** $p < .01$ n = 71 – 126 at the between-person level and 1278 – 2268 at the within-person level. We controlled for education level in all four models.

DISCUSSION

The aim of this study was to investigate the moderating effect of task complexity on the relationship between GMA and task performance on an ATC simulator computer task. Our first hypothesis was not confirmed: The interaction between Time and Condition was not significant, which means that there is no difference in the performance trajectories of individuals in the control versus the complex condition. Our second hypothesis was partly confirmed: The three-way interaction between Time, Task complexity and GMA was significantly related to the performance of individuals; however, the skill acquisition curve looked different from what we expected. In the quadratic model, individuals high and low on GMA showed a similar performance trajectory at first, with individuals high on GMA performing slightly better. However, this difference disappears in the later phase of skill acquisition. This means that the quadratic trend differed between individuals high versus low on GMA. We hypothesized that there would be a flatter learning curve for the individuals high on GMA, but we found that the decline in performance is steeper in the last trials for individuals high on GMA. This only applies to the complex condition, not to the control condition. This means that the skill acquisition indeed differs between the two groups, but this difference occurs at the later stage in the form of a performance decline.

Our results are in line with findings by Beilock and colleagues (Beilock & Carr, 2001; Beilock & DeCaro, 2007). They found that when people have to work under high pressure, the performance advantage that high GMA individuals have, disappears. Previous research proposed that people with high GMA have more strategies to choose from and they make use of rule based processing (Beilock & Carr, 2001; Beilock & DeCaro, 2007). Individuals choose the best strategy and execute this strategy by applying the relevant rules during task performance. This leads to better performance than performance of people with low GMA; They use a simpler, less effective strategy which hence lowers their performance. However, this is different in a complex task. Individuals will have experienced the higher level of complexity as higher levels of work pressure. When individuals experience high levels of complexity, this will impact the attentional demands for the task and individuals will need more time to finish the task (Ackerman, 1992; Farrell & McDaniel, 2001). Individuals high on GMA lose their performance advantage by choosing a simpler strategy while performing, which means that hypothesis 2 was partly confirmed.We showed that the skill acquisition curve was different between individual high versus low on GMA and this difference occurred in the last phase of skill acquisition. Beilock and Carr refer to this phenomenon as “choking under pressure”: “performing more poorly than expected given one’s level of skill” (Beilock & Carr, 2001, p. 701). In a more recent study, Howe (2019) also found evidence that there are certain situational characteristics that will nullify the positive relationship between GMA and performance. Lang and Bliese (2009, p.413) also acknowledge that “those with high ability (a) tend to switch to simpler problem-solving strategies, (b) devote proportionally less cognitive processing capacities to the execution of the task, and (c) have difficulties finding new solution strategies when they face task demands".

In our study, we showed a difference between individuals high versus low on GMA in the last few trials. This makes sense if we consider the fact that rule based processing, which high GMA individuals use (Beilock & Carr, 2001; Beilock & DeCaro, 2007), might not be the best option in a complex task. In a complex task, individuals typically need to process a lot of information (see e.g. Ackerman, 1988; Ackerman & Cianciolo, 2002). Rule based processing is an automatic process: Individuals will process information in a more automatic way, which is not the most effective way if a task highly complex. A more conscious way of information processing would be more effective in such a task, so that individuals would consciously pay attention to the task. In our study, the high versus low GMA group showed a similar performance trajectories at first, because the high GMA individuals could still spend their attentional resources to the task, while towards the later phase of task performance, their resources might have been drained, leading to a sharper decrease in their performance in the last few trials of the task. The high GMA group was working under pressure: choking under pressure (Beilock & Carr, 2001; Beilock & DeCaro, 2007). Individuals have less attentional resources available because of the high levels of task complexity and will also experience time pressure. This explains why the learning curve is different for high GMA individuals in the complex condition. However, for the low GMA individuals, this did not have such an effect, since they simply use their strategies as they always do, independent from the level of task complexity. The high GMA individuals have a broader spectrum of strategies that they can choose from, because they have more cognitive resources available (Hunter & Schmidt, 1996; LePine et al., 2000). This means that in a non-complex task they can use more demanding strategies, since they have enough attention and working memory 'left'. These strategies then lead to even better performance for them. In a complex task, they opt for a simpler strategy (Beilock & Carr, 2001; Beilock & DeCaro, 2007; Lang & Bliese, 2009), since they experience the higher work pressure of the complex task: More attention and working memory is needed. They do not have enough attention and working memory left to use the more difficult strategy, however, they keep on applying their rule based strategy. Because of the higher pressure caused by the high level of task complexity, it is not possible anymore to use rule based processing. There is not enough time to apply the rules all the time, and actually more associative processing would be more effective. Associative processing lowers the demands on working memory and attention (Beilock & Carr, 2001; Beilock & DeCaro, 2007), which is why we find different performance trajectories between individuals high and low on GMA in the final stage of task performance.

An alternative explanation of the effect of GMA on task performance could be that it is caused by boredom or fatigue, especially towards the end of the task. It might be the case that GMA is just not that relevant anymore for task performance, because individuals are bored and are losing their focus or are distracted while performing the task. Following this line of reasoning, one would expect such an effect of boredom especially in the non-complex condition. In this version of the task, individuals had to process less information compared to the complex condition and this version of the task was also easier to perform for participants, so it could be argued that especially in the non-complex task, individuals would become easily bored and distracted, which would lead to lower levels of performance. However, this is not the case. We only see a difference in the learning curve in the complex condition, not in the non-complex, which cannot be explained by boredom effects.

PRACTICAL IMPLICATIONS

Our study shows that the relationship between individual characteristics and task performance is not simple: Task characteristics also play a role. This means that in selection procedures, the focus should not only be on whether certain traits predict job performance (cf. Schmidt & Hunter, 1998), it is important that the characteristics of the job are also taken into account and, more specifically, the interaction between these task characteristics and how performance develops over time, i.e. dynamic performance. Our study focuses on GMA, but other research showed similar effects for personality traits (Le et al., 2011).

Also, our study shows that the influence of GMA is not always straightforward. We showed that the performance advantage of high GMA individuals is smaller in a complex task environment, and even disappears, in the later phases of skill acquisition. Previous research showed that this could be associated with the less optimal strategies individuals use (Beilock & DeCaro, 2007), and for example training programs could be considered to see whether their strategies can be improved, so that individuals learn how to use the most optimal strategy to perform in both a complex and less complex task environment.

STRENGTHS AND WEAKNESSES OF THE STUDY

Our study extends previous research by showing a three-way interaction effect of time, individual and task characteristics on performance. Also, by studying performance over time, we gave an overview of how people learn a task and acquire a skill over a short period of time. By applying growth modeling analyses, we were able to study the performance trajectories of individuals. As Roe (2008) already indicated it is important to incorporate the temporal aspects when looking at performance, because focusing on "what happens" gives us much more information about a phenomenon than focusing on "what is".

A recent study by Howe (2019) showed that the type of goal that individuals are trying to achieve also has an interactive effect with GMA on performance. This paper is in line with the paper by Beilock and Carr (2001) and shows, like our study, that certain factors influence whether or not individuals will choke under pressure. For future research, we would therefore recommend to study different predictors of choking under pressure, because both individual and task characteristics can influence this. It would be interesting to know under exactly which boundary conditions individuals with high GMA lose their performance advantage, because this would also have implications for practice.

Our study took place in the lab, and hence it would be interesting to replicate the study in the field, looking at actual job performance instead of simulator performance. Also, future research should compare tasks that differ more strongly in their level of complexity. In our study, the two tasks were significantly different from each other looking at complexity, but it would be interesting to see if our findings would be more pronounced when the difference between conditions would be larger. However, the fact that we did find significant effects shows that even when differences in task complexity are not extreme, there is a moderating effect of GMA on the relationship between task complexity and job performance.

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4

TASK CONSISTENCY AS A MODERATOR OF ADAPTIVE RESPONSES TO UNFORESEEN CHANGE: AN EXPERIMENTAL STUDY IN AN ATC ENVIRONMENT

ABSTRACT

In this study we examined the influence of task consistency on two types of adaptation. We used the task change paradigm to distinguish between transition adaptation, i.e. the immediate response to an unforeseen change, and reacquisition adaptation, i.e. the re-learning phase that follows and we expected that it is more difficult to respond to an unforeseen change in an inconsistent task compared with a consistent task. One hundred and thirty one participants took part in an air traffic control simulator task and halfway through the experiment an unforeseen change was introduced. We used discontinuous growth modeling to analyze the data and found a significant interaction between transition adaptation and consistency: Participants in the inconsistent condition had more difficulties in adapting to the unforeseen change than participants in the consistent condition, while there was no difference between the conditions in the reacquisition phase. This means that it is more difficult to adapt to an unforeseen change in an inconsistent task, which is in line with skill acquisition research.

KEYWORDS

Adaptive performance, task consistency, discontinuous growth modeling

THE INFLUENCE OF TASK CONSISTENCY ON ADAPTIVE PERFORMANCE

Job performance is a dynamic construct (Murphy, 1989; Sonnentag & Frese, 2009), which can be influenced by several factors. A factor of interest in this study is the fact that employees will learn at the job, which will lead to an increase in performance. Of course, also other factors influence the level of job performance. Some of these factors are related to the work itself (e.g. a change in the responsibilities of the employee, which might initially lead to a performance decrease), while other are related to the employee him- or herself (e.g. the employee is not feeling well which influences his performance negatively) (Sonnentag & Frese, 2009). Performance can hence not only differ between individuals, but also within individuals over time. Dynamic performance can be defined as a specific type of task performance, in which the focus is on how performance changes over time (Sonnentag & Frese, 2009). This enables scholars to study performance trajectories over time, and furthermore to study the relationship between predictors of job performance and outcomes of it over time (Ackerman, 1992; Farrell & McDaniel, 2001; Murphy, 1989; Voelkle et al., 2006), which is relevant for the development of personnel selection instruments.

A more specific type of dynamic performance has also received much attention in the literature, namely adaptive performance (e.g. Chen, 2005; Lang & Bliese, 2009; LePine, Colquitt, & Erez, 2000; LePine, 2003, 2005; Pulakos, Arad, Donovan, & Plamondon, 2000) and the related characteristic of the individual, namely adaptability. In the current paper, adaptability will be defined as the ability to effectively respond to unforeseen changes in work tasks. Until now, the focus in the field of adaptability has been on the role of individual difference characteristics. Scholars are interested to see whether individuals can be selected based on their level of adaptability and studies have focused at the individual level on factors as goal orientation (Kozlowski et al., 2001), general mental ability (Lang & Bliese, 2009; LePine et al., 2000), conscientiousness (LePine et al., 2000), and openness to experience (LePine et al., 2000). However, the influence of task characteristics has been mainly neglected, while we know from other studies (e.g. Farrell & McDaniel, 2001) that task characteristics such as task consistency influence dynamic job performance. Task consistency is defined as the degree to which the mapping between stimulus and response is consistent in a task (Shiffrin & Schneider, 1977). Simply stated, task consistency is the degree to which individuals need to apply the same rule again and again during task performance. In a fully consistent job, individuals have to perform the exact same task all the time, for example when working at an assembly line. Obviously, most jobs are not fully consistent; a certain degree of inconsistency in the tasks is much more common.

Previous research (Ackerman, 1992; Ackerman & Cianciolo, 2002; Farrell & McDaniel, 2001) has shown that task consistency negatively influences performance, because it is easier to learn a consistent than an inconsistent task. However, it is not yet clear if this also applies to *adaptive* performance. Adaptive performance means that an employee is being confronted with unforeseen changes in the work he/she is doing. After an unforeseen change, employees are required to adapt to this change, which means that in a sense they have to adjust their strategies and relearn the task after each change. Nowadays, it is expected from employees in many jobs that they are capable to show adaptive performance at the workplace (see e.g. Burke, Pierce, & Salas, 2006). Therefore, more knowledge is needed about the job characteristics that might hinder employees to do so. In this way, jobs can be designed in such a way that dealing with unforeseen changes will be facilitated by the job characteristics. Since task consistency is an important task characteristic that has been shown to negatively influence skill acquisition (Ackerman, 1992; Ackerman & Cianciolo, 2002; Farrell & McDaniel, 2001), this led to the research question in the current study: how does task consistency influence adaptive performance?

ADAPTIVE PERFORMANCE

Performance can be defined as "the process by which people try to achieve a given work goal" (Roe, 1999, p. 234). According to the model by Roe (1996, 1999), the individual is confronted with goals by the environment, for example in his job or in an experimental task. The individual has to transform this goal to reach a certain outcome; this is the process of performance. In this model, the environment can be seen as a complex construct and it includes many different aspects, such as the materials that are needed to reach the outcome, procedures, information, but also co-workers and clients. Adaptive performance can then be seen as a specific type of performance in which individuals have to respond to a change in the environment and it can take place in many forms. Pulakos and colleagues (2000, 2002) defined adaptive performance as a construct of individual-level job performance which can be divided in eight dimensions of adaptive job performance. The authors state that adaptive performance consists of (a) solving problems creatively, (b) dealing with uncertain or unpredictable work situations, (c) learning new tasks, technologies, and procedures, (d) demonstrating interpersonal adaptability, (e) demonstrating cultural adaptability, (f) demonstrating physically oriented adaptability, (g) handling work stress and (h) handling emergencies or crisis situations. This taxonomy shows that adaptability is a multifaceted concept and that it is an important skill in many aspects of work.

In lab studies, it has been shown that adaptive performance can be distinguished from task performance, which can be done by using the task change paradigm (see e.g. Lang & Bliese, 2009; LePine et al., 2000; LePine, 2005). In this (semi-)experimental research paradigm, individuals first have to learn how to perform a relatively new and complex task. As soon as they have reached a certain level of performance, an unforeseen change is introduced and

individuals have to adapt their strategies to remain effective in the changed task. Obviously, individuals can show different skill acquisition trajectories before the unforeseen change is introduced, because they differ in the pace in which they learn a new skill. This means that they will have reached different performance levels when confronted with an unforeseen change in a task. When studying adaptive performance it is thus important to also look at the level of skill acquisition before the unforeseen change.

The task-change paradigm was used to develop a framework to distinguish adaptive performance from basal task performance (Lang & Bliese, 2009). When focusing on performance in general there are two aspects to consider. The first aspect is the basal level of performance, which indicates how well a person performs in general, i.e. mean-level performance (Lang & Bliese, 2009). The second aspect of basal task performance is the level of skill acquisition: the pace in which a person learns a novel task, the rate of change in performance measured over time.

When it comes to adaptive performance, there are two more aspects to be considered. The first aspect is transition adaptation, which indicates the immediate reaction to an unforeseen change in a task; typically this is a decrease in performance. The second aspect is reacquisition adaptation, which indicates the pace in which a person re-learns the task after the immediate response to the unforeseen change. Reacquisition adaptation can be seen as the phase that follows after transition adaptation. It is important to make a distinction between these aspects of adaptive performance, because this framework enables us to investigate adaptive performance more specifically over time. When using the task-change paradigm, it is possible to first look at the basal performance of an individual, and additionally, the level of skill acquisition. When an unforeseen change is introduced, skill acquisition will be followed by adaptive performance: first transition adaptation, and second, reacquisition adaptation. Moreover, conclusions about the level of adaptive performance can also differ regarding the type of adaptive performance that one focuses on. Individuals can differ in how fast they respond to an unforeseen change, depending on both personal characteristics and characteristics of the task. Differences are possible in both transition adaptation and reacquisition adaptation.

ADAPTIVE PERFORMANCE IN ATC

Adaptability is especially important for people working in complex and dynamic environments, such as air traffic controllers (ATCos). ATCos have to process a lot of information that is continuously changing, such as monitoring the radar, and their task often changes by the introduction of new technologies or software (Niessen & Eyferth, 2001). Also, if the amount of air traffic continues to increase in the future, this means that the role and responsibilities of an ATCo in future air traffic management systems will change (see for example Langan-Fox, Sankey, & Canty, 2010; Metzger & Parasuraman, 2001; Rovira & Parasuraman, 2010), which has implications for both selection, training and job design. It is hence highly important to know to which extent individuals are able to respond to unforeseen changes at work and which characteristics, both of the person and the task, are related to this.

The job of an ATCo concerns processing a lot of inconsistent information, which is continuously changing. There is always a certain level of unpredictability in the task of an ATCo. A task that has a high level of inconsistency is difficult to predict and individuals need all their attention to perform the task. An ATCo has to monitor his radar, paying attention to all the aircraft under her control, while at the same time communicating with pilots and other ATCos. During his work, many (partly) unforeseen changes can happen, for example the direction of the wind can change which requires the airport to use a different runway. This means that all of a sudden the ATCo has to redirect the aircraft to another runway, which has implications for the routes she can use. This is just an example of an unforeseen change in the work of an ATCo that happens on a regular basis. Of course, there are also unforeseen changes that are much rarer, for example if there are problems with the radar system and it is hence not working optimally. However, both in the case of a more common and a rare unforeseen change, the ATCo has to be able to respond to it as quickly as possible, to prevent safety issues.

SKILL ACQUISITION AND TASK CONSISTENCY

Using the task-change paradigm, individuals first go through a learning phase to acquire the skill, before they are confronted with an unforeseen change. Ackerman (1988, 1992, 2007) developed a theory on skill acquisition, based on previous work of Anderson (1982) and Schneider and Schiffrin (1977) in which he proposed that skills can be automatized if they are practiced more often over time. When people acquire a skill, there is a transition from controlled processing, to more automatic processing (Fitts & Posner, 1967; Shiffrin & Schneider, 1977). Controlled processing is an effortful process in which individuals need a lot of attention to perform. Performance is relatively slow and error prone compared to automatic processing. For some tasks, it is easier to accomplish automatic processing than for other tasks; and some people are faster in learning a task than others. This depends on several factors (Ackerman, 2007), on the one hand there are characteristics of the person himself, such as domain specific knowledge, personality and motivation, but on the other hand there are also several characteristics of the task that can influence this: task complexity and task consistency.

Task complexity involves the amount of information that is available for the individual, the memory load, and the number of subtasks that a person has to do. Complexity is related to the amount of attention that is needed when performing a task: A very complex task demands a lot of attention and individuals will make more mistakes and need more time to complete a complex task when compared to a less complex task. Task consistency, in contrast, involves the predictability of the task and it is an essential characteristics of a task, because without a certain level of consistency, no skill acquisition can take place (Voelkle et al., 2006). A consistent task can be performed by continuously applying the same rule when performing the task. Research has shown that the level of consistency of a task or a job influences the learning curve of a person (Ackerman, 1988; Farrell & McDaniel, 2001). In general, in a consistent task, the learning curve is steeper: People learn the task in a faster way. If a task only comprises inconsistent aspects, then skill acquisition will not progress beyond the first stage, the cognitive phase (Voelkle et al., 2006). This means that for an inconsistent task, skill acquisition develops in a different way, either it only takes place in the first stage or there is a slower shift to the second and third phase compared with a consistent task (Ackerman, 1988; Farrell & McDaniel, 2001). Moreover, skill acquisition is not only slower in an inconsistent task, performance can also stabilize in a later phase than in a consistent task (Farrell & McDaniel, 2001). In an experimental study, Ackerman and Cianciolo focused on the effect of task consistency manipulations on performance in an air traffic control (ATC) simulator task. They found that their manipulation of task consistency had a profound effect on the performance of the participants, especially when information processing demands were high. These findings indicate that manipulations of the consistency of a task have an important influence on basal task performance. Farrell and McDaniel (2001) showed that the effect of consistency on performance is not restricted to laboratory studies: They analyzed data from a large database that comprises, among other things, information about job characteristics, personal characteristics and job performance. They concluded that in relatively inconsistent jobs, the learning curve (i.e. the development of performance over the years of experience a person has) is less steep than for consistent jobs, which is in line with Ackerman's findings in the lab setting.

In particular, consistency is a key task characteristic in the context of adaptability. When people are confronted with an unforeseen change in a task, this automatically means that there is a level of inconsistency. Moreover, in the task-change paradigm the demands that are posed are often high, which might lead to an even lower level of performance when confronted with an inconsistent task (Ackerman & Cianciolo, 2002). Both in lab and field studies, it has been shown that an inconsistent task takes more time to learn, which results in a flatter learning curve. For jobs that are composed of primarily consistent tasks, job performance improves faster and in the learning curve the asymptote is reached earlier than for jobs composed of inconsistent tasks (Farrell & McDaniel, 2001). This implies that an inconsistent task is more difficult for individuals to perform. This is important for adaptive performance. Task consistency has such a profound effect on basal task performance (i.e. the mean differences between individuals in performance over time, see Lang & Bliese, 2009), and furthermore, it is important to take into account the level of skill acquisition that is reached before the unforeseen change is introduced. Following this line of reasoning, it is expected that an inconsistent task makes it more difficult for people to adapt to an unforeseen change. A consistent task is easier to perform and people will automatize the task more quickly (Ackerman, 1988, 2007; Ackerman & Cianciolo, 2002; Farrell & McDaniel, 2001), which leaves more attentional resources to respond to an unforeseen seen. Hence, in our task-change experiment this would mean that better transition adaptation and reacquisition adaptation can be expected following this line of reasoning.

AN OPPOSING VIEW: A POSITIVE EFFECT OF TASK INCONSISTENCY

So far, we discussed task inconsistency as a factor that can impede adaptive performance. However, theoretical ideas could also lead to a different conclusion, namely that people would perform worse when they have to adapt to an unforeseen change in a consistent task, because of the fact that in a consistent task people reach automaticity earlier and hence develop a routine. This would then actually lead to more problems with adapting to an unforeseen change. According to theories on adaptive decision making (Payne, Bettman, & Johnson, 1993), individuals take decisions based on strategies that they have used successfully in the past. These routines enable individuals to quickly solve problems, because individuals save time in this way by not needing to create a completely new strategy. However, if the task changes the routine might no longer be the best option. Studies by Betsch and colleagues (Betsch, Brinkmann, Fiedler, & Breining, 1999; Betsch, Haberstroh, Molter, & Glöckner, 2004) showed that people often stick to a routine when they are confronted with a change in a task, even when this routine is no longer the optimal solution. In their studies, participants first developed a routine in a decision making task, and after a while they kept using this routine even though this was no longer the correct solution to the task. This indicates that new information did not overrule their prior knowledge. Participants did not change their strategy.

If we apply this to the field of adaptive performance, it would mean that people that are learning to perform a consistent task develop a routine, which actually makes it more difficult to switch strategy when they are confronted with an unforeseen change. Since they developed a routine, they will hold on to their original strategy which is no longer optimal, which will lead to poor transition adaptation and reacquisition adaptation. Betsch and colleagues showed that participants especially held on to their previous routine when they had to perform under high time pressure, which is often the case in studies on adaptive performance: People have to perform a difficult task in which an unforeseen change takes place. This leads to experience of high pressure.

To sum up, there are two opposing views when it comes to the influence of task consistency on adaptive performance. On the one hand, following the literature on skill acquisition, it can be argued that because a consistent task is easier to perform, more attention can be divided to the unforeseen change, which leads then to better adaptive performance. Participants will not need all their attention to perform well on the task and will hence respond better to an unforeseen change. On the other hand, following literature on routines, it can be argued that in a consistent task, people will develop a routine, which actually makes it more difficult for them to adapt to an unforeseen change and will hence lead to worse adaptive performance. At this point, it is not possible to conclude which view is the correct one, since there is empirical evidence for both points of view.

THE PRESENT STUDY

In the present study we used the task-change paradigm to study the effect of task consistency on adaptive performance. We build upon existing work in the field of skill acquisition on the influence of task consistency (cf. Ackerman, 1988, 2007; Farrell & McDaniel, 2001) and extend previous work by integrating this within the context of adaptive performance. Also, by contrasting on the one hand the literature on skill acquisition (cf. Ackerman, 1988, 2007; Farrell & McDaniel, 2001) and on the other hand on routines (cf. Betsch et al., 1999, 2004), our study extends previous research by giving more insight in these two views. In our study we furthermore were interested in studying the two different types of (adaptive) performance that can be distinguished (Lang & Bliese, 2009), to see whether it is indeed possible to make this distinction and to see whether task consistency has an effect on both of the adaptation types. Our first hypothesis is based on the assumption that there needs to be significant skill acquisition, transition adaptation and reacquisition adaptation before we can test the influence of task consistency. We expect that participants will first learn the task (i.e. skill acquisition), after the unforeseen change is introduced performance will decrease (i.e. transition adaptation), and hereafter they will re-learn the task (i.e. reacquisition adaptation). We operationalized skill acquisition, transition adaptation, and reacquisition adaptation by using dummy coding (see Table 4.1; for more information see: Lang & Bliese, 2009; Singer & Willett, 2003). To illustrate, in a task that consists of 30 trials in total, i.e. 15 trials before the unforeseen change and 15 after, trial 1 will be coded as 0, trial 2 as 1, trial 3 as 2, and so on, until trial 15, for skill acquisition. After trial 15 this will be kept as a constant, because skill acquisition only takes place before the unforeseen change. By including this dummy coded variable in our analyses, we can check if participants indeed show the expected learning curve. For transition adaptation, the trials before the change are coded as being 0 and after the change as 1, because in transition adaptation the focus is only on the absolute difference between what happens before and after the change. Reacquisition adaptation is dummy coded in a similar way as skill acquisition, but then it is kept constant before the change, since reacquisition adaptation only takes place after the change. Trial 16, the first trial after the change, will be dummy coded as 0, trial 17 as 1, trial 18 as 2, and so on.

Hypothesis 1: Over time, we expect significant skill acquisition (hypothesis 1a), followed by transition adaptation (hypothesis 1b), and reacquisition adaptation (hypothesis 1c).

Since we want to distinguish skill acquisition from transition and reacquisition adaptation, it is necessary to test the effect of consistency on skill acquisition first, and we expect that task consistency has a positive effect on skill acquisition. In a consistent task, individuals will learn a task at a quicker pace than in an inconsistent task, which is a replication of previous research (Ackerman, 1992; Farrell & McDaniel, 2001).

Hypothesis 2: Task inconsistency will have a negative effect on the level of skill acquisition, such that participants that are confronted with an inconsistent task will show lower levels of skill acquisition than participants that are confronted with a consistent task.

The present study extends previous research by not only defining adaptive performance more specifically by distinguishing the two types of adaptation, but also by focusing on the influence of task consistency on adaptive performance. As described earlier, there are two different views possible on the influence of task consistency on adaptive performance, one based on the skill acquisition literature; the other based on the routine literature. Since we found empirical evidence for both views, we formulate opposing hypotheses regarding the relationship between task consistency and adaptation.

Hypothesis 3a: Task inconsistency will have a negative effect on the level of transition adaptation, such that participants in the inconsistent task condition will show a larger decline of performance after the unforeseen change than participants in the consistent task condition.

Hypothesis 3b: Task inconsistency will have a positive effect on the level of transition adaptation, such that participants in the inconsistent task condition will show a smaller decline of performance after the unforeseen change than participants in the consistent task condition.

Hypothesis 4a: Task inconsistency will have a negative effect on the level of reacquisition adaptation, such that participants in the consistent task condition will show lower levels of reacquisition adaptation than participants in the consistent task condition.

Hypothesis 4b: Task inconsistency will have a positive effect on the level of reacquisition adaptation , such that participants in the consistent task condition will show higher levels of reacquisition adaptation than participants in the consistent task condition.

METHOD

To test these hypotheses we performed an experiment in the laboratory, using the task change paradigm. When participants came to our lab, they signed the informed consent form, and they started with filling in a questionnaire about background information (age, gender, educational background). When they were finished with this questionnaire, they received both written and oral instructions on our computer task. This experimental task was an Air Traffic Control (ATC) simulator task, in which participants had to direct aircraft to the correct airport. This task comprised of 30 trials and after trial 15 an unforeseen change was introduced. After these 15 pre-change trials 15 post-change trials followed. In total the experiment lasted for 90 minutes (3 minutes per trial). Participants agreed to participate voluntarily and students received course credit for their participation. Approval of the Ethical Committee was obtained before the start of this study.

PARTICIPANTS

In total 131 (mean age = 23, *SD* = 3.57 45 males) university students took part in this study. Every participant was randomly assigned to either the consistent condition (N = 63) or the inconsistent condition (N = 68); see below for an explanation of the difference between the two conditions. As proposed by Bliese and Ployhart (2002), we first inspected the data to see if there is any slope variation. For eight participants, the individual graphs that we plotted showed that they did not have any slope at all. This could indicate either that they were not paying attention during the task or that they did not understand the task. These participants did not show any skill acquisition in the first phase of the experiment. They did not display any learning curve and their performance remained on a very low level throughout the entire experiment. Since skill acquisition is a prerequisite for investigating performance after an unforeseen change, they were excluded from the analyses. This led to a total of 123 participants (mean age = 23, SD = 3.55, 41 males), 59 in the consistent condition and 64 in the inconsistent condition.

EXPERIMENTAL TASK AND PROCEDURE

We used an ATC simulator, namely ATC-lab Advanced (Fothergill, Loft, & Neal, 2009), to measure adaptive performance. In our task there were three different airports and every trial contained 22 aircraft. The aim for the participant was to redirect aircraft to the correct airport. Every aircraft had its label attached to it, which included information on the altitude, speed and type (i.e. light, medium, or heavy) of the aircraft. Participants received written instructions specifying which type of aircraft (light, medium or heavy) needed to be directed to which of the three airports. Participants were divided into two conditions: a consistent and an inconsistent condition. For the consistent condition, all the light aircraft came from the left, all the medium from above and all the heavy from the right. In this way, participants in this condition quickly learned the rule that all the aircraft from the left needed to be directed to airport A, all the medium aircraft to airport B and all the heavy to airport C. For the inconsistent condition, no such rule existed and all types of aircraft could enter from every direction, which implied that participants in this condition had to check in every trial for each airplane separately to which airport it needed to be directed. See figure 4.1 for a screenshot of this task.

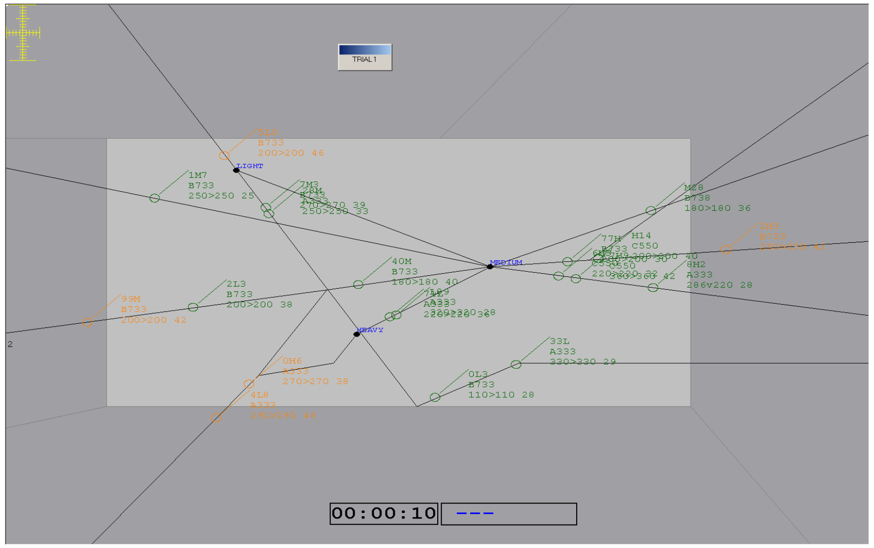

Figure 4.1. Screenshot of the ATC-lab Advanced computer task.

From previous experience with the task and also from studies that used ATC-lab Advanced before (Yeo et al., 2009; Yeo & Neal, 2004, 2006, 2008), we knew that participants needed at least 10-12 trials to have enough time to learn our version of the task, so in this study we chose 15 trials before the unforeseen change was introduced. Every trial can be seen as a different scenario, including different aircraft that had to be redirected and that lasted for 3 minutes. The unforeseen change consisted of a bad weather front that blocked one of the airports, which meant that participants had to redirect the aircraft that originally should be directed to this airport, to one of the other airports. This means that there is an increase of workload in the task after the unforeseen change; there are more aircraft that need to be

redirected in the post-change trials than in the pre-change trials. This unforeseen change was identical in both conditions. Hence, participants in the inconsistent condition worked with an inconsistent task both before and after the change, and participants in the consistent condition worked both before and after the change with the consistent version of the task. Our dependent variable was the performance of the participant, which we calculated by calculating the number of aircraft that were not or wrongly redirected by the participant. We randomized the order of the trials to rule out any possible effects of differences in the level of difficulty between the trials. Hence, every participant was confronted with a different order of the trials. We used a mixed design, which means that we had a within subjects factor: performance on the computer task, measured over time; and a between subjects factor: the condition in which the participant was placed (consistent or inconsistent).

When participants entered the lab they first received the informed consent form, after which they had to fill in a short questionnaire with some background questions (age, sex, education, and profession). Hereafter, they received the ATC manual, which included information about the task. The experimenter gave an oral explanation of the task and participants could read the manual, after which the experimenter checked if everything was clear. Then the ATC task started, in which participants were confronted with 15 pre-change learning trials, after which the unforeseen change was introduced, which was followed by 15 post-change adaptation trials. Each trial lasted for three minutes, so the computer task took about 90 minutes to complete. After the experiment, participants received a short debriefing and they could indicate whether they wanted to receive the results of the study.

STATISTICAL ANALYSES

We conducted discontinuous growth modeling analyses following the approach by Bliese and Ployhart (2002) and Lang and Bliese (2009), using the nlme (linear and nonlinear mixed effect models; Pinheiro, Bates, DebRoy, & Sarkar, 2011) and the lme4 (linear mixed effect models using S4 classes; Bates, Maechler, & Bolker, 2011) package in the open source software R and restricted maximum likelihood estimation (RMLE). Growth modeling analysis is a specific type of multilevel analysis which makes it possible to study performance over time. In growth modeling analyses, the level 1 variable is the variable 'time' and the level 2 variable is the variable at the individual level. Growth modeling analysis makes it possible to investigate performance over time and furthermore to study the effect of level 2 variables, which were only measured or manipulated once, in this case task consistency, on level 1 variable 'time'. The difference between growth modeling and discontinuous growth modeling is that with the latter a discontinuity is involved, in our case the unforeseen change. We calculated the scores per trial in the number of errors that participants made, 15 trials before the unforeseen change and 15 trials after the unforeseen change. To specifically analyze the effects of skill acquisition (SA), transition adaptation (TA) and reacquisition adaptation (TA) we used dummy coding (see table 4.1, for more information see: Lang & Bliese, 2009; Singer & Willett, 2003). Since skill acquisition only takes place before the unforeseen change is introduced, we coded trial 1 until 15 from 0 until 14 and after that (i.e. trial 16 until 30) we kept it at a constant for the last 15 trials. For our final analyses, we also took the quadratic form of this. Transition adaptation can be seen as the difference between the trials before and after the change and hence we gave the first 15 trials the value 0 and the last 15 trials value 1. Reacquisition adaptation only takes place after the change, so the first 15 trials received value 0, and after the change (trials 16 – 30) we coded the trials from 0 till 14. Again, after this we also took the quadratic form of this for our analyses. Also, in our final analyses we included the order of the trials and the change variables as random factors.

Firstly, we accounted for linear change only and secondly we also accounted for quadratic change. Measurements occasions at Level 1 were nested within individuals at Level 2. We first examined Level 1, in which we added the change variables SA, TA and RA to our model (firstly, we added only the linear variables, secondly, we also added the quadratic variables), after which we added consistency as a Level 2 predictor to explain differences in Level 1 change.

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Table 4.1. Coding of the Change Variables

	Measurement occasion																													
Variable	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Skill acquisition (SA)	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14
Transition adaptation (TA)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Reacquisition adaptation (RA)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Quadratic skill acquisition (SA2)	0	1	4	9	16	25	36	49	64	81	100	121	144	169	196	196	196	196	196	196	196	196	196	196	196	196	196	196	196	196
Quadratic reacquisition adaptation (RA2)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	4	9	16	25	36	49	64	81	100	121	144	169	196

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RESULTS

INTERCORRELATIONS AND INTRACLASS COEFFICIENT

Table 4.2 shows the means, standard deviations, and intercorrelations of the main study variables. We calculated the mean score of the trials before the unforeseen change (trial 1 – 15; prechange performance) and the mean of the trials after the unforeseen change (trials 16 – 30; postchange performance). As to be expected, prechange and postchange highly correlated with each other in both conditions. The correlation between pre- and postchange performance was $r = .662$ ($p < .05$) in the consistent condition and $r = .706$ ($p < .05$) in the inconsistent condition.

According to Bliese and Ployhart (2002) the first step in growth modeling is to inspect the dependent variable by calculating the intraclass coefficient (ICC). The ICC indicated the proportion of variance in the dependent variable that can be explained by between-person differences. Our analyses revealed an ICC of .43, which indicates that between-person variance explained 43 % of the variance in performance across time, which suggested that there were sufficient individual differences in performance across time.

Table 4.2. Means, Standard Deviations, and Correlations of the Study Variables

	M	*SD*
Consistent condition		
1. Prechange performance consistent condition	72.96	21.23
2. Postchange performance consistent condition	64.71	30.68
	M	*SD*
Inconsistent condition		
3. Prechange performance inconsistent condition	78.23	23.88
4. Postchange performance inconsistent condition	82.39	26.89

LINEAR MODEL

For our analyses at level 1, we added the change variables to our null model. First, we tested a model with only fixed effects, after which we added both SA, TA and RA as random effects to the model. This model appeared to fit the data better than the first model: $\chi 2diff(9) = 663.19$, $p < .001$. In the next step we furthermore added the order of the trials (because of randomization every participant was confronted with a different order of the trials, to filter out learning effects. See also the method section.) as a random effect, which again led to improvement of our model $\chi 2diff(1) = 298.46$, $p < .001$. We added consistency as a Level 2 predictor for each of the Level 1 components, to test for individual differences in change resulting from a different level of consistency, for both the linear and the quadratic model (for more information see Lang & Bliese, 2009). This led to our final linear model: $\chi 2diff(4) = 13.35$, $p < .01$. Our results indicated that there was significant skill acquisition, transition adaptation and reacquisition adaptation (see Table 4.3). Significant skill acquisition means that before the change, people acquired the computer task and reached a relatively stable level just before the unforeseen change occurred. After the unforeseen change, they showed significant transition adaptation: Participants made more mistakes when confronted with the unforeseen change compared with the skill acquisition phase. Furthermore, we found significant reacquisition adaptation, which indicates that they re-learned the task after their immediate response to the unforeseen change.

Table 4.3. Discontinuous Growth Models Predicting Adaptive Performance as a Function of Task Consistency

	Model 1			Model 2		
Variable	Coef.	Coef. SE	t	Coef.	Coef. SE	t
Fixed effects						
Final Level 1 model						
Intercept	6.17	0.22	28.42**	6.91	0.20	34.59**
SA	-0.19	0.02	-9.01**	-0.52	0.06	6.81**
TA	1.21	0.39	3.9**	0.70	0.33	2.13*
RA	-0.06	0.02	-3.21**	-0.17	0.05	-3.12**
SA2				0.02	0.00	6.81**
RA2				0.01	0.00	2.01*
Final Level 2 model						
Consistency	0.14	0.24	0.56	-0.26	0.21	-1.23
SA x Consistency	0.03	0.03	1.10	0.21	0.08	2.78**
TA x Consistency	0.42	0.35	1.21	0.76	0.38	1.98*
RA x Consistency	0.03	0.03	1.02	0.05	0.07	0.72
SA2 x Consistency				-0.01	0.00	-2.64**
RA2 x Consistency				0.00	0.00	-0.34

Note. SA = Skill Acquisition; TA = Transition Adaptation; RA = Reacquisition Adaptation; SA2 = Quadratic Skill Acquisition; RA2= Quadratic Reacquisition Adaptation.
*p < .05, ** p < .01

QUADRATIC MODEL

We also accounted for quadratic change in our final level 1 model. Again, we first tested the model without random effects, after which we added SA, TA, RA, SA^2, and RA^2 as random effects to the model, which led to a better fitting model: $\chi 2diff(20) = 760.23$, $p < .001$. Next, we tested the model also including the trial order as a random factor which again led to an improvement of model fit: $\chi 2diff(1) = 320.68$, $p < .001$, see Model 1 in Table 4.3. Results for our final level 1 model were as expected. We found significant quadratic skill acquisition, which indicated a typical learning curve. Also, our results revealed significant quadratic reacquisition adaptation. Hence, the results showed that there was a learning curve both before the unforeseen change (in the SA phase) and also after the unforeseen change (in the RA phase). This means that our first hypothesis was confirmed.

For the quadratic model, we also added consistency as a Level 2 predictor for each of the Level 1 components, for the model including both the time variables and the trial order as random factors, which led to our final level 2 model: $\chi^2_{diff}(6) = 20.73$, $p < .01$. Results are presented in Table 2. For the final quadratic level 2 model we found significant interactions between on the one hand consistency and skill acquisition (Hypothesis 2) and on the other hand between consistency and transition adaptation (Hypothesis 3). For skill acquisition the effect was in the expected direction: Participants in the consistent condition showed stronger skill acquisition than participants in the inconsistent condition, which means that our second hypothesis was confirmed. Furthermore, Hypothesis 3a was also confirmed: We found a significant interaction between task consistency and transition adaptation. Participants in the inconsistent condition showed a larger relapse of performance after the unforeseen change. This automatically means that hypothesis 3b was not confirmed, since we had opposing hypotheses here. Next, hypothesis 4 was not confirmed: Consistency did not have an effect on reacquisition adaptation, which means that participants in both the consistent and inconsistent condition showed a similar pattern of relearning the task after the unforeseen change was introduced. Here we also had opposing hypotheses, but neither was confirmed since we found no effect of task consistency on reacquisition adaptation. Figure 4.2 clearly summarizes these results: It shows that participants in the consistent condition made fewer mistakes overall and that those participants learned the task at a quicker pace (i.e. they showed stronger skill acquisition). Furthermore, the graph depicts that there is larger relapse (transition adaptation) in the inconsistent condition, while the pace of re-learning the task (i.e. reacquisition adaptation) is the same in both conditions. In Table 4.4 and 4.5 the results of the random effects are presented, both for our final linear (Table 4.4) and our final quadratic model (Table 4.5).

Table 4.4. Random Effects for the Final Linear Model for Predicting Adaptive Performance

			Correlations		
	Variance	SD	1.	2.	3.
Random effect					
1. Intercept	1.34	1.16			
2. Skill acquisition	0.02	0.13	-0.02		
3. Transition adaptation	3.04	1.74	0.05	-0.63	
4. Reacquisition adaptation	0.03	0.17	-0.20	-0.68	0.23
Trial (Intercept)	0.24	0.49			
Residual	1.99	1.41			

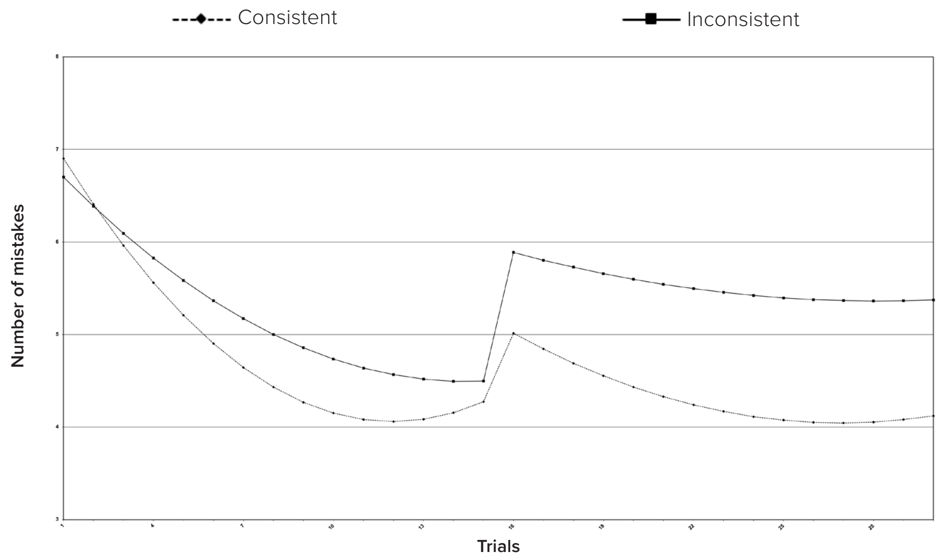

Figure 4.2. Predicted values for the consistent and inconsistent condition for predicting adaptive performance

Table 4.5. Random Effects for the Final Quadratic Model for Predicting Adaptive Performance

			Correlation				
	Variance	SD	1.	2.	3.	4.	5.
Random effect							
1. Intercept	0.52	0.72					
2. Skill acquisition (SA)	0.09	0.29	0.579				
3. Quadratic SA	0.00	0.02	-0.83	-0.89			
4. Transition adaptation	2.73	1.65	0.60	-0.23	-0.05		
5. Reacquisition adaptation (RA)	0.07	0.27	-0.29	0.01	0.09	-0.38	
6. Quadratic RA	0.00	0.02	0.12	-0.06	-0.02	0.21	-0.88
Trial (Intercept)	0.25	0.50					
Residual	1.83	1.35					

DISCUSSION

The aim of the present study was to investigate the influence of task consistency on adaptive performance, for which we distinguished three different phases: skill acquisition, transition adaptation and reacquisition adaptation. Based on skill acquisition theory (Ackerman, 1988), we hypothesized a positive effect of task consistency on the three change variables. Our first hypothesis was confirmed: As expected, we found significant effects for quadratic skill acquisition, transition adaptation, and quadratic reacquisition adaptation. This means that in our study, individuals first learned the task, and then their performance dropped after the unforeseen change, which was followed by a re-learning phase, i.e. reacquisition adaptation. Participants showed a typical learning curve (i.e. the quadratic effect for both skill acquisition and reacquisition adaptation). Hypothesis 2 indicated a positive effect of task consistency on skill acquisition and this is indeed what results showed. Participants in the inconsistent condition showed a flattened learning curve compared with participants in the consistent condition. This means that if individuals have to perform a rather inconsistent task, they need more time to learn the task.

We also found evidence for Hypothesis 3a: Task consistency is indeed related to transition adaptation. Participants in the consistent condition showed a smaller relapse of performance immediately after the unforeseen change. This means that we did not find evidence for the routine literature (e.g. Betsch et al., 1999, 2004), but for the skill acquisition literature (e.g. Ackerman, 1988, 1992; Farrell & McDaniel, 2001). However, for Hypotheses 4a and b, the relationship between consistency and reacquisition adaptation, we did not find a significant result. Participants in both conditions re-learned the task after the change at a comparable pace. Apparently, consistency only had an effect on adaptive performance immediately after the unforeseen change, but not on the re-learning phase. When performing a highly inconsistent task, it is more difficult to effectively respond to an unforeseen change, although the inconsistency does not have an effect on the re-learning phase that followed. A possible cause of this might be the fact that participants in the inconsistent condition needed more attention to perform the task. For participants in the consistent task, the task was relatively easy to learn. In the beginning they had some difficulties with the task, because it was a novel task for them: They had to process a lot of information in the task and had to find an effective strategy to perform the task. This last point makes an important difference between the two conditions: Participants in the consistent condition could apply the exact same rule in each of the trials, whilst for participants in the inconsistent condition such a rule did not exist. Hence, the latter group needed more attention to perform the task, since they could not simply apply the same rule in every trial. It might be the case that, because they needed all their attention to perform well on the trials, they did not discover the unforeseen change quickly. In the consistent condition, participants could perform the task relatively easily with not that much attention and for them it was thus easier to notice the unforeseen change and attend to it. This is in line with skill acquisition research (e.g. Ackerman & Cianciolo, 2002; Ackerman, 1988, 2007; Farrell & McDaniel, 2001), which also assumes that in a consistent task individuals need less attention to perform the task, which leads to better performance when compared with an inconsistent task. We did not find evidence for the alternative explanation, i.e. that individuals in a consistent condition would develop a routine and held on to it, despite the fact that this routine is no longer the most optimal strategy after the unforeseen change has been introduced (cf. Betsch et al., 1999, 2004). Individuals in the consistent condition actually showed a smaller drop of performance, which means that they responded more quickly to the unforeseen change than the people in the inconsistent condition. It might be that people in the consistent condition developed a routine: After a few trials, they knew exactly which strategy was optimal to successfully perform in every trial. This explains why their performance stabilized after a few trials. However, when the unforeseen change was introduced they were able to change their strategy instead of sticking to the previously developed routine. With these findings, we extend previous research by giving evidence for literature on skill acquisition, by showing that task consistency has a positive effect on adaptive performance. This is a first step in resolving the conflicting predictions between on the one hand research on routines and on the other hand research on skill acquisition.

We expected that for the inconsistent condition it would also be more difficult to re-learn the task after the change (i.e. reacquisition adaptation). However, we did not find any effect of consistency on reacquisition adaptation. We think this is related to the characteristics of the unforeseen change itself. The change implied the introduction of a bad weather front, which made it impossible to direct aircraft to one of the three airports. It might be that the participants saw this change as some sort of extra 'rule' that had to be applied in the task. Although we expected that the change made the task more difficult, it might be the case that, because the unforeseen change can be seen as an extra rule to apply, participants in the inconsistent condition actually experienced the change as a welcome variation in the task. For them it was the first time that they could simply apply a rule in each of the trials, though for participants in the consistent condition this rule did not add anything: They were already applying a specific rule in all the trials, so it might be that the unforeseen change actually made the task more difficult to re-learn. We can conclude from this that unforeseen changes force participants to switch strategies in performing the task, but that this change in strategy depended on the condition participants were assigned to.

From a theoretical point of view, our study adds to the existing literature by showing that task characteristics can have a differential effect on adaptive performance, depending on the type of adaptation one focuses on. In a review paper (Baard, Rench, & Kozlowski, 2013) the importance of longitudinal designs for investigating adaptive performance is also acknowledged. By looking at performance trajectories instead of one-time measurements of adaptive performance, one is able to get more insights in the dynamics of performance. Also, we extended the current literature by showing that task consistency not only has an influence on skill acquisition, but also on transition adaptation. Previous studies (e.g., Ackerman & Cianciolo, 2002; Ackerman, 1992; Farrell & McDaniel, 2001) have shown that task consistency influences learning curves, we added a step to this by showing the impact of consistency when a person is confronted with an unforeseen change. Our study highlights the importance of the influence of task characteristics on adaptive performance.

STUDY LIMITATIONS

Since the current study was performed in the laboratory, our findings might lack generalizability. We used a complex computer task and hence we expect our findings to be generalizable to other complex tasks. Complex processes like the ones described in the current paper can only be studied in the lab and by using a realistic ATC simulator, we tried to make our findings as generalizable as possible. However, in practice employees are often confronted with several consecutive unforeseen change. Therefore, as a next step the focus in research should be to conduct experiments that focus on more than one unforeseen change. In addition, for future research it is important to investigate the influence of task consistency on adaptive performance in different tasks and with different types of change in the task. Lastly, field studies would be necessary to gain a better understanding of adaptive performance in practice. Work is complex and dynamic, probably much more than can be captured in an experiment.

PRACTICAL IMPLICATIONS

The present findings might have implications for both job design and training. Firstly, our findings stress the importance of focusing on task characteristics as well, besides looking at factors at the individual level. Our findings show that the level of inconsistency of a task influences the adaptive performance that a person displays, which indicates the importance of paying attention to job design, especially for highly inconsistent jobs in which employees are confronted with unforeseen changes. Our findings suggest that for people working in an inconsistent job, it is more difficult to quickly respond to an unforeseen change and it is hence highly relevant to ensure relevant warning systems in these types of jobs. Secondly, and related to the former point, it is also important to pay attention to training. Since our findings suggest that it is more difficult to quickly respond to an unforeseen change when performing an inconsistent task, it is important to develop relevant training programs for this purpose. However, research concerning the trainability of adaptability in different task contexts is still lacking.

Our findings are relevant for people working in highly complex and dynamic environments, such as ATC. ATCos are confronted with unforeseen changes at a daily basis. Especially when ATCos are confronted with inconsistent circumstances, it is highly necessary to make sure that warning systems are available, so that the ATCo can react effectively when there is an unforeseen change in his job. However, our advice would not be to make the job of an ATCo completely consistent. When work becomes too predictable, this might lead to boredom and hence to lower performance (see e.g. Langan-Fox et al., 2010). A balance has to be achieved when it comes to the level of consistency or predictability of the job. This can

be related to the Job Characteristics Model (Hackmann & Oldham, 1976). According to this model, a task or a job should contain the appropriate levels of skill variety, skill identity, and skill significance, which will lead to experienced meaningfulness of work, which will in turn lead to motivation, satisfaction and work effectiveness. Also, autonomy and feedback are important. When considering task consistency, skill variety in particular is the characteristic, which is the most relevant one. A job should have enough variety in tasks and in the type of skill that is required to perform the task, in other words, a task should have some degree of inconsistency to avoid that it becomes too monotonous. Even if a job is rather consistent, multiple key tasks have to present to break the monotony, so that employees will work effectively, while staying motivated and satisfied with their job.

Our study attempted to provide insights into the influence of task consistency on adaptive performance and we added to the existing literature by showing that an inconsistent task can lead to a decrease in performance when people have to respond to an unforeseen change. It is necessary to examine our findings in a realistic work setting, so that it becomes clear how our findings can be translated into specific practical recommendations. Future research should also continue to investigate the effects of other task characteristics on the different types of adaptive performance, so that recommendations for job designs can be made.

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5

WORK ENVIRONMENT COMPLEXITY AND ADAPTATION TO UNFORESEEN CHANGES

ABSTRACT

The aim of the present study was to examine the effect of work environment complexity on adaptation to an unforeseen change by experimentally manipulating work-environment complexity. Participants worked in either a highly complex or a less complex air-traffic control environment. Halfway through a 2-hour experiment, participants in both groups needed to adapt to an unforeseen system failure causing a breakdown of a major support function of the ATC system. Discontinuous growth models were used to investigate the effect of the system failure on participants' ability to adapt to the unforeseen change over time. Participants' discontinuous adaptation trajectories differed between the high-complexity and the low-complexity group, suggesting that task complexity is a relevant moderator of adaptive reactions in complex environments. Performance of the participants in the complex condition improved immediately after the change, while participants in the non-complex condition showed the expected drop of performance (i.e. transition adaptation). During the reacquisition period, individuals in the non-complex condition re-learned the task faster and achieved a higher level of overall performance.

WORK ENVIRONMENT COMPLEXITY AND ADAPTATION TO UNFORESEEN CHANGES

Nowadays, in the fast changing world of work, organizations face many changes such as globalization, tighter economic resources and technological changes, that require employees to be adaptive (Cascio, 2003; Ployhart & Bliese, 2006). Employees need to stay up to date to be able to cope with these rather unpredictable circumstances in their work. Because of these developments, scholars have recently gained increasing interest in the topic of adaptability. Adaptability is defined as "an individual's ability, skill, disposition, willingness, and/or motivation to change or fit different task, social and environmental features" (Ployhart & Bliese, 2006, p. 13). One specific stream of research focuses on adaptability seen as task performance and more specifically on predictors of adaptive task performance (for an overview see Baard et al., 2013; Ployhart & Bliese, 2006). Previous studies (e.g. Lang & Bliese, 2009; LePine et al., 2000; LePine, 2003, 2005) mostly focused on individual factors that are related to adaptive performance, such as personality or general mental ability, however there are no studies yet that focus on the relationship between task characteristics and adaptive performance. We know from the literature on skill acquisition and performance that task characteristics have a profound influence on performance (see for example Ackerman, 1988; Farrell & McDaniel, 2001). This is relevant from a practical point of view, because for job analysis and job (re)design purposes it is important to know how task characteristics influence the performance of employees, so that jobs can be designed in such a way that the task characteristics enable employees to perform optimally. From a theoretical point of view, it is already clear that task characteristics influence performance (see e.g. Ackerman 1988; 1992; Farrell & McDaniel, 2001). However, we add to the existing literature by focusing on dynamic performance, i.e. performance trajectories. By doing so, we can more specifically study how and when task characteristics influence performance. This gives us much more information than simply focusing on performance. In the current study, we build upon these previous findings and studied the influence of task characteristics on adaptive performance, a specific form of dynamic performance. We focused on the influence of task complexity on two types of adaptive performance: transition adaption, which is the immediate drop in performance after individuals are confronted with an unforeseen change, and reacquisition adaptation, which is the re-learning phase that follows the fast drop of performance (Lang & Bliese, 2009). Our study builds upon and extends previous research on adaptability in two ways. Firstly, we provide a reliable overview of how performance changes over time by distinguishing skill acquisition and basal task performance from two types of adaptive performance: transition adaptation and reacquisition adaptation (Lang & Bliese, 2009). We see adaptive performance as a dynamic and ongoing phenomenon, and thus it needs to be measured over time (see Roe, 2008). Secondly, we extend previous research by examining characteristics of the task itself, instead of focusing solely on individual difference factors.

This chapter is based on the same dataset as Chapter 3. In Chapter 3, the focus is solely on the pre-change period, i.e. there we focus on skill acquisition and, more specifically, on the role of General Mental Ability (GMA). In the current chapter, we focus on adaptive performance, which means that in the current chapter we studied what happens after an unforeseen change and how task complexity influences adaptive performance. For an overview of all the variables used in these chapters and their correlations, I added a table in Chapter 1 (see Table 1.1 on page 19).

TYPES OF ADAPTATION

Several scholars have argued for the importance of examining performance over time (e.g. Bliese, Chan, & Ployhart, 2007; Roe, 2008), which is highly relevant for the field of adaptability. This enables scholars to focus on "what happens" rather than "what is" (Roe, 2008, p. 41), in such a way that scholars can study broader phenomena instead of specific variables. Especially when focusing on performance, it is important to focus on the dynamic nature of performance and hence measure it over time. This makes it possible to study individual change trajectories (Bliese, Chan, & Ployhart, 2007; Lang & Bliese, 2009; Roe, 2008), highlighting how performance develops over time.

In the field of adaptive performance, Lang and Bliese (2009) propose a framework to make a distinction between two components of basal performance, basal level of task performance and rate of skill acquisition, and two adaptation components, transition adaptation and reacquisition adaptation. When comparing two individuals in the task change paradigm, an individual that has a higher level of task performance will perform better or at a higher level than the other individual, both before and after the change. This means that basal task performance can be seen as mean-level performance (Lang & Bliese, 2009). An individual that has a higher rate of skill acquisition will learn quicker, both before and after the change. The learning curve will thus be steeper for this individual.

The two adaptation types are transition adaptation and reacquisition adaptation. Lang and Bliese (2009) mention three aspects of transition adaptation: Firstly, it occurs immediately after the change, secondly, transition adaptation is a flexible reaction that leads to a minimal decrease of performance and thirdly, it is measured relative to the level of performance and the learning rate before the change: It is the immediate relapse of performance. Reacquisition adaptation is different from transition adaptation in the sense that reacquisition adaptation is about the process of recovering after the unforeseen change. Unlike transition adaptation, reacquisition adaptation is about the learning behavior that is necessary to understand the changed task so that performance can return to the pre-change level. The differentiation of

these two types of adaptation is important to describe adaptive performance over time in an accurate way (Lang & Bliese, 2009). In studies that measure performance of an individual immediately after an unforeseen change, the focus is on transition adaptation. However, if the individual has the opportunity to adjust his/her strategies and to re-learn the task, it is possible that performance will improve strongly. If performance will be measured on a later point in time, it is possible to not only examine transition adaptation, but also reacquisition adaptation. Lang and Bliese's results stress the importance of examining performance over time.

TASK COMPLEXITY

Many studies in the field of adaptability focus on individual characteristics that enable employees to successfully deal with unforeseen changes (e.g. Chen, Thomas, & Wallace, 2005; Lang & Bliese, 2009; LePine, Colquitt, & Erez, 2000) while not examining the characteristics of the task itself. Task complexity is an important factor that moderates the relationship between individuals' cognitions and task performance (Ackerman, 1988, 1992; Ackerman & Cianciolo, 2002). Ackerman (1988, 1992) distinguishes three phases of skill acquisition. The first phase is the cognitive phase, in which processing is controlled and individuals need all their attention while performing the task. After a while, performance becomes faster and less attention is needed. Individuals enter then the second phase: the associative phase. Thirdly, the task will become fully automatized, which is called the autonomous phase.

As mentioned before, task complexity is an important factor that influences how individuals learn a novel task (Ackerman & Cianciolo, 2002). A complex task is a task that demands a lot of attention and in which a lot of information needs to be processed. Because of this, individuals will make more mistakes and need more time to perform the task. According to action regulation theory (Frese & Zapf, 1994; Hacker, 2003; Zijlstra, 1993) there are three different levels of awareness of the process of how people regulate their work activities. The first level is the automated level, in which people unconsciously can perform an activity, applying the same routines continuously. The second level is the knowledge based level, in which people (partly) consciously apply rules to perform a task. The third and highest level is the intellectual level, in which people have to consciously create new solutions for problems, which makes performance slower because it works in a serial mode. When people have to perform a very complex task, it will probably be very hard to perform fully automatic; they will probably need to be conscious of what is the best solution and be flexible in finding new solutions.

Ackerman and Cianciolo (2002) state that manipulations of task complexity have a profound influence on the performance of individuals and that changes in the level of complexity are furthermore reflected in correlations between ability and performance. In their experiment they manipulated task complexity among other things, using an air traffic control (ATC) simulator. Participants were responsible for the air traffic within their own sector and had to handle different types of flights: 1. overflights, which were the least demanding for the participant (low complexity), 2. arrivals, which were the most demanding flight type (high complexity) and 3. departures, which represented a medium level of complexity. The level of complexity was determined by the degree to which the task places demands on the information processing system. When the level of complexity was high, participants needed to process a lot of information and needed to execute several different operations. Their results indicate that manipulations of complexity have a profound effect on performance, although it remains unclear how complexity is related to adaptive performance.

More insights into the role of task complexity on performance can be gained from a study in the field of work interruptions (Gillie & Broadbent, 1989). Gillie and Broadbent (1989) found that people experience complex interruptions, i.e. an interruption that requires more attention from the individual who is performing the task, as highly disruptive. They conclude that interruptions that are complex, place higher demands on the working memory of individuals, require more attention and are hence more difficult to process. This is in line with the results of Ackerman and Cianciolo (2002), that in a complex task individuals need more time to process information and hence show a lower performance than individuals who are performing a less complex task.

THE PRESENT STUDY

In the present study we examined whether task complexity has a detrimental effect on adaptive performance. More specifically, we were interested in distinguishing the two adaptation components from the two basal performance components that Lang and Bliese (2009) proposed to examine adaptive performance over time. To do this, we used an ATC simulator that has been used in previous research with non ATC experts (Fothergill, Loft, & Neal, 2009) and furthermore we chose to use the task-change paradigm to examine performance over time. In this experimental paradigm people first acquire a skill until a certain level is achieved. At a certain moment some elements of the task will change unexpectedly which requires participants to adapt to the new situation, i.e. to display adaptive behavior. The use of an ATC simulator is relevant for this type of research since the task is sufficiently complex and task characteristics can be relatively easily changed (Ackerman & Cianciolo, 2002). We hypothesized that complexity has a negative influence on skill acquisition, transition adaptation and reacquisition adaptation, since an ATC task is complex and rather difficult to perform. We therefore follow Ackerman's (1988) line of reasoning that the effect of complexity on performance will be negative because a complex task puts higher demands on the individual: More information processing is necessary which leads to a higher cognitive load for the individual. This led to the following three hypotheses:

Hypothesis 1: Task complexity will impair the level of skill acquisition, in such a way that participants in the complex condition will show lower levels of skill acquisition than participants in a control condition.

Hypothesis 2: Task complexity will impair the level of transition adaptation, in such a way that participants in the complex condition will show a larger drop of performance immediately after the change than participants in the control condition.

Hypothesis 3: Task complexity will impair the level of reacquisition adaptation, in such a way that participant in the complex condition will show lower levels of reacquisition adaptation than participants in the control condition.

METHOD

PARTICIPANTS

In this study 135 students (60 males) with a mean age of 21.82 years (SD = 4.27, range = 17 – 49) participated voluntary. All participants provided informed consent and received a written debriefing after participating. After participating, they received either course credit or a gift coupon. Participants were randomly assigned to one of two conditions: A complex condition (n = 76) in which participants performed a task with a high level of complexity and a non-complex condition in which participants performed a task with a low level of complexity (n = 59). Because of technical problems, data of 9 participants were not saved on the computer. Consequently, a total number of 69 participants in the complex condition and 57 in the non-complex condition were included in the analyses. The task of participants in the non-complex condition was less complex both before and after the unforeseen change, that is, they had to deal with a smaller number of aircraft, conflicts and aircraft that had to be accepted (see below).

EXPERIMENTAL TASK

In this study an air traffic control task was used, which was based on Yeo and Neal's conflict recognition task (2004; Yeo & Neal, 2006, 2008), using the ATC-lab Advanced program

(Fothergill, Loft, & Neal, 2009). In this computer task people in the complex condition were confronted with 18 aircraft in each trial. In the non-complex condition there were 15 aircraft. Some of these aircraft were in conflict with each other at certain points in the trial, that is, the distance between aircraft was less than 5 kilometers, which corresponds to approximately 1 centimeter on the screen. It was chosen to use kilometers instead of nautical miles, which is the usual unit of measurement in air traffic control, since our participants were not familiar with this concept.

The main aim of the ATC task was for the participant to indicate which pairs of aircraft will become a conflict. In the complex condition each trial contained 4 pairs of conflicting aircraft; in the control group there were 3 pairs. If participants recognized a conflict, they had to take action: They could change the speed and altitude of the aircraft to prevent conflicts. Another aim of the task was to accept aircraft that are entering the participant's sector. In each trial there were 9 aircraft that had to be accepted in the complex group; in the non-complex group 5 aircraft had to be accepted. To eliminate the strategy that participants just change speed and/or altitude of all the aircraft to prevent conflicts, 4 points were deducted when participants change speed/altitude while this was not necessary. Results of previous studies and our own experience with the ATC task indicated that this truly distinguishes between a complex and non-complex task (Yeo, Loft, Xiao, & Kiewitz, 2009; Yeo & Neal, 2004, 2006, 2008).

UNFORESEEN CHANGE

In the first 20 (pre-change) trials the participants saw the flight routes on their screen: lines that indicate which routes the aircraft can follow. There were several intersections of flight routes on the map, which made it relatively easy to follow where an aircraft was heading to and where conflicts between aircraft would arise.

After trial 20 the unforeseen change took place: The flight routes were no longer visible, which made it much more difficult to follow the direction of the aircraft. Because of this change it was inevitable for participants to use several tools to for example measure the distance between two aircraft to check whether aircraft will be in conflict. In the pre-change period participants could also use these tools, but they could also perform the task successfully without using them.

PROCEDURE

The experiment took place in a laboratory. In each session 1 – 8 participants were tested simultaneously, but they all worked independently. Every participant in one session was in the same experimental condition: complex or non-complex. First, participants completed the questionnaire about background information. Next, they received a manual with the

instruction for the ATC task and the experimenter went through this manual together with the participant. After this, the participants could start with the computer task. This task involved 40 three-minute trials: 20 pre-change and 20 post-change trials.

A first inspection of the performance of the participants to check compliance on the different trials revealed that eight trials deviated. For two trials, this could be explained by a programming error. For the other six trials, it was attributable to fatigue or decrease in motivation. These were the final six trials of the task and we noticed during the experiment that many participants were not paying attention anymore to the task during this final part. Several of our participants were unfortunately distracted during their participation; we observed them checking their phones instead of actually working on our computer task. When we checked their individual data, we saw that they did not fill in anything for the last few trials, their performance score was 0 and, more specifically, we could see in the data that they did not use their mouse or keyboard at all for those trials. Hence we decided to leave out these eight trials in our analyses, because it was clear that participants did not comply with our instructions during these trials. Since we were mainly interested in what happened directly after the unforeseen change, this would not have consequences for testing our hypotheses. By leaving out these trials we wanted to avoid that the performance trajectory would be biased: This would give a skewed picture of the actual performance, influenced by fatigue instead of the task itself. This led to a total of 32 trials, which, for the purpose of data analysis, were grouped into blocks of 2 trials (cf. Lang & Bliese, 2009). This led to 10 blocks in the prechange period and 6 blocks in the postchange period.

STATISTICAL ANALYSES

We conducted discontinuous growth modeling analyses, which is a specific form of multilevel mixed effects model (Bliese & Ployhart, 2002; Singer & Willett, 2003). We used the nlme package in the open source software R and restricted maximum likelihood estimation (RMLE). We calculated the scores per trial in the percentage of correctly solved conflicts between aircraft. Measurements occasions at Level 1 were nested within individuals at Level 2. Discontinuous growth modeling is a step-by-step procedure, in which we first examined Level 1, after which we added complexity as a Level 2 predictor to explain differences in Level 1 change. Also, in growth modeling analyses, first the linear change will be modeled, and secondly the quadratic change (Bliese & Ployhart, 2002; Snijders & Bosker, 1999). To include the time variables skill acquisition (SA), transition adaptation (TA), and reacquisition adaptation (RA), we used dummy coding (see table 5.1; cf. Lang & Bliese, 2009; Singer & Willett, 2003). For skill acquisition we focused on the slope of the change in performance before the change, which we did both for a linear change over time (i.e. SA) and for a quadratic change over time (i.e. SA2). For transition adaptation we dummy coded the trials in such a way that pre-change and post-change performance were contrasted, to account for the unforeseen change in the task. Here, there is no need to include a linear and a quadratic trend of TA, because TA is simply the contrast between the trials before and after the change. Lastly, we modeled reacquisition adaptation as the level of skill acquisition after the change. Reacquisition adaptation is coded relative to skill acquisition, again both linear (RA) and quadratic (RA2). This means that for reacquisition adaptation, the trials before the change are coded as zero, since reacquisition is what happens after the unforeseen change. RA indicates the linear change that takes place after the unforeseen change, relative to the linear change that takes place before the change. RA2 indicates the quadratic change that takes place after the unforeseen change, relative to the quadratic change that takes place before the change.

Table 5.1. Coding of the change variables

	Measurement occasion														
Variable	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Skill acquisition (SA)	0	1	2	3	4	5	6	7	8	9	9	9	9	9	9
Transition adaptation (TA)	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1
Reacquisition adaptation (RA)	0	0	0	0	0	0	0	0	0	0	0	1	2	3	4
Quadratic skill acquisition (SA2)	0	1	4	9	16	25	36	49	64	81	81	81	81	81	81
Quadratic reacquisition adaptation (RA2)	0	0	0	0	0	0	0	0	0	0	0	1	4	9	16

RESULTS

DESCRIPTIVES AND INTERCORRELATIONS

Table 5.2 shows the means, standard deviations and intercorrelations for the prechange and postchange period in the non-complex and complex condition respectively. The mean score is higher in the non-complex condition both in the pre- and postchange period. As to be expected, the correlation between pre- and postchange performance is positive.

Table 5.2. Means, Standard Deviations, and Correlations for Prechange and Postchange Performance

	M	*SD*	1.	2.
Non-complex condition				
1. Prechange performance noncomplex condition	60.32	16.97		.76*
2. Postchange performance noncomplex condition	69.56	22.77	.76*	
	M	*SD*	3.	4.
Complex condition				
3. Prechange performance complex condition	53.15	19.01		.85*
4. Postchange performance complex condition	64.23	23.85	.85*	

* $p < .01$

INTRACLASS COEFFICIENT

According to Bliese and Ployhart (2002) the first step in growth modeling analyses is the calculation of the null model and the intraclass coefficient (ICC): the proportion of between-person variance in the overall variance. Analyses revealed that ICC = .39, which indicates that between-person variance explained 39 % of the variance in performance across time (and thus 61 % of the variance was explained by within-person variance). This suggested that there is sufficient within-person variation of performance across time to continue with the growth modeling analyses.

LEVEL 1 ANALYSES

The first step in our Level 1 analyses was to account for linear change only so we added the change variables SA, TA, and RA to the null model. We first tested a model with only fixed effects, and in the next step we included SA, TA, and RA also as random effects. Analyses revealed that the model with both fixed and random effects had a better fit to the data than the model with fixed effects only ($\chi 2diff[9]= 104.16$, $p < .01$). This model showed significant amount of skill acquisition during the prechange period, a significant negative transition adaptation effect and a significant negative reacquisition adaptation effect (see Table 5.3 for the fixed effects and random effects), which indicated that performance dropped when people were confronted with the unforeseen change and that the reacquisition adaptation slope was flatter during the postchange period relative to the prechange skill acquisition period.

The next step was to extend the basic linear discontinuous mixed-effect model to account for quadratic change. This was the final Level 1 model, including the variables to account for quadratic change. The results for the quadratic Level 1 model were similar to the results of the linear model, but the quadratic model was an improvement compared to the linear model ($\chi 2diff[2] = 149.04$, $p < .01$). In the quadratic model we found a significant effect for quadratic skill acquisition, a negative transition adaptation effect, indicating a significant drop in performance after the unforeseen change, and a significant negative reacquisition effect. This already indicated that participants first show a learning curve (i.e. significant SA2), followed by a drop of performance (i.e. significant TA), and lastly, participants showed the typical re-learning after the change (i.e. significant RA).

Table 5.3. Discontinuous Mixed-Effect Growth Models Predicting Change in Performance as a Function of Complexity

	Model 1 (linear model)			Model 2 (extended quadratic model)		
Variable	Coef.	Coef. SE	t	Coef.	Coef. SE	t
Fixed effects						
Final Level 1 model						
Intercept	36.92	1.48	25.00 a **	22.89	1.67	13.73 d**
Skill acquisition (SA)	4.33	.30	14.40 a **	14.85	.65	22.95 d**
Transition adaptation (TA)	-17.37	1.88	-9.22 a **	-14.61	2.03	-7.19 d**
Reacquisition adaptation (RA)	-1.80	.48	-3.72 a **	-11.20	1.42	-7.90 d**
Quadratic skill acquisition (SA2)				-1.17	.06	-18.31d**
Quadratic reacquisition adaptation (RA2)				-.22	.24	-.94 d
Final Level 2 model						
Complexity	-2.10	2.96	-.71 c	-1.35	3.33	-.41 c
SA x Complexity	-.75	.60	-1.26 b	-1.32	1.30	.31 e
TA x Complexity	13.88	3.73	3.72 b**	15.19	3.89	3.90 e **
RA x Complexity	-3.01	.96	-3.15 b**	-4.69	2.83	-1.66 e †
SA2 x Complexity				.06	.13	.49 e
RA2 x Complexity				.45	.48	.93 e
			Correlations			
	SD	1.	2.	3.	4.	
Random effect						
1. Intercept	13.48	-				
2. Skill acquisition	2.82	-.12	-			
3. Transition adaptation	11.02	.03	-.97	-		
4. Reacquisition adaptation	2.98	.07	-.67	.78	-	
Residual	16.49					

Note. SA = Skill Acquisition, TA = Transition Adaptation; RA = Racquisition Adaptation; SA2 = Quadratic Skill Acquisition; RA2 = Reacquisition Adaptation.
† p < .10. * p < .05. **p < .01   a df = 1887, b df = 1884, c df = 124, d df = 1885, e df = 1880

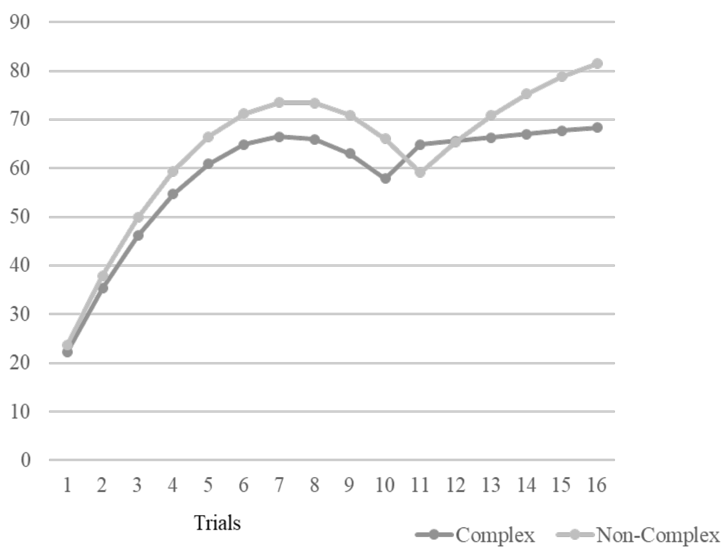

Figure 5.1. Predicted performance as a function of complexity
Note. The unforeseen change took place after trial 10 and is depicted by the vertical black line in this figure

LEVEL 2 ANALYSES

We added complexity as a Level 2 predictor for each of the Level 1 components, to test for individual differences in change resulting from a different level of complexity, for both the linear and the quadratic model, to see if participants showed a linear or a quadratic change trajectory, and the latter would indicate a typical learning curve as was found in previous studies (e.g. Ackerman, 1988; Farrell & McDaniel, 2001; Lang & Bliese, 2009). We showed that both our linear model including complexity fitted the data better than the model without complexity ($\chi 2diff[4] = 16.16$, $p < .01$), and furthermore that our quadratic model with complexity fitted the data even better than the linear one ($\chi 2diff[4]= 150.40$, $p < .01$). Results for the quadratic final level 2 model are presented in Table 5.3 For our final model, the interaction between complexity and linear skill acquisition was not significant, which means that Hypothesis 1 was not confirmed. The interaction between complexity and transition adaptation was significant, in the sense that individuals in the complex condition had a smaller decrease in performance than individuals in the non-complex condition. The interaction between linear reacquisition adaptation and complexity was marginally significant, indicating that individuals in the non-complex condition re-learned the task faster than individuals in the complex condition. Our findings are summarized in Figure 5.1. Figure 5.1 depicts the effects of complexity on the performance over time by using the model parameters of our final curvilinear model to predict performance at each measurement occasion for individuals in the complex and non-complex condition. The figure shows that for individuals in the complex condition, performance actually increased immediately after the change, while this was not the case for individuals in the non-complex condition. Hypothesis 2 (transition adaptation) was not confirmed; we actually found the opposite effect. Participants in the non-complex group showed the expected drop in performance after the unforeseen change was introduced, while participants in the complex group actually benefited from the unforeseen change. Their performance, focusing on transition adaptation, increased immediately after the unforeseen change. Our third hypothesis was confirmed, which focused on reacquisition adaptation. Individuals in the non-complex condition re-acquired the task at a faster pace than individuals in the complex condition.

DISCUSSION

The aim of the present study was to examine the relationship between work environment complexity and adaptability. Hypothesis 1 was not confirmed: We did not find a significant interaction between skill acquisition and complexity. Looking at the graph (Figure 5.1), we can see that especially during the first few trials there is no difference between the low and high complexity group. This makes sense, since the Air Traffic Control task that we used was new to all our participants, so it seems that at first the level of complexity does not influence their skill acquisition at all. However, Hypothesis 3 was confirmed: Complexity is indeed negatively related to reacquisition adaptation. People in the complex condition re-learned the task at a slower pace after the unforeseen change than people in the non-complex condition. Individuals in the non-complex condition recovered relatively fast during the reacquisition period and achieved a higher level of performance than during the prechange period within several trials.

We found the opposite effect from what we expected regarding Hypothesis 2: Complexity is positively related to transition adaptation. In the complex condition performance actually increased after the unforeseen change, while for the non-complex condition we found a direct decrease in performance after the unforeseen change was introduced. Contrary to our expectations, these findings suggest that when individuals have to perform a complex task, an unforeseen change can actually be beneficial and immediately lead to an increase in performance. Although the mean performance of individuals in the non-complex condition was consistently higher, both during the pre- and postchange period, their performance was more strongly and negatively influenced by the unforeseen change. This finding is in line with previous research that also showed that complexity leads to an increase in information-processing demands and hence decreases the level of basal task performance (Ackerman & Cianciolo, 2002). Notably however, Ackerman and Cianciolo's research focused on performance conceptualized as a stable construct while our study examined the relationship between complexity and *adaptive* performance as a dynamic construct. In the complex condition, there was no decline in performance at all: At the end of the prechange period their performance stabilized and after the change their performance actually increased. In contrast to the non-complex condition, individuals in the complex condition had to perform a task that demanded a lot of attention. They made more mistakes and needed more time to understand the task, which made it difficult for them to develop a routine; they could not automatize their task performance. This relates to action regulation theory (Frese & Zapf, 1994; Hacker, 2003; Zijlstra, 1993). Participants in the complex condition performed on the intellectual level. They needed all their attention to solve the problems during the task (i.e. to solve conflicting aircraft), while participants in the non-complex condition were performing on the automatic level. This could be an explanation for the fact that performance in the complex condition increased rather than decreased after the unforeseen change. These participants did not develop a clear routine yet, which made it easier for them to adapt to the unforeseen change in the task. They were still in their problem solving mode, not in the routine mode: they did not reach automaticity yet. Action regulation theory (Hacker, 1978; 1986; 2003) states that individuals can use different levels of regulation when performing an activity. It seems as if in our study, participants in the complex condition were unable to reach the level of automaticity. This is in line with Ackerman's explanation of complexity (Ackerman, 1988): More attention is needed and it will

take longer before individuals can perform the task automatically. The level of complexity has an influence on task performance, because higher levels of complexity put greater demands on attention (Kanfer & Ackerman, 1989): People will need more time to acquire the skill, and will need more time in the first phase of skill acquisition, the cognitive phase. Cognitive load is high, high levels of attention are needed and it will take more time to automatize the task (Ackerman, 1988) and hence to develop a routine.

PRACTICAL IMPLICATIONS

The findings are relevant for the job of air traffic controllers. During night shifts, the amount of air traffic that has to be controlled by the ATCo is often reduced, that is, the environment is less complex than during the day shifts. One of the dilemmas for ATC is the question if ATCos should be allowed to take a nap during their night shifts (see for more information Pasztor, 2011). If we generalize our findings to the ATC setting, this would mean that during night shifts, the decrease in performance after an unforeseen change should be larger than during day shifts. Therefore, it is necessary to think about alternatives to avoid that the task becomes too much of a routine for the ATCo. We would propose that taking a nap could be a good and useful opportunity for the ATCos to rest, so that they will be more focused and can invest all the effort that is needed when they return from their brake.

The present findings are of course also relevant for individuals working in other safety relevant environments, such as control rooms, power plants). In any kind of job it is important to organize work in such a way that unforeseen changes are prevented as much as possible, to prevent performance to drop and hence delay in production. The level of task complexity should be taken into account to make sure that people are able to respond effectively to unforeseen changes. In job design, one should make sure that the level of complexity does not become too low, so that employees will become bored easily. Instead, attention should be paid to include enough stimuli in every job, so that employees will stay focused and are capable to respond to unforeseen changes in an effective way.

STUDY LIMITATIONS AND FUTURE RESEARCH

One limitation of our study is that our experiment might have lasted too long for the participants, as they showed signs of fatigue towards the end of the study. Both just before the unforeseen change was introduced and also at the end of the task, performance decreased, probably because of fatigue. For future research, we would recommend to either use shorter trials or to use fewer trials than we did in our current study. Another option would be to actually measure fatigue during task performance, for example after every trial. However, we have chosen this number of trials based on previous research (Lang & Bliese, 2009; Yeo & Neal, 2004), to make sure that our participants show a learning curve.

Another limitation of the study might be the specific type of unforeseen change that we have chosen. As Baard and colleagues already indicated (Baard et al., 2013), there is no agreement on how adaptation or an unforeseen change should be defined. According to them, this results in a “a vibrant, yet chaotic, line of inquiry” (Baard et al., 2013, p. 13). Focusing on their taxonomy, our definition of adaption would fit into the performance change definition: “adaptation is an operationally defined criterion within the context of a new or more complex performance situation” (Baard et al., 2013, p. 36). Although scholars within this approach use different operationalizations in defining adaptation, a main strength of our approach is that we were able to measure performance over time, which enabled us to capture the dynamic characteristic of performance (cf. Roe, 2008).

Despite several limitations our study extends previous research by examining performance over time by distinguishing transition and reacquisition adaptation and furthermore, by focusing on the role of task complexity. Our research shows that complexity does not necessarily have a negative influence on performance and that it can even lead to improved performance when individuals in a complex environment are confronted with an unforeseen change.

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6

GENERAL DISCUSSION

In many jobs, it is expected from employees that they are flexible and are able to cope with unforeseen changes in their task. Especially in complex environments, in which individuals have to process a lot of information, are responsible for different tasks and have to keep safety regulations in mind, such as Air Traffic Control (ATC), it is crucial that employees can respond effectively if something changes in their task. Because of plans to change the way of working in ATC (see e.g. Brooker, 2008a), it becomes even more important that air traffic controllers (ATCos) are flexible and able to quickly respond to changes. That is why I tried to answer the following question in this thesis: How do characteristics of the individual and of the task influence dynamic performance, and, more specifically, skill acquisition and adaptive performance?

Figure 6.1., which was explained in the general introduction of this thesis, shows the overall research model. The main hypotheses were confirmed. In Chapter 3, I showed that GMA, task complexity and time have an interaction effect on the performance of individuals, which is, in particular, visible in the final stage of skill acquisition. I showed that the performance advantage of high GMA individuals compared with low GMA individuals was smaller when performing a complex task, and even disappears completely at the end. In Chapter 4, I showed that task consistency has an effect on adaptive performance and in Chapter 5, I showed that task complexity has an effect on adaptive performance as well. Furthermore, it was shown that task complexity and task consistency both have a different effect on adaptive performance (i.e. on transition and reacquisition adaptation). These findings will be discussed in more detail in the next section.

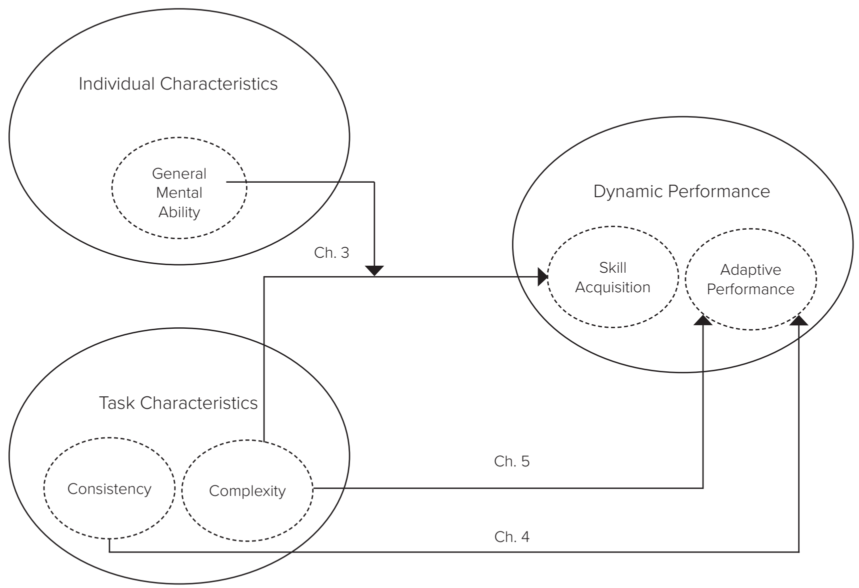

Figure 6.1. Overall model of the different constructs in this thesis.

THEORETICAL IMPLICATIONS AND DIRECTIONS FOR FUTURE RESEARCH

In the studies described in this thesis, I showed that not only individual characteristics, such as GMA, influence dynamic performance, but also the characteristics of the task. In my research I built upon the work of Ackerman and colleagues (Ackerman, 1988, 1992, 2007; Ackerman & Cianciolo, 2002) by studying the effect of task complexity and consistency on skill acquisition and adaptive performance. We used the framework by Lang and Bliese (2009), who distinguished transition adaptation, the immediate response to an unforeseen change, from reacquisition adaptation, the re-learning phase that follows.

TASK CHARACTERISTICS

In my experiments, I showed that task characteristics influence task performance, in the sense that a task that is more complex or less consistent, leads to lower performance on that task. Moreover, when focusing on the two types of adaptation, task characteristics influence transition adaption and not so much reacquisition adaptation. This means that task characteristics mainly influence the immediate response that follows after an unforeseen change. This is probably related to the fact that during the transition adaptation phase, individuals have to become aware of the unforeseen change and think about how they could change their strategy to remain effective in their performance. A task that has a low level of complexity or a high level of inconsistency will make it more difficult to discover an unforeseen change. In both cases there is divided attention of the individual, although the explanation is different for complexity and consistency. When levels of complexity are low, people get bored and their attention get distracted from task performance. If then something changes in the task, it takes more time to respond to it since people are not paying enough attention to the task. This is different for tasks with a high level of inconsistency. In these tasks, people need all their attention to focus on the task, since it is difficult to predict what happens in the task. Because of this, there is no attention left to attend when something changes. People need more time to react to the unforeseen change, since it is harder for them to notice it. In conclusion, I extended previous research by showing that the influence of task characteristics on dynamic performance is dependent on the specific type of task characteristics (i.e. task complexity or task consistency) and the type of dynamic performance (i.e. skill acquisition, transition adaptation, and reacquisition adaptation). This indicates that the influence of task characteristics is not always straightforward and that levels of task complexity and consistency should be taken in careful consideration when designing or redesigning jobs, especially in jobs that require dynamic performance.

In the introduction of this thesis, I described the crash that took place in Überlingen in 2002 (see German Federal Bureau of Aircraft Accidents Investigation, 2004): A midair collision between two aircraft. Of course, there will never be simply one factor that causes such a major accident, which can be explained by the Swiss Cheese Model (Reason, 1990; Reason, Hollnagel, & Paries, 2006). According to this model, there are always several factors that cause an accident to happen. The model suggests that all these factors, the holes in the cheese, have to be alligned for an accident to happen. These factors can be on different levels, ranging from an individual taking a wrong decision, to a lack of or unclear safety regulations on a mangerial, organizational, or even governmental level. In a field such as ATC, there are many safety regulations, making sure that accidents will be avoided. These safety regulations, posed by the management, organization or a government, can be seen as the cheese itself in the model. An accident will only occur if all the holes are alligned, meaning that factors on different levels contribute to the cause of an accident. The Überlingen accident was a complex accident: Many different causes were indicated (ranging from 36 to 42 different factors; see Brooker, 2008b; Johnson, 2004; Reason, et al., 2006).

At the time of the accident, only one ATCo was responsible for the entire traffic in the airspace of Zürich. He was confronted with several unforeseen changes that night: a delayed flight that need to be handled, using a fallback system because the normal system was not working due to maintenance, and the use of the TCAS, the on-board aircraft collision avoidance system, was still relatively new. During nightshift, the tasks of an ATCo are often relatively passive (Brooker, 2008b); the ATCo mainly has to monitor the airspace and there is not a lot of traffic. This means that the ATCo is performing a rather consistent task during a nightshift: he has to monitor the traffic, but the situation will be relatively easy to predict since there is not that much traffic. The normal nightshift is also not that complex as compared to a dayshift. There are fewer aircraft to be handled and there is not a lot of information to be processed. However, the ATCo that was on duty that night was all of a sudden confronted with many different unexpected events, which made situation highly complex and no longer consistent. In Chapter 5, I showed that dealing with an unforeseen change is actually more difficult if a participant is performing a task that is not complex. Individuals can use different levels of action regulation in task performance (Hacker, 1986; 2003). If a task has a rather low level of complexity, individuals will develop a routine and will automatize their task performance, which makes it more difficult for them to respond to an unforeseen event. It takes more time to realize that a routine is not effective anymore and that the individual has to change her strategy to perform effectively. In a complex task, individuals will need all their attention to process the available information and hence they will develop a routine, which can explain why it is easier to effectively respond to an unforeseen change in a complex than a non-complex task.

Of course, the Überlingen accident was analyzed in detail (German Federal Bureau of Aircraft Accidents Investigation, 2004: Johnson, 2004; Brooker, 2008b) and improvements

have been made on different levels to improve ATM safety performance. Brooker (2008b, p. 1502) states: "Eurocontrol now is not the same as Eurocontrol before Überlingen". However, the field of ATM is higly dynamic and especially if the air traffic will indeed in the future (Brooker, 2008a), it will remain important task complexity and task consistency will be balanced, so that a safe ATM can be guaranteed.

INTERACTION BETWEEN TASK AND INDIVIDUAL CHARACTERISTICS

In chapter 3, I showed that there is a three way interaction between GMA, time and task complexity on performance (operationalized as skill acquisition in that study). This stresses the importance of not only looking at task characteristics or individual difference characteristics, but also at the interaction between the two. I showed that the difference between people with low and high levels of GMA is more pronounced in a task with a low level of task complexity, in the last phase of skill acquisition. The initial performance advantage of individuals high on GMA, as compared to individuals low on GMA, completely disappears at the end of skill acquisition in a complex task. As I explained in chapter 3, this might be because previous research indicated that individuals with high GMA have more cognitive resources available, and, because of this, use more demanding strategies in a noncomplex task (Hunter & Schmidt, 1996; LePine et al., 2000). In a complex task, they might opt for a simpler strategy, because they experience pressure in this condition, which is comparable to findings of Beilock and colleagues (Beilock & Carr, 2001; Beilock & DeCaro, 2007) on *choking under pressure*. They argue that individuals choke (i.e. they perform on a lower level than you would expect because of their skill level) because they keep on applying a strategy that is no longer relevant. This might also be due to boredom: At a later phase of skill acquisition, the high GMA group might be bored by the task and that is why they seem to put in not enough effort anymore in their performance, which leads to a difference between the two groups in the last phase of skill acquisition. GMA differences between individuals are not always that relevant, which is related with previous research that showed that GMA is negatively related to transition adaptation (Lang & Bliese, 2009). Taken together, it is important to focus on interaction between characteristics of the individual and the task, as previous studies also showed by focusing on personality traits (see e.g. Debusscher, Hofmans, & Fruyt, 2016; Le et al., 2011).

DEFINING ADAPTIVE PERFORMANCE

As stated before, dynamic performance can be seen as a specific type of performance in which the focus is on how performance changes over time (Roe, 1999; Sonnentag & Frese, 2009). A more specific form of dynamic performance is adaptive performance. One important issue in the field of adaptive performance is the lack of a clear definition of the concept of adaptive performance. In chapter 2 I described that the field is fragmented and scholars use different definitions to describe adaptive performance, dynamic performance, adaptability, or yet another related concept they use. An overview of this topic has been published (Baard et al., 2013) in which four different theoretical approaches are discussed. Still, according to their classification there are four different types of definitions, while I think it would be very helpful to get more agreement on one specific definition. This would also make it easier to apply findings in practice, because if there is no agreement on the definition, it is very difficult to compare different studies on the same topic and also for practitioners it is even harder to apply findings in practice. I think that the definition by Ployhart and Bliese (2006, p. 13), that I also used in this thesis, is an excellent definition that can be both used in research and practice: "Individual adaptability represents an individual's ability, skill, disposition, willingness, and/or motivation, to change or fit different task, social, and environmental features." Note that in this definition adaptability is seen as a characteristic of the individual. The level of adaptability of an individual will then lead to a higher or lower level of adaptive performance. Studies on this topic should specifically explain whether they focus on individual adaptability, as a trait of the individual, or on adaptive performance, a behavioral outcome.

A related issue is the fact that the studies that have been done in this field use different research paradigms. Several studies used the task-change paradigm (cf. Chen, Thomas, & Wallace, 2005; Lang & Bliese, 2009; LePine et al., 2000; LePine, 2003, 2005), which is an improvement, but still it is difficult to compare studies. Although they use the same paradigm in which they introduce an unforeseen change in a task, the type of change that they introduce is different. I think it is important that future research will focus on describing the relationship between the type of change and the following types of adaptive behavior, at least by paying more attention to this when describing the task in their Methods section. This will make it clear exactly what kind of change leads to a specific type of behavior and it will improve the usefulness of findings in the field of dynamic performance.

Fur future research, I also recommend to study dynamic performance in a more realistic setting. In my studies, I used an ATC simulator, which is relatively realistic since it was developed in accordance with an existing ATC organization (Fothergill et al., 2009). However, in real life employees experience often many unforeseen changes, while I focused on just one unforeseen change during the task. It would be interesting and more realistic to see how individuals respond to a series of unforeseen changes. Are the patterns of transition and reacquisition adaptation then still visible? Do individuals respond differently when confronted with more than one change? Are the same individual characteristics relevant for tasks in which several unforeseen changes take place? Also, dynamic performance should be studied outside the lab, especially focusing on how tasks can be organized in such a way that dealing with unforeseen changes is facilitated.

Related to the previous point, future research should also focus on the interplay between different task characteristics. In my studies I only focused on either task complexity or task consistency, but of course in real life employees are often confronted with task that are both highly complex as well as highly inconsistent. Future studies should look at the interplay between these two characteristics, as well as at different types of change. What are the implications if a task changes from noncomplex to complex of from consistent to highly inconsistent? Will individuals be able to effectively respond to this? These would be interesting questions to be answered by future studies.

Lastly, another aspect that should be taken into account for future research is training. Many studies see adaptability as a characteristic of the person (for an overview see Baard, Rench, & Kozlowski, 2013), but until now it is not clear whether it is possible to train individuals on this characteristics. Often it is assumed that adaptability is a relatively stable characteristics of the person (Ployhart & Bliese, 2006), but does this mean that it not possible to train it at all? This, of course, is very relevant information to find out.

PRACTICAL IMPLICATIONS

My studies confirm the importance of looking at individual characteristics to select individuals for jobs in which dynamic or adaptive performance is relevant. In my literature review (chapter 2) I showed that especially self-efficacy, openness to experience and conscientiousness are important, and that, more specifically, one sub-facet of conscientiousness is especially relevant for adaptive performance: achievement striving. Previous research (LePine, 2003; LePine et al., 2000) shows that this factor is highly related to performance, because individuals who score high on achievement striving are in general highly motivated to do their jobs in the best possible way. The other sub-facet of conscientiousness, dependability, does not seem to be beneficial for adaptive performance, since individuals who score high on this factor are a bit rigid and stick too much to the rules, which makes it difficult for them to effectively respond to an unforeseen change in their task. They are simply not that flexible. Also, more research is needed on the role of GMA. Previous research already indicated that GMA is not always beneficial for adaptive performance (Lang & Bliese, 2009) and in chapter 3 I showed that individuals with high levels of GMA actually have more difficulties in a complex task in the later phase of skill acquistion. However, it remains unclear exactly why GMA is only beneficial in certain situations.

In respectively chapter 4 and 5 I showed that a certain degree of task complexity and consistency is actually beneficial when people are confronted with an unforeseen change. Apparently, individuals need a certain degree of complexity and consistency to be able to notice that something has changed in their task and to act upon it. For air traffic controllers (ATCos), this means that a balance has to be made. On the one hand, a certain degree of complexity is positive for their performance, because it keeps their attention to the task. On the other hand, when there is too less complexity, there is the risk that an unforeseen change will not be noticed because for example their attention drifts away. This is something that should be taken into account when there is less traffic to control, for example during night shifts. There is less information to process for the ATCo at that time, which means a lower level of task complexity. This might make it more difficult for her to respond if something unforeseen change happens. It is important that the ATCo will not be subject to vigilance decrements. One option would to make sure that the ATCo is involved in several tasks at night, when there are only a few aircraft to be handled. Pop, Stearman, Kazi, and Durso showed that engaging individuals in a simple task (e.g. clicking on each incoming aircraft) could already help to improve the level of vigilance. In ATM, one has to make sure that the tasks during nightshifts are complex enough so that the ATCo will be able to stay focused and vigilant.

The job of an ATCo is always inconsistent to a certain degree, however, if it becomes too inconsistent, which makes the task very hard to predict, again there is the risk that an unforeseen change will remain unnoticed. Luckily, there of course already exist many safety regulations and warning systems to prevent that an unforeseen emergency happens. This is important during a shift when there is a lot of traffic, but also during nightshift, when the there might be only a few aircraft that need to be handled and the ATCo might become fatigued.

Of course, ATCos are not the only ones experiencing fatigue related issues. Pilots for example are also experiencing fatigue, especially during long haul flights (Avers & Johson, 2011; Siebrichs & Kluge, 2018; Stewart, Koorneef, & Akselsson, 2011). Several in-flight countermeasures have been taken to avoid or overcome fatigue during these flights, which are partly similar to the measures that are being taken in ATM (Avers & Johson, 2011; Siebrichs & Kluge, 2018), such as napping and increased cockpit lighting. Furthermore, the safety management system can be enhanced by a fatigue risk management system (Stewart, et al., 2011), which is an integrated approach to detect, measure, evaluate and of course to prevent fatigue related issues as much as possible. Especially during long-haul flights, when cruising, pilots still have to perform certain checklist activities (see e.g. Degani & Wiener, 1990), to ensure safety, but also to make sure that the pilots keep their attention to the task and do not become too fatigued. For future air traffic control, this is something to also take into account. My research indicates that if the level of complexity of a job is too low, it is more difficult to respond to unforeseen changes. This means that one has to be careful when it comes to introducing more automation in ATC. Based on my studies, I assume that it is crucial that the ATCo keeps active in his role and he should not solely monitor automated systems.

LIMITATIONS

One might assume that a limitation of the studies described in this thesis is that I used an ATC simulator in all my studies and thus findings might not be generalizable to the 'real' world. However, I do think that our results will also apply in other settings. The ATC simulator that I used, ATC-lab Advanced (Fothergill et al., 2009), was developed by psychologists in accordance with air traffic controllers, which gives the simulator the advantage of both realism and experimental control. The specific computer task that the participants had to perform in my studies, were all highly complex task which required participants to use problem solving strategies. I therefore assume that my results are generalizable to other complex tasks in other settings. Of course, more research is needed to confirm this.

A second limitation of my studies might be the type of change that I introduced in the studies described in chapter 4 and 5. I introduced just one single type of change in each of the experiments, while employees are often confronted with many different types of changes at work. For future research, I would recommend focusing on introducing more than one single change in an experiment and also introducing different types of changes, in this way making the experiment more realistic.

A third limitation is that I focused on the influence of only one variable at a time in chapters 4 and 5, but it would also be possible that there is an interaction between task characteristics (for example between task complexity and task consistency) or between task characteristics and individual characteristics, as I showed in chapter 3 (an interaction between GMA and task complexity). There are only a few studies focusing on the interaction effects between task characteristics (e.g. Ackerman & Cianciolo, 2002) and on interaction effects between task and individual characteristics (e.g. Debusscher, et al., 2016; Le et al., 2011; Niessen & Jimmieson, 2016) so more research is needed in this direction.

GENERAL CONCLUSION

In this thesis I showed that not only characteristics of the individual have an important influence on dynamic performance, but that also characteristics of the task play a role. Both task complexity and task consistency influence basal task performance (i.e. the mean level of performance over time), and more specifically, influence the level of transition adaptation:

the immediate response of individuals to an unforeseen change. Adaptability is a trait that is important for many jobs and will also remain to be important in the future, since more and more flexibility will be required of employees. The studies described in this thesis show that performance is indeed dynamic and that unforeseen changes widely influence individual's task performance.

In chapter 1 I described the mid-air collision between two aircraft near Überlingen in 2002. As with most collisions, there was not one specific factor causing this crash. It was a complex situation with several unforeseen factors playing a role that particular night and a night shift with working conditions that were different from normal shifts. I think it is important to gain more knowledge about how ATCos and employees in general deal with unforeseen events at work and how we can enable them to work as effective as possible in a dynamic work environment. ATCos are always confronted with a lot of information that they need to deal with during a shift and there are constant changes in the airspace with inboud and outbound aircraft. Luckily, not many accidents happen, but knowledge about improving their working conditions is an ongoing and never ending process. Especially when considering the role of ATCos in future air traffic management (SESAR, 2018), it is crucial to gain better insights in these topics. This thesis adds to this knowledge by focusing on the role of individual and task characteristics in dynamic performance.

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A

SUMMARY
SAMENVATTING
IMPACT PARAGRAPH
DANKWOORD
CURRICULUM VITAE

SUMMARY

Nowadays, employees are faced with many changes in their work (Cascio, 2003; Ployhart & Bliese, 2006). Dealing with unforeseen changes is something that is crucial in Air Traffic Control. An Air Traffic Controller (ATCo) has to be able to effectively respond to an unforeseen change in the task, to ensure safe air traffic. Therefore, it is important to know which task and individual characteristics are beneficial when individuals are confronted with unforeseen changes in the task, which is the focus of this thesis.

First, I conducted a literature review on the topic of dynamic performance, which is described in chapter 2. I discovered that this research field is rather fragmented. It includes several different research areas that are closely related to each other: skill acquisition, task switching, interruptions and adaptive performance. Most of the previous research that has been conducted, especially in the field of adaptive performance, focuses on the influence of individual characteristics such as general mental ability (GMA) and personality on adaptive performance, while the influence of task characteristics received much less attention. That is why I chose to not only to take into account characteristics of the individual, but also to focus on task characteristics in my empirical studies, which I described in chapter 3, 4 and 5.

The previous mentioned research areas also differed in the used methodologies, but a useful methodology that is used in several studies on adaptive performance (e.g. Lang & Bliese, 2009; LePine, Colquitt, & Erez, 2000; LePine, 2003, 2005) is the task-change paradigm. This is a pseudo-experimental research paradigm, in which individuals first have to learn a task or acquire a skill, after which an unforeseen change in the task is introduced. This unforeseen change requires the individual to change her strategies and to adapt to a changed task at hand. I chose to use this paradigm in my research, since it enabled me to both study skill acquisition (before the introduction of an unforeseen change) and adaptive performance (after the introduction of an unforeseen change). More specifically, I distinguished two types of adaptation in my studies (cf. Lang & Bliese, 2009; Niessen & Jimmieson, 2016): transition adaptation, which is the immediate response to an unforeseen change, and reacquisition adaptation, which can be seen as the re-learning phase after the unforeseen change has been introduced.

In my empirical studies I used a realistic ATC simulator computer task, ATC-lab Advanced (Fothergill et al., 2009), to study individual performance over time. In every study, non-ATC experts came to the laboratory to fill in several questionnaires and to participate in the ATC task. In my first study, described in chapter 3, the emphasis was on the influence of GMA and task complexity on skill acquisition. Previous research showed that GMA is a good predictor of job performance (Schmidt & Hunter, 1998), however, this can differ

depending on the characteristics of the task. In chapter 3 we showed that when individuals have to perform a less complex task, individuals with high GMA have a clear performance advantage. However, this is different in a more complex task: The difference between individuals with high and low GMA is much smaller and disappears towards the end of the task. This can be explained by the fact that individuals with high GMA have more strategies and also more complex strategies to choose from than individuals with low GMA (Beilock & DeCaro, 2007). In a less complex task, they can think about which strategy works best and opt for the strategy that requires the least amount of effort and attention. However, in a complex task, they need all their attention and effort and because they often use more complex strategies, this can be a disadvantage in a complex task environment. They do not have enough attention left to execute their strategies well enough and hence they lose their performance advantage.

In chapter 3 we showed that task complexity has a profound influence on basal task performance (i.e. the mean level of performance over time), and thus the next step was to focus on the influence of task characteristics on adaptive performance. Hence, the research question in this study was: what is the influence of task consistency on adaptive performance? To define adaptive performance, we used the taxonomy developed by Lang and Bliese (2009). They distinguish two types of adaptation: transition adaptation and reacquisition adaptation. Transition adaptation refers to the immediate response after an unforeseen change has been introduced. Typically, it can be seen as a steep drop in performance of the individual. After this immediate response, individuals show a pattern of recovery: They slowly learn how to effectively perform the changed task. This is reacquisition adaptation: slowly re-learning the task after the unforeseen change has been introduced.

In chapter 4 we studied the effect oft tsk consistency. We used the task-change paradigm in which we introduced an unforeseen change halfway through the ATC simulator task. Result revealed that the level of task consistency only influences the transition adaptation and not the reacquisition adaptation. This means that individuals that had to perform an inconsistent task, showed a steeper decline in their performance immediately after the change than individuals that had to perform a consistent task, while there was no difference in the level of reacquisition adaptation. In a consistent task, individuals have to perform the same rule all the time. This makes it easier to respond to an unforeseen change, since individuals still have attention left to pay attention to unforeseen changes. In an inconsistent task, there is no way to predict how the task progresses and individuals need all their attention all the time to check if the strategy that they are using is still applicable. This is in line with earlier work on skill acquisition (Ackerman, 1988, 1992; Farrell & McDaniel, 2001; Keil & Cortina, 2001), that also shows that inconsistent tasks are more difficult to predict.

Lastly, in chapter 5 we found that task complexity has a main effect on performance: A complex task is more difficult than a less complex task. More importantly, we showed that task complexity only affects transition adaptation and that it does not influence reacquisition adaptation. Surprisingly, we found that individuals that had to perform a complex task actually showed an increase of performance immediately after the change, instead of the predicted decrease. Individuals in the less complex condition showed the expected decrease in performance. This relates to action regulation theory (Frese & Zapf, 1994; Hacker, 2003). According to this theory, there are three levels of awareness that regulate work activities: an automated level of regulation, a knowledge based level of regulation and an intellectual level of regulation (Frese & Zapf, 1994; Hacker, 2003). Depending on the characteristics of the task, individuals can perform in either one of those levels, however, it is not always possible to reach the level of automaticity (cf. Ackerman, 1988, 1992). We argue that participants in our complex condition performed on the intellectual level. They needed all their attention to solve the problems during the task (i.e. to solve conflicting aircraft), while participants in the non-complex condition were performing on the automatic level. In the automated level of regulation, participants in the non-complex condition were performing without conscious awareness, which made it more difficult for them to switch to a different strategy when the unforeseen change was introduced. In the complex condition performance increased after the change, because participants did not develop a clear routine yet. This enabled them to quickly recognize the unforeseen change and to find a new and effective strategy when the unforeseen change was introduced. They were still in their problem solving mode, not in the routine mode: they did not reach automaticity yet.

In the studies described in this thesis, I showed that not only individual characteristics, such as GMA, influence dynamic performance, but also the characteristics of the task. A task that is more complex or less consistent, leads to lower performance on that task. Moreover, when focusing on the two types of adaptation, task characteristics influence transition adaption and, to a lesser extent, reacquisition adaptation. These findings have implications for the job of an air traffic controller. My studies show that if the level of complexity of a job is too low, it is more difficult to respond to unforeseen changes. For future air traffic management, one has to carefully evaluate the effect of more automation. If the job of an air traffic controller becomes too passive, i.e. if the air traffic controller mainly has to monitor the systems instead of actively handling air traffic, it might become more difficult for the controller to respond to unforeseen changes, for example if one of the automated systems fails. Based on the results of my studies, I would conclude that it is crucial that the air traffic controller stays active in controlling air traffic.

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SAMENVATTING

Tegenwoordig worden werknemers geconfronteerd met vele veranderingen op het werk (Cascio, 2003; Ployhart & Bliese, 2006). Omgaan met onverwachte veranderingen is cruciaal in de luchtverkeersleiding. Een luchtverkeersleider moet effectief kunnen reageren op veranderingen in haar taak, om ervoor te zorgen dat het luchtverkeer veilig verloopt. Daarom is het van belang om te weten welke kenmerken van de taak en van het individu een positief effect hebben op prestaties als individuen geconfronteerd worden met onverwachte veranderingen in het werk, wat de focus is van dit proefschrift.

Ten eerste heb ik een literatuurstudie uitgevoerd over het onderwerp *dynamic performance,* welke wordt beschreven in hoofdstuk 2. Dit onderzoeksveld is gefragmenteerd en het omvat meerdere onderzoeksgebieden die nauw aan elkaar verwant zijn: onderzoek naar het verwerven van nieuwe vaardigheden, naar het switchen tussen taken, naar interrupties in het werk en adaptieve prestatie. Veel van dit eerdere onderzoek, vooral in het veld van adaptief presteren, richt zich op de invloed van kenmerken van het individu, zoals intelligentie en persoonlijkheid, op adaptief presteren, terwijl de invloed van taak kenmerken onderbelicht is. Daarom heb ik ervoor gekozen om me in mijn empirische studies niet alleen te richten op kenmerken van het individu, maar ook van de taak. Deze studies staan beschreven in de hoofdstukken 3, 4 en 5.

De hiervoor genoemde onderzoeksgebieden verschillen ook in de methodologieën die worden toegepast. Een bruikbare methodologie die in verschillende studies naar adaptieve prestaties wordt toegepast (zie bijvoorbeeld Lang & Bliese, 2009; LePine, Colquitt, & Erez, 2000; LePine, 2003, 2005) is het zogenoemde *task-change* paradigma. Dit is een pseudo-experimenteel onderzoeksparadigma, waarin het individu eerst een nieuwe taak leert, waarna een onverwachte verandering in de taak wordt geïntroduceerd. Door deze onverwachte verandering moet het individu zijn strategieën veranderen en zich aanpassen aan de veranderde taak. Ik heb gekozen voor dit paradigma, omdat het hierdoor mogelijk is om zowel het leren van de taak in kaart te brengen (de zogenaamde *skill acquisition* fase, voordat de onverwachte verandering wordt geïntroduceerd), als ook de adaptieve prestatie (de fases nadat de verandering is geïntroduceerd). In mijn studies kijk ik specifieker naar adaptief presteren door een onderscheid te maken tussen twee types van adaptatie (zie bijvoorbeeld Lang & Bliese, 2009; Niessen & Jimmieson, 2016): *transition adaptation*, de onmiddellijke reactie van een individu na de verandering, en *reacquisition adaptation*, de fase waarin het individu als het ware de taak opnieuw leert nadat de verandering is geïntroduceerd.

In mijn empirische studies heb ik een realistische luchtverkeersleidings- simulator taak gebruikt, *ATC-lab Advanced* (Fothergill et al., 2009), om zo individuele taakprestatie over tijd te kunnen bestuderen. In elke studie heb ik deelnemers die geen ervaring hadden met luchtverkeersleiding gevraagd naar het lab te komen om een aantal vragenlijsten in te vullen en om deel te nemen aan de luchtverkeersleidingstaak. In mijn eerste studie, die beschreven staat in hoofdstuk 3, lag de nadruk op de invloed van intelligentie en taak complexiteit op het leren van een nieuwe taak, dat wil zeggen op *skill acquisition*. Eerder onderzoek heeft aangetoond dat intelligentie een goede voorspeller is van prestaties op het werk (Schmidt & Hunter, 1998). Dit verschil kan echter afhangen van de kenmerken van de taak. In hoofdstuk 3 heb ik aangetoond dat als individuen een minder complexe taak uitvoeren, individuen met een hogere intelligentie een duidelijk voordeel qua presteren hebben. Dit is echter anders als de taak complexer is. Het verschil tussen mensen met hoge en lage intelligentie is veel kleiner en verdwijnt zelfs aan het einde van de taakuitvoering. Dit kan verklaard worden door het feit dat individuen met hogere intelligentie meer strategieën tot hun beschikking hebben en ook meer complexe strategieën hebben om uit te kiezen dan mensen met een lagere intelligentie (Beilock & DeCaro, 2007). In een minder complexe taak kunnen ze nadenken over welke strategie het beste werkt en zo kiezen voor de strategie die hen het minste moeite en aandacht kost. Dit is anders in een complexe taak waar ze al hun inspanning en aandacht nodig hebben. Aangezien ze gewend zijn om meer complexe strategieën te gebruiken, kan dit een nadeel zijn in een complexe taakomgeving. Deze groep heeft dan te weinig aandacht over om hun strategie goed genoeg uit te voeren en dus verliezen ze het voordeel dat ze aanvankelijk hadden bij het uitvoeren van de taak.

In hoofdstuk 3 heb ik aangetoond dat taak complexiteit een effect heeft op de algehele taakprestatie (d.w.z. het gemiddeld niveau van de prestatie over tijd). Daarom wilde ik in een volgende stap kijken naar de invloed van taakkenmerken op adaptief presteren. De onderzoeksvraag in deze studie was dan ook: wat is de invloed van taak consistentie op adaptief presteren? Om adaptief presteren te definiëren heb ik de taxonomie gebruikt die ontwikkeld is door Lang en Bliese (2009). Zij maken een onderscheid tussen twee types adaptatie: *transition adaptation* en *reacquisition adaptation*. *Transition adaptation* verwijst naar de directe reactie nadat een verandering is geïntroduceerd. Het kan typisch gezien worden als een steile daling in de prestatie van een individu nadat een verandering is geïntroduceerd. Na deze directe reactie laten individuen een herstel zien in hun prestatie. Ze leren dan langzaam hoe ze de veranderde taak effectief kunnen uitvoeren. Dit wordt *reacquisition adaptation* genoemd: het langzaam herleren van de taak nadat een verandering is geïntroduceerd.

In hoofdstuk vier heb ik het effect van taak consistentie bestudeerd. We hebben het *task-change* paradigma gebruikt waarin we halverwege de luchtverkeersleidingstaak een onverwachte verandering hebben geïntroduceerd. De resultaten lieten zien dat het niveau van taak consistentie alleen de *transition adaptation* fase beïnvloedt, niet de *reacquisition adaptation* fase. Dit betekent dat individuen die een inconsistente taak moesten uitvoeren een diepe daling in hun prestatie lieten zien direct nadat de onverwachte verandering was geïntroduceerd, vergeleken met individuen die een consistente taak hadden uitgevoerd. Er was geen verschil tussen beide groepen in het niveau van *reacquisition adaptation*. In een consistente taak moeten individuen steeds dezelfde regel opnieuw uitvoeren. Dit maakt het makkelijker om te reageren op een onverwachte verandering, omdat de individuen nog voldoende aandacht over hadden om te reageren op de onverwachte verandering. Dit is anders in een inconsistente taak, want daar is het niet mogelijk om te voorspellen hoe de taak zich zal ontwikkelen. Individuen hebben dan al hun aandacht nodig om constant te checken of de strategie die ze toepassen nog steeds effectief is. Dit komt overeen met eerdere bevindingen op het gebied van het leren van taken (Ackerman, 1988, 1992; Farrell & McDaniel, 2001; Keil & Cortina, 2001), waarin ook is aangetoond dat inconsistente taken moeilijker te voorspellen zijn.

Tot slot heb ik in hoofdstuk 5 aangetoond dat taak complexiteit een effect heeft op de prestatie: een complexe taak is moeilijker uit te voeren dan een niet complexe taak. Daarnaast hebben we ook laten zien dat taak complexiteit alleen de *transition adaptation* fase beïnvloedt en niet de *reacquitision adaptation* fase. Tot onze verbazing hebben we gevonden dat individuen die een complexe taak uitvoerden een verbetering in hun prestatie lieten zien direct na de verandering, in plaats van de daling in prestatie die we hadden verwacht. Individuen in de minder complexe conditie lieten wel de voorspelde daling in prestatie zien. Dit kan verklaard worden door actie regulatie theorie (Frese & Zapf, 1994; Hacker, 2003). Volgens deze theorie zijn er drie niveaus van bewustzijn die onze werkactiviteiten reguleren: een geautomatiseerd regulatieniveau, een kennis gebaseerd niveau en een intellectueel niveau van regulatie (Frese & Zapf, 1994; Hacker, 2003). Afhankelijk van de kenmerken van de taak kan een individu presteren binnen een van deze niveaus. Het is echter niet altijd mogelijk om het niveau van volledig automatisering te bereiken (zie bijvoorbeeld Ackerman, 1988, 1992). Wij gaan ervanuit dat deelnemers in onze complexe conditie presteerden op het intellectuele niveau. Ze hadden al hun aandacht nodig om problemen op te lossen tijdens de taak (ze moesten conflicten tussen vliegtuigen oplossen), terwijl deelnemers in de niet-complexe conditie op het geautomatiseerde niveau presteerden. In het geautomatiseerd niveau van regulatie konden de deelnemers in de niet-complexe conditie de taak uitvoeren zonder bewuste aandacht, welk het moeilijk voor hen maakte om te switchen naar een andere strategie toen de onverwachte verandering werd geïntroduceerd. In de complexe conditie verbeterde de prestatie na de verandering, omdat deelnemers hier nog geen routine hadden ontwikkeld. Hierdoor was het voor hen mogelijk om de onverwachte verandering snel te detecteren en een nieuwe en effectieve strategie te vinden na de verandering. Zij zaten nog in de modus van probleem oplossen,

niet in de routine modus. Het niveau van volledig automatiseren was nog niet bereikt.

In de studies beschreven in dit proefschrift heb ik aangetoond dat niet alleen kenmerken van het individu zoals intelligentie *dynamic performance* beïnvloeden, maar ook kenmerken van de taak zelf. Een taak die complexer of minder consistent is, zal leiden tot een lagere prestatie in die taak. Bovendien beïnvloeden taakkenmerken vooral *transition adaptation* en in mindere mate *reacquisition adaptation.* Deze bevindingen hebben implicaties voor de functie van luchtverkeersleiders. Mijn studies laten zien data als het niveau van complexiteit in een baan te laag is, het moeilijker is om te reageren op een onverwachte verandering. Voor de functie van de toekomstige luchtverkeersleiders is het van belang om het effect van meer automatiseren nauwkeurig te bekijken Als de baan van een verkeersleider te passief wordt, d.w.z. als zij vooral systemen moet monitoren in plaats van het actief afhandelen van het luchtverkeer, het moeilijker zal zijn voor de verkeersleider om te reageren op een onverwachte verandering, bijvoorbeeld als een van de geautomatiseerde systemen uitvalt. Gebaseerd op mijn studies concludeer ik dat het van cruciaal belang is dat luchtverkeersleiders een actieve rol houden bij het begeleiden van luchtverkeer.

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A

IMPACT PARAGRAPH

GOAL OF THIS DISSERTATION

Nowadays, it is expected from employees that they are flexible and are able to deal with unforeseen changes at work. This is what has been called dynamic performance or adaptive performance (Cascio, 2003; Ployhart & Bliese, 2006). In Air Traffic Control (ATC), it is obviously even more important that Air Traffic Controllers (ATCos) are able to deal with all the information they receive. They have to cope with a high workload, for example, navigating all the aircraft in their sector to the correct airport, checking their radar and paying attention to any changes in the weather forecast. In the light of sudden technological failures, it is important to find out which factors predict how effective employees can respond to such a failure. In this way, information will be gained on how to cope with for example these technological failures and how we can assist professionals to cope with these type of unforeseen changes in the work. The goal of my PhD thesis was to study which factors can predict how effective individuals respond to unforeseen changes in their work. To do so, I conducted a literature review and, building upon that, I presented three empirical studies in this thesis.

MAIN FINDINGS

In my literature review, I showed that several factors are related to dynamic performance. On the one hand, individual difference characteristics, such as personality factors and general mental ability (GMA, general intelligence) can predict the level of dynamic performance. On the other hand, characteristics of the task itself are also predictive of how effective individuals can respond to unforeseen changes in their work. If a task is complex, which means that individuals have to process a lot of information during the task, it is more difficult to respond to unforeseen changes. Also, if a task is inconsistent, which means that it is more difficult to predict how the task will develop, individuals will have more difficulties in dealing with unforeseen changes.

In my empirical studies, I used an ATC computer task. Participants in my studies had to fill several questionnaires on individual difference characteristics, and they had to perform this ATC task in the lab. Halfway through this task, an unforeseen change was introduced, which means that participants had to change their strategies during the task to remain effective after the unforeseen change. I showed that individuals with a higher level of GMA are overall better in performance on the ATC task, but that the difference between individuals high and low on GMA became smaller towards the later phases of task performance. This indicates that the performance advantage that individuals with a high level of GMA have, became smaller towards the end of the task. Building upon this, I ran another study in which I looked at the influence of task consistency on adaptive performance. In this study, I showed that when there is an inconsistent task, individuals found it more difficult to respond to the unforeseen change. However, after a while individuals that performed the inconsistent task were able to reach a high level of performance again, indicating that the level of consistency mainly influences the difficulty to detect an unforeseen change. In the last empirical study, I focused on complexity again and I showed that a higher level of complexity can actually lead to an increase in performance instead of the expected decrease. This indicates that complexity is not necessarily a bad thing.

RELEVANCE, TARGET GROUP AND IMPLEMENTATION

The findings reported in this thesis are relevant for ATCos, but they have also implications for employees in general. If there will be more automation in the job of an ATCo, the role of the ATCo will change from actively controlling the air traffic to more passively monitoring automated systems. In case of a technical failure, the ATCo has to be able to switch immediately from his more passive task to a very active one after such an unforeseen change. Especially in this scenario, attention needs to be paid to the task so that ATCos will also be able to respond in an effective way if something changes in their task, for example if one of the automated systems fails to work properly. With more automation, the task of the ATCo will become more consistent, which means that attention has to be paid so that the ATCo will remain active in her role. Previous research confirms that even a simple action such as clicking on each incoming aircraft can help to achieve this (Pop, Stearman, Kazi, & Durso, 2012). Also in other jobs where employees have a monitoring task, it is important to consider other task that they can engage in to remain in a more active mode, so that they are able to keep their attention to the task and to effectively respond to unforeseen changes. Taken together, the knowledge gained by my studies can be used by organizations to improve selection, training and job design, especially in jobs in which employees have to monitor systems, but being able to deal with unforeseen changes at the same time, switching from a more passive to a more active role. Jobs have to be designed in such a way that employees are capable of keeping their full attention to the task. Furthermore, the levels of task complexity and consistency in a job have to be balanced so that employees will not get bored and can apply effective strategies when performing their tasks. In conclusion, carefully designing jobs, focusing on the level of task complexity and consistency, will enable employees to perform as effective and safe as possible.

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CURRICULUM VITAE

Alicia Walkowiak was born on 11 February 1985 in Heerlen, the Netherlands. She attended the Sint Maartenscollege in Maastricht where she graduated in 2003. She started studying at Maastricht University in 2003 where she finished her Bachelor of Psychology with distinction in 2006. She continued her studies at the same university and graduated cum laude in 2007, when she completed the Master of Work and Organizational Psychology. After graduating, she started working as a research and teaching assistant at the department of Work and Social Psychology, Maastricht University. In 2009, she started her PhD project at the same department. In 2017 and 2018 she combined her job at Maastricht University with a teaching position at the department of Work and Organizational Psychology at the Open University in Heerlen. Currently, she is working as a lecturer at the department of Work and Social Psychology at Maastricht University.