Is Cognitive Ability a Liability?:
A Critique and Future Research Agenda on Skilled Performance

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Abstract

Over a century of psychological research provides strong and consistent support for the idea that cognitive ability correlates positively with success in tasks that people face in employment, education, and everyday life. Recent experimental research, however, has converged on a different and provocative conclusion, namely that lower-ability people can actually be more effective performers within special environments characterized by features such as time pressure, social evaluation and unpredictable task change. If this conclusion is true, it has extensive implications for practices such as personnel selection, training design, and teaching at all levels. The current paper re-examines and reinterprets this research within the context of well-established resource theories of cognitive processing and skill acquisition leading to a less provocative conclusion that serves to reiterate the benefits of cognitive ability for task performance. Following this re-examination, we conclude by providing a research agenda for examining the determinants of skilled performance in dynamic task environments, including: (a) broadening the range of abilities and task difficulties examined, (b) considering the role of non-ability traits and goals in skilled performance (e.g., personality, learning and performance goals), (c) investigating the processes (e.g., problem solving strategies) that people use in complex environments, (d) developing research designs and analytic strategies for examining adaptive performance, and (e) investigating how best to train for adaptive performance. (216)

Is Cognitive Ability a Liability?:

A Critique and Agenda for Future Research on Skilled Performance

Over a century of psychological research has provided a wealth of empirical support for cognitive ability as one of the most critical determinants of skilled performance. Setting aside the nature-nurture controversies surrounding the development of peoples' cognitive ability (Neisser, 1998), it is a well established and uncontroversial finding that cognitive ability can be reliably measured and is a consistent and strong predictor of important societal outcomes, such as work performance and career accomplishments (Campbell, McCloy, Oppler, & Sager, 1993; Hunter & Hunter, 1984; Neisser, et al., 1996; Park, Lubinski, & Benbow, 2007; Schmidt & Hunter, 2004), performance in academic environments (Binet & Simon, 1916; Kuncel, Hezlett, & Ones, 2001), and successful navigation of the complexities of everyday life (Gottfredson, 1997; Griener, Snowdon, & Schmitt, 1996). Certainly, theoretical disagreements about the exact nature and structure of cognitive abilities remain (e.g., see the exchange by Ackerman, Beier, & Boyle, 2005; Kane, Hambrick, & Conway, 2005; Oberauer, Schulze, Wilhelm, & Süß, 2005), and non-ability traits such as interests, personality, and motivation are critically important determinants of performance (Schmidt & Hunter, 1998). Nonetheless, there is a strong scientific consensus that higher levels of cognitive ability yield positive benefits for virtually all types of skilled performance.

A spate of recent research, however, has directly challenged this tenet, suggesting that under certain conditions, higher levels of cognitive ability can actually *impair* performance on complex tasks. For example, some of these research findings indicate that social and evaluative pressures can be more detrimental to higher-ability performers than to their lower-ability counterparts. Authors of these studies have reached conclusions such as “individuals who are

most likely to fail under performance pressure are those with high WMC [working memory capacity]” (Gimmig, Huguet, & Caverni, 2006, p. 1008). Conversely, lower-ability people in these same circumstances are said to experience “success under stress” (Beilock & DeCaro, 2007, p. 983) because relative to their higher-ability counterparts, they do not experience extensive decrements in their performance under stressful circumstances.

As another example, task changes in a skill-acquisition context impair the performance of higher-ability people more than lower-ability people, leading to the suggestion that higher-ability people are less adaptable than lower ability people (Lang & Bliese, 2009). As a practical implication of this research, the authors recommend “training tailored for high GMA [ability] people to increase competencies relevant to adaptive performance” (Lang & Bliese, 2009, p. 426), supposedly because lower-ability people are already sufficiently adaptable in dynamic performance environments. On certain complex tasks (e.g., tasks so complex that optimal processing is thought to occur outside of conscious control, DeCaro, Thomas, & Beilock, 2008), lower-ability people have also been shown to perform *better* than higher-ability people. This latter claim that “less is more” when it comes to adapting to changes and performance on certain complex tasks is provocative and requires strong evidence for its support, especially in light of a century of research on the critical contribution of cognitive ability to success across a wide range of academic, occupational, and interpersonal life tasks (Gottfredson, 1997). It is beneficial for new findings to challenge or qualify previous research and it is perhaps understandable that the popular press finds hope in tentative findings that lower-ability people may have advantages in certain situations (e.g., Carey, 2004). Nonetheless, we sound a note of caution should these findings influence educational policy, workforce training, or other high-stakes or high-cost societal interventions without serious scrutiny in the context of prior theory and research.

In this paper, we review several research paradigms that converge on this provocative conclusion that higher cognitive ability tends to be detrimental to task performance. The goal of this paper is not to dispute the specific design and execution of this research, but instead to position it within the broader context of scientific theories involving skill acquisition and cognitive ability-performance relationships that we will claim better account for its findings and that challenge conclusion that “less is more.” The studies reviewed herein were chosen based on a comprehensive literature review over the past decade on research showing that cognitive ability is a *liability* for task performance. We chose to review these studies rather than to produce empirical research that refutes each claim individually because we believe that such a review is a powerful way to identify overarching issues in the “less is more” message found in a variety of research paradigms (from basic to applied) research. Additional research is warranted, however, on the conditions that moderate the effects of cognitive ability, and the conclusion of our paper provides some future research directions regarding individual differences and situational characteristics that critically contribute to skilled performance and its maintenance in complex task environments.

Prelude

Recent claims about the benefits of lower cognitive ability are not new; they merely resurface periodically in the literature. Over 40 years ago, Zeaman and House (1967) reviewed an array of experimental studies concerned with cognitive ability and learning. Although the lion’s share of these studies demonstrated that cognitive ability was positively related to task performance and learning, some found no relationship, and a few actually showed that “less is more.” In their attempts to understand the sources of variability in the relationships found across studies, these authors discovered that the magnitude and direction of ability-performance

relationships depended not only on the cognitive ability (or intelligence) of the performer, but also on the cognitive demands of the tasks themselves. Studies using either very easy or very difficult tasks yielded range-restricted data, and therefore cognitive ability did not correlate highly with performance (nor would any other predictor of performance). Slight negative relationships between intelligence and performance were more evident when the tasks were extremely easy, presumably because higher-ability people were less engaged in the task than lower-ability people. The authors concluded that ability-performance relationships can be obscured or misunderstood “by either subject selection procedures or unhappy choice of task difficulty level” (Zeaman & House, 1967, p. 202).

Since this review, 40 years of additional research and theory on cognitive abilities have compounded the fundamental point made by Zeaman and House (1967): The cognitive ability of the performer and characteristics of the task must be considered *together* to understand the nature of relationships between cognitive ability and task performance with any clarity and depth. Below we review theoretical frameworks relevant to this claim.

Theoretical Frameworks

Dual process theories. Dual process theories claim that there are two alternative cognitive processes associated with executing a task: automatic and controlled processing.¹ *Automatic processing* is a function of domain specific stimulus-response patterns and generally occurs outside of conscious awareness. *Controlled processing*, by contrast, occurs largely within conscious awareness and operates through cognitive effort and the sequential processing of information. Automatic processing requires a minimum of attentional resources, whereas

¹ The terms *automatic processing* and *controlled processing* are used in the skill acquisition and resource theory literatures discussed in this paper. We should note that alternative labels with very similar meanings exist in other theories (e.g., *associative* and *procedural* in place of *automatic*; *rule-based* and *declarative* in place of *controlled*; DeCaro & Beilock, 2010; Maddox & Ashby, 2004).

controlled processing requires high levels of attentional control. Attentional control is equated with cognitive ability (or working memory) in most dual process theories (Barrett, Tugade, & Engle, 2004). In other words, cognitive ability is a critical determinant of the attentional control that people bring to performance situations.

Dual process theories of attentional control have been employed to explain the finding that lower ability could be advantageous across a wide range of situations, including those involving language learning, probability estimates, and performance pressure (DeCaro & Beilock, 2010). In most cases, increased cognitive resources should lead to improved controlled processing and better task performance. DeCaro and Beilock (2010), however, demonstrate situations where higher-ability people may be more likely to decide to engage in controlled processing when automatic processing would be more efficient. For instance, when complex problems can be solved using an elaborate algorithm (controlled processing) or a short-cut strategy (automatic processing), higher-ability people are thought to be more likely to choose and use the elaborate algorithm, probably because this strategy is likely to pay off in the long run. Nonetheless, a short-cut strategy can be useful when no algorithm is evident beyond what can be determined from the gist of the problem at hand, or when the benefits of experience and quick judgment offset any marginal gains from investing additional time and effort.

DeCaro and Beilock (2010) posited that higher-ability people who invest the time in learning elaborate algorithms for solving complex problems will have greater difficulty than lower-ability people in solving different-but-related problems that require departing from those algorithms. This paper examines the possibility that higher ability people show functional fixedness, where they remain immersed in controlled processing even when it would be advantageous to switch to using short-cuts and other more efficient approaches.

Resource theories. One limitation of dual process theories for explaining the “less is more” phenomenon is that these models, and studies based on them, largely ignore important types and levels of task characteristics, such as how complex the task is and how related the elements of the task are to one another. Task characteristics are critically important to acknowledge because they influence how much controlled or automatic processing is required for performance. Resource theories include the same consideration of automatic and controlled processing as dual process theories; however, they are broader because they include a consideration of both the person characteristics and task characteristics that jointly affect how cognitive or attentional resources are allocated for task performance (Kanfer & Ackerman, 1989; Norman & Bobrow, 1975).

In resource theory, the relationship between cognitive ability and performance is described along two dimensions: Resource limitations and data limitations (Kanfer & Ackerman, 1989; Norman & Bobrow, 1976). Resource limitations are defined by the amount of cognitive resources a person has available for the task. Specifically, a process is *resource-limited* when allocating cognitive or attentional resources to task execution results in better performance. For example, for most college students, moderately difficult math problems are resource limited because performance on these problems will tend to improve with increased cognitive effort. Performance on resource-limited tasks is also said to be *resource-dependent*, because performance is generally impaired when attention is diverted from the task, such as through psychological pressure or simultaneous cognitive demands from other tasks.

In contrast to resource-limited processes, the performance process is said to be *data-limited* when one’s level of task performance is relatively immune to the amount of cognitive effort or attention applied (Kanfer & Ackerman, 1989; Norman & Bobrow, 1976). Data-limited

processes result when a person finds that tasks are either (a) extremely easy or well learned (i.e., the task can be performed with little to no cognitive effort), or (b) extremely difficult or cannot be learned (i.e., task performance does not improve, even when applying maximum cognitive effort). Because performance on data-limited processes is not a function of the cognitive resources available, it is said to be *resource-insensitive*. For example, both single-digit addition problems and thermodynamics problems are likely to be data-limited for most first-year college students, because the former are very easy for them, and the latter are very difficult. It might seem a bit unusual that very difficult tasks can be just as data-limited as very easy tasks; however, research verifies that when performing very difficult tasks, people will withdraw their attention when effort and performance do not pay off (Kane & Engle, 2000). In such cases, people may be able to retrieve some information from memory that aids performance (e.g., shortcuts or satisficing solutions), but when they lack the knowledge and skills essential to completing a complex task, they usually achieve suboptimal results (see Rosen & Engle, 1997).

Figure 1 (adopted from Norman & Bobrow, 1975) illustrates how data-limited and resource-limited processes affect task performance. The dotted part of each curve represents processes that are resource-limited; in other words, as a function of the task and the person performing the task, increased effort results in increased performance. The solid part of the curves represents processes that are data-limited; in other words, for these tasks and these people, increased effort in this region does not pay off in terms of increased performance. Curve A represents a process that is relatively more resource-limited than Curve B, where increased effort generally pays off, except at very high levels of effort. Curve B represents a process that is relatively more data-limited, where a low level of effort pays off, but higher levels of effort do not. Many other curves could illustrate different effort-performance relationships as a function

different people and tasks (see Norman & Bobrow, 1975).

Resource theories have been criticized in the past for a lack of specificity related to how cognitive resources operate and which activities require those resources (Navon, 1984). Some of that criticism is from experimental paradigms that highlight relevant group phenomena as a function of task conditions and manipulations, but are relatively less concerned with the role of individual differences. Nonetheless, individual differences are central to resource theories because cognitive resources are generally assessed as individual differences in fluid intelligence and working memory capacity measured with items requiring different levels of information processing, storage and recall (Just & Carpenter, 1992; Unsworth & Engle, 2007). Cognitive resource availability is also influenced by emotions and motivational characteristics (Kanfer & Ackerman, 1989). We examine resource theory within a relatively broad experimental and individual differences framework by revisiting the influence of both the task and the individual, respectively, on complex task performance. In doing so, the purpose is to summarize across the specific research in the areas we review, but we do not discount the need to continue to refine and investigate the tenets of resource theory (e.g., see Schmeichel, 2007 for a recent experimental treatment of resource theory).

Skill acquisition theory. Skill acquisition theory applies the principles of resource theory to the process of acquiring a skill over time, a process that eventually contributes to successful performance on complex tasks for those who master the skill (Ackerman, 1988; Anderson, 1982). These theories typically describe the skill acquisition process in three phases: Phase 1 is the *declarative knowledge phase* and involves slow and effortful processing as the learner develops knowledge about the task. Phase 2 is the *knowledge compilation phase*, which involves practice on the task and increased speed and efficiency in task execution. Phase 3 is the

procedural knowledge phase, which is exemplified by automatization of task performance, meaning that the task can be executed with very little attentional effort. The initial stages of skill acquisition are thought to require the most attentional effort, because the task is novel and resource limited (i.e., more controlled processing will be necessary for performance). As a learner moves into the later stages of skill acquisition, the skill becomes increasingly data limited (i.e., it can be executed with less attentional effort).

Task consistency and complexity have been considered in skill acquisition theory because they critically influence how easy the task will be to learn. Consistently mapped tasks are those for which the rules for performance, the task components that are to be processed, and the sequence to process those components are invariant across task practice (Ackerman, 1987). Because they are invariant, consistent tasks can be learned through practice involving the allocation of attentional resources (i.e., controlled processing). After the components are learned, performance becomes automatic. Conversely, variably mapped tasks are those for which the rules to perform the task, task components, and task sequences are constantly changing. Unlike consistently mapped tasks, variably mapped tasks cannot be learned and will require controlled processing and attentional resources for task performance. Task complexity can be thought of as determined by the number of task components and the dynamic nature of the task (i.e., see Wood, 1986, for an extensive discussion of task complexity). Task consistency and complexity will influence how resource-limited and data-limited tasks change over time throughout the skill acquisition process. For instance, tasks that are relatively complex and that have some consistent and inconsistent components will be relatively resource-limited throughout all stages of skill acquisition (i.e., performance will be improved through cognitive effort).

Other theoretical models. Additional theoretical models can be employed to discuss the

studies we review. For instance, arousal theories posit that moderate levels of arousal – as opposed to high or low levels of arousal – can increase the attentional resources available and improve performance on complex tasks (Kahneman, 1973). Distraction and explicit monitoring theories also specifically address how pressure affects performance. Distraction theories posit that high-pressure situations harm performance because pressure diverts attentional focus from the task at hand. Explicit monitoring theories posit that high-pressure situations increase self-consciousness about performance – that is, there is an internal worry rather than external distraction – that leads people to focus their attention on skill execution (DeCaro, Thomas, Albert, & Beilock, 2011). Explicit monitoring theories account the phenomenon of choking under pressure on well learned tasks (e.g., a golf pro missing an easy putt because he/she is thinking about each step of the putting process, which displaces what is normally an automatic putting routine). We selected resource theory – and by extension, skill acquisition theory – to frame our argument because it provides predictions about attentional effort and performance more generally than arousal, distraction, and monitoring theories and it can account for simple and complex task performance across a range of situations.

Three “Less is More” Research Paradigms

Note that the authors whose research we review make use of various terms that refer to different cognitive ability constructs, such as *working memory capacity* (Beilock & Carr, 2005; Beilock & DeCaro, 2007; DeCaro & Beilock, 2010; DeCaro et al., 2008) and *general mental ability* (Lang & Bliese, 2009). We are sensitive to these distinctions, but we use the terms *cognitive ability* or *ability* to encompass all of these related constructs. Using this overarching term allows for clearer exposition without taking away from important underlying distinctions that may be useful for other purposes. Three recent research paradigms have highlighted

potential problems associated with higher levels of cognitive ability (i.e., that “less is more”): (1) the pressure-to-perform paradigm, (2) the proceduralized learning paradigm, and (3) the adaptive performance paradigm.

The pressure-to-perform paradigm. Studies that fall under the *pressure-to-perform* paradigm posit that higher-ability people should generally exhibit greater performance decrements whenever there is perceived pressure on a task requiring skilled performance (Beilock & Carr, 2005; Gimmig et al., 2006). Under this paradigm, high and low task pressure is either manipulated in within-subjects designs (Beilock & Carr, 2005) or between groups of subjects (Beilock & DeCaro, 2007; Gimmig et al., 2006). Notably, the tasks used in these studies tend to be either very easy to perform or very difficult for most people, without examining intermediate levels of difficulty that might be more resource limited. Participants receive high-pressure performance manipulations, such as by being informed about reward (pay is tied to high performance), monitoring (their performance is being video recorded), social comparisons (performance will be compared with others), or even a combination of these factors.

Typical results from these studies are illustrated in Figure 2, Panel A (adapted from Beilock & Carr, 2005, p. 423), where on easy tasks (the dotted lines in both graphs), performance tends to be high regardless of a person’s cognitive ability and regardless of how much task pressure is present. For difficult tasks (the solid lines in both graphs), lower-ability people do not perform very well, regardless of the level of task pressure (top left side), whereas higher-ability people perform well on difficult tasks when task pressure is low, but when task pressure increases, their performance declines, sometimes to the same level as lower-ability people. It is important to note that, although they are more significantly decremented by the pressure manipulation, the performance levels of higher-ability people generally do not fall

below those of lower-ability people in this research paradigm. Rather, when pressure is introduced, there is no difference in performance between higher and lower ability people.

Based on this pattern of results, researchers espousing the pressure-to-perform paradigm have concluded that lower-ability people are more adaptable because they are less likely to show performance decrements under task pressure (Beilock & Carr, 2005; Gimmig et al., 2006). For instance, researchers have claimed that “pressure specifically targets individuals who have high working memory capacity [ability]” (Beilock & Carr, 2005, p. 104). Conversely, low ability people are thought to experience “success under stress” (Beilock & DeCaro, 2007, p. 983; and see Figure 2, Panel A). The use of terms such as “success under stress” is unfortunate and misleading because they imply a benefit to lower ability in high-pressure situations and potentially distort a true understanding of the nature of the relationships under study. In fact, the performance of lower ability people does *not* exceed that of higher ability people in these studies (Beilock & Carr, 2005; Beilock & DeCaro, 2007; Gimmig et al., 2006). Furthermore, the “success under stress” conclusion implies that the *decrement* in performance experienced by higher-ability people is more important than their *absolute* performance levels, which is certainly debatable. One might conclude that high-ability people show more success under stress because their absolute levels of performance remain the same or higher than low-ability people regardless of the pressure manipulation. Nonetheless, the performance decrement for high-ability people compared to the stability of low-ability people under pressure does seem surprising. When explained within the context of resource theories of task performance as discussed above, however, this finding aligns with prior thinking (Kanfer & Ackerman, 1989; Norman & Bobrow, 1975).

Recall that studies in the pressure to perform paradigm (Beilock & Carr, 2005; Gimmig

et al., 2006) typically found that on easy tasks, performance was uniformly high for both higher-ability and lower-ability people and was unaffected by a psychological-pressure manipulation. This suggests that easy tasks in these studies generally required data-limited processing. That is, performance on these tasks was relatively less dependent on attentional resources, probably because they were easy and/or relied on skills that were well learned. For difficult tasks, people with lower ability were also likely to use data-limited processing. Their performance levels were uniformly low, suggesting that difficult tasks required cognitive resources beyond their capacity, even in the absence of a psychological-pressure manipulation. Lower-ability people probably maintained at least a minimal level of performance on difficult tasks under both high- and low-pressure conditions by relying on shortcuts, heuristics, or satisficing strategies. Although not optimal, shortcuts can be moderately effective in tasks where a minimal level of proficiency is possible (Rosen & Engle, 1997). Higher ability people most likely used resource-limited processing to execute the difficult task successfully, and additional psychological pressure manipulations served to reduce their attentional resources to the point that they tended to use shortcuts or satisficing strategies for task performance – just as lower-ability people tended to do for difficult tasks regardless of the presence or absence of psychological pressure. One implication of this idea is that high ability people have more flexibility than low ability people in which task strategies they use (e.g., complex strategies and satisficing/heuristic strategies).

The resource-limited and data-limited interpretation of task processing not only explains predictions from pressure-to-perform paradigm; it extends them: Performance on resource-limited processes will be negatively affected by task pressure, whereas performance on data-limited processes will not. Whether a process is resource-limited or data-limited, however, depends not only on the ability level of the person performing; it also depends on the nature of

the task as well. Further evidence collected by Beilock and DeCaro (2007) supports the resource theory explanation. They examined the strategies that higher-ability and lower-ability people applied to solving difficult problems under conditions of high pressure and low pressure. They found, as we would predict, that higher-ability people tended to revert to short-cut strategies and satisficing solutions under high pressure, presumably because the difficult tasks become data-limited for them. Additional evidence for the importance of cognitive resources for task performance comes from research on stress inoculation training. Specifically, training to increase resistance to stress includes practicing situational reappraisal and coping skills, which frees-up attentional resources for task performance (Saunders, Driskell, Johnston, & Salas, 1996). This type of training would presumably reduce any decrement in performance for resource-limited tasks when pressure is introduced.

Contrary to the conclusions of researchers studying “success under stress” (Beilock & DeCaro, 2007, p. 983), then, we would not conclude that lower-ability people are better able than higher ability people to handle task pressure when facing a difficult task. Within the theoretical framework of resource-limited and data-limited processes we can offer predictions that are more encompassing than those covered by the pressure-to-perform paradigm. For instance, we would predict that performance of lower-ability people *can* be negatively affected by psychological pressure, but *only* when they have adequate cognitive resources to perform a given task proficiently in the first place – that is, only when the task requires them to engage in resource-limited processing. Conversely, psychological pressure should *not* affect performance for higher-ability people when a task requires data-limited processing, meaning whenever the task is either exceedingly easy or so difficult that its demands exceed even their ample attentional resources. Figure 2, Panel B, illustrates these predictions. In this example, we have included tasks of

intermediate difficulty, in addition to extremely easy and extremely difficult tasks. Psychological pressure does not affect performance when tasks are extremely easy or extremely difficult for all people, because the processes used to perform these tasks are generally data-limited.

Nonetheless, task pressure negatively affects performance on tasks that people (given their ability level) find to be of intermediate difficulty, because these tasks would generally require resource-limited processing. In summary, the resource-limited and data-limited theoretical framework can accommodate predictions for how pressure (or any other factor that affects attentional resources) will affect performance across all ability and task difficulty levels.

The proceduralized learning paradigm. The second research paradigm that finds a reversal of the benefits of cognitive ability is the *proceduralized learning* paradigm. Theories of procedural learning are similar to skill acquisition theories described previously, where the initial stages of learning are dominated by an explicit learning system, whereby a person identifies and follows concrete facts, rules and scripts about the task to be performed (i.e., controlled processing). Explicit learning then shifts to procedural learning under one of two conditions: The task becomes well learned and does not require much cognitive effort, or at the other extreme, explicit learning does not lead to identifiable rules that can be applied successfully to improved performance, and the learner either persists with the task remaining at a performance plateau or he or she withdraws cognitive resources from the task, either partially or entirely. *Procedural tasks* refer to those tasks that more heavily rely on the procedural system, where rules for performing them are supposed to be more difficult to verbalize explicitly (although see Nissen & Bullemer, 1987, for evidence that those who perform best on procedural tasks are, in fact, better able to verbalize what they are learning). Optimal performance on procedural tasks is presumably not a result of explicit rule-following, but rather a result of stimulus-response

associations derived implicitly over time (Maddox & Ashby, 2004). Procedural tasks would require more automatic processing, in the parlance of resource theories.

Research on the relationship between procedural learning and ability has examined the hypothesis that some higher-ability people do not perform some complex tasks well because they spend time developing and committing to a problem-solving strategy that is inefficient compared to heuristic approaches that may not be perfect, but are efficient and have a high probability of success, at least in the short term (Beilock & DeCaro, 2007; DeCaro & Beilock, 2010).

Conversely, lower-ability people may not spend time on explicit rule development because they do not have the cognitive capacity to develop and commit to it; instead they are more likely to apply more heuristic or automatic processes to tasks (DeCaro et al., 2008). Therefore, lower-ability people are thought to be more flexible and effective when performing certain tasks.

Within this procedural learning research paradigm, DeCaro et al. (2008) examined the relationship between general cognitive ability and performance on two fundamentally different tasks: a relatively simple rule-based task and a more complex information integration task. For both tasks, participants were required to categorize visual stimuli that varied along four dimensions: The color, number, and shape of the figures presented, and the color of the background. For the simple rule-based task, participants were supposed to use only one dimension to categorize stimuli (e.g., categorizing figures by their background color) and ignore the other dimensions. For the complex information-integration task, participants were to ignore one dimension and then apply a specific rule to categorize the stimuli based on the remaining dimensions. For example, ignoring background color, if at least two of the three following statements were true for a given stimulus, the stimulus was Category A; otherwise it was Category B: (a) two figures, (b) square shape, and (c) gray figures. For both the simple rule-

based task and the complex information-integration tasks, participants were not provided with any hints or rules in advance; they had to discern the rules themselves based on the feedback they received after every trial (see Maddox & Ashby, 2004).

DeCaro et al. (2008) hypothesized that cognitive ability would be positively related to performance on the simple rule-based task because controlled processing facilitates performance, and because higher-ability people are better able to identify and follow the rules. They also hypothesized that cognitive ability would be *negatively* related to performance in the information-integration task. This is because lower-ability people would more quickly and successfully engage in procedural learning than higher-ability people, who would be impaired by attempting to engage in controlled processing, which ends up “limiting the ability of procedural learning processes to take over” (DeCaro et al., 2008, p. 287). It is important to note that this limitation of “overthinking” in higher-ability people is not merely thought to reduce their task performance; it is hypothesized to impair performance to the point that lower-ability people actually *surpass* the performance of higher-ability people. The dependent variable in this study was a task-mastery criterion, defined by correctly answering eight successive categorization trials.

DeCaro et al.’s (2008) results supported their predictions: Higher-ability people were quicker to master the simple rule-based categorization task. For the complex information integration task, lower-ability people were in fact quicker to reach the task-mastery criterion. These results are indeed surprising. Although previous research showed greater performance *decrements* for high-ability people in situations where task execution requires controlled processing (Beilock & Carr, 2005; Gimmig et al., 2006), they had not shown a *reversed* pattern of results. Yet as DeCaro et al. (2008) hypothesized, it could be that lower-ability people quickly

and effectively reaped the advantages of procedural learning. Short-cut strategies, such as memorizing whether each specific stimulus was correct or incorrect, could have led lower-ability people to achieve eight correct responses in a row more quickly than higher-ability people, who were expending the effort to figure out the underlying rules based on task feedback. Thus, there may be a short-term advantage here for taking short cuts to learn this specific task. In the longer term, would the performance of higher-ability people eventually benefit from learning the rules if the task-mastery criterion instead were more stringent, or would the short-cut strategies of lower-ability people remain more beneficial?

Another possibility lies in the fact that the participants were not given an explicit mastery goal of eight correct trials in a row; they do not appear to have been given any goal whatsoever except to “learn the task.” Without a specific goal, it is unclear whether the authors’ results would have differed if the goal of eight successful consecutive trials were given explicitly to participants. Moreover, it is not clear why eight trials were chosen as opposed to a different goal that might yield different findings. Unfortunately, due to the newness of this particular form of research, these findings are relatively isolated from the literature and may be relevant only for this specific task, sample, and post hoc goal.

This said, if we assume support for DeCaro et al. (2008)’s hypothesis, it could be that lower-ability people quickly and effectively reaped the advantages of procedural learning, so much so that they outperformed their higher-ability counterparts, who were more likely to attempt to develop a deeper strategy. Surface-level short-cut strategies, such as memorizing whether each particular stimulus was correct or incorrect, could have led lower-ability people to achieve eight correct responses in a row more quickly than higher-ability people, who were expending the effort to figure out the underlying rules based on task feedback. Thus, there may

be a short-term advantage for taking short cuts to achieve the eight-in-a-row criterion. In the longer term, would the performance of higher-ability people eventually benefit from learning the rules if the task-mastery criterion instead were more stringent, or would the short-cut strategies of lower-ability people remain more beneficial?

DeCaro, Carlson, Thomas, and Beilock (2009) addressed this question in a subsequent study, inspired by the worry expressed by Tharp and Pickering (2009) that lower-ability people might not be using procedural learning to meet the eight-in-a-row goal; that they were using short-cut strategies instead. To address this concern, DeCaro et al. (2009) extended the criterion for task mastery from 8 successes in a row to 16, which caused the previous advantage for lower-ability people performing complex tasks to disappear. More traditional findings emerged, where higher-ability participants showed the highest levels of performance on *both* the simple rule-based and the complex information-integration tasks. As such, it appears that the information-integration task does call upon a relatively more resource-limited process for higher-ability people, who in the short run may have lower levels of performance, but who in the long run achieved higher levels of performance by expending cognitive effort to identify and apply rules of successful task performance as shown in Curve A in Figure 1. This initial rule-based processing that eventually leads to automated performance with practice would be predicted by skill acquisition theory (Ackerman, 1988; Anderson, 1982). By contrast, the complex task called on a more data-limited process for those lower in ability. Lower-ability people were able to reach some minimal level of proficient performance by using shortcut strategies – which might have been procedural or nonverbal rules, or might have been simplified versions of the complete and complex rule. Regardless, as a result, their level of performance exceeded that for higher-ability people in the short term, as shown in Curve B in Figure 1. In the longer term, however, their

performance was superseded by that of high-ability people.

In sum, the conclusion that higher-ability people are impaired by their elaborate problem solving strategies, at least in the short term, is premature given the present research. It is still unknown, for example, whether high ability people can revert to short-cut or satisficing problem solving strategies when they know that the performance environment calls for such strategies (i.e., if they understand the performance or learning goal). The DeCaro et al. (2008, 2009) studies were conducted in a laboratory environment with college students, an environment where the assumption may have been that focused attention on the task was necessary and desired by the researchers. Turning to the activities of everyday life, this environmental assumption does not seem to hold: People assign tasks different priorities and allocate attention in ways that permit them to accomplish their goals, which often requires satisficing solutions even for high-ability people. DeCaro et al.'s (2008) study results are promising, however, in suggesting that higher-ability people have more problem-solving options because more tasks will be resource-limited for them. That is, they can derive rule-based methods, or they can apply satisficing solutions when appropriate or necessary (lower-ability people would be more limited to this latter option).

The adaptive performance paradigm. The *adaptive performance* paradigm is conceptually distinct from the two previously discussed in that the primary focus is on the nature of skill acquisition and complex task performance measured over time. To provide a specific example, Lang and Bliese (2009) conducted a study of adaptive performance in complex skill acquisition where a major change in the task was introduced. The skill to be learned was military tank navigation within a complex computer simulation, where the goal was to shoot and destroy adversarial tanks while avoiding getting shot by them. Players engaged in the task over 600

trials. After trial 300, several unforeseen changes to the first task were introduced, including increasing the number of adversarial tanks, changing the terrain to be navigated and altering the rules of engagement. The authors inferred that players are highly adaptable to the extent they can maintain their level of performance in light of these changes from the first task (i.e., the task before the change) to the second task (i.e., after the change).

Although a positive correlation between cognitive ability and adaptive performance has been established in past research (e.g., LePine, Colquitt, & Erez, 2000), Lang and Bliese (2009) were interested in expanding this work by theoretically distinguishing between two types of adaptive performance: *Transition adaptation* is defined as how quickly people minimize performance decrements directly after a task change. Transition adaptation is operationalized as a performance *difference* between performance at the beginning of the second task and performance at the end of the first task. *Reacquisition adaptation* refers to the rate of recovery after a task change is introduced, and it presumably depends on the learner's ability to determine which skills acquired in the first task will transfer to the second task. Reacquisition adaptation is operationalized as the learning *slope* after the task change, controlling for the rate and level of skill acquisition on the first task.

Lang and Bliese (2009) found that cognitive ability was significantly and positively correlated with overall tank navigation scores in both the first task and in the second task. Transition adaptation and reacquisition adaptation within each person was examined by way of a complex analysis called a hierarchical linear model of discontinuous growth. This analysis showed that after controlling for the main effects of cognitive ability on performance, cognitive ability was not associated with the rate of skill acquisition before the task change (i.e., slopes for the first task), nor was it associated with reacquisition adaptation (i.e., slopes for the second

task). Their most central finding was that cognitive ability was *negatively* related to transition adaptation – a form of “less is more.” More specifically, higher-ability people showed a more pronounced drop in performance when switching from the first to the second task, whereas lower-ability people maintained their task performance, albeit at a lower level (see Figure 3, Panel A, adapted from Lang & Bliese, 2009, p. 423). From this pattern of findings, the authors concluded that lower-ability people were more adaptable than higher-ability people when it came to anticipating and effectively responding to unforeseen rule changes in complex performance environments.

An alternative explanation based on resource and skill acquisition theory is that higher-ability people experienced a larger decrement in performance after the unforeseen switch between tasks not because they were less adaptable than lower-ability people, but because they had learned more of the first task and had more to lose or unlearn than lower-ability people prior to the task change. As such, higher-ability people were required to change performance routines that were more established for them than they were for lower-ability people.

It is useful to explore the implications of the conclusions reached by Lang and Bliese (2009) within the context of existing theory and research concerning cognitive ability and skilled performance. If these authors are correct – if cognitive ability is the main determinant of a greater loss of skill whenever the rules change on dynamic tasks – then we would expect ability to be negatively related to the acquisition of complex skills. Whereas Lang and Bliese examined patterns of acquisition and change across two tasks, we held on to their assumptions and extrapolated from their research findings to multiple tasks of a similar nature. Figure 3, Panel B, shows two trials per task before the task changes (modeling more than two trials per task would yield the same theoretically expected pattern of results). Consistent with Lang and Bliese, we

modeled ability differences in initial performance (intercepts), with no differences in acquisition slopes by ability level (i.e., cognitive ability predicted neither skill acquisition nor reacquisition adaptation in the Lang and Bliese study). Also consistent with Lang and Bliese, we modeled a steeper drop in performance for higher-ability people than for lower-ability people when the task changes, which is also aligned with Lang and Bliese. As can be seen in the panel, if higher-ability people are at a disadvantage in transition adaptation as Lang and Bliese concluded, then ability would be negatively related to skill acquisition across complex tasks, with the negative relationship strengthening as the number of tasks (i.e., the number of changes introduced during skill acquisition) increases. Our predictions with regard to multiple task changes over time appear highly contrived; however, they are a logical and direct extension of findings from the adaptive performance paradigm presented by Lang and Bliese when multiple tasks are involved or when the rules of a complex skill constantly change.

Predictions that are instead more aligned with resource and skill acquisition theory (Ackerman, 1988; Anderson, 1982) are modeled in Figure 3, Panel C. The pairs of trials are similar to the previous example; however Panel C illustrates our theoretical prediction, based on skill acquisition research and theory (e.g., Ackerman, 1988; Kanfer & Ackerman, 1989), that higher-ability people acquire more of a skill within a task (i.e., two consistent trials) than lower-ability people. When switching to new tasks, we model a steeper decline in transition adaptation for higher-ability people, just like the findings of Lang and Bliese (2009); however, the critical difference lies in the prediction made by skill-acquisition theory, namely that higher-ability people will acquire more of the skill that is common across multiple tasks than lower-ability people.

The idea that the performance of people who have acquired more task-relevant skills will

be more negatively affected when tasks change has been suggested in early research on skill acquisition (Shiffrin & Schneider, 1977) and cognitive aging (Rogers, 1992). Shiffrin and Schneider examined how changes in a consistently mapped task (i.e., reversal of targets and distracters) affected performance after that task had been well learned. Although they did not explicitly examine ability in this research, they measured the level of disruption in performance when the task changed as an indicator of over-learning. That is, they assumed and found that those who experienced the greatest decrement when the consistently mapped task changed were those who had acquired the most skill. Similarly, Rogers (1992) examined performance differences between a younger and older sample (the older sample suffering increased memory deficits), finding that older adults' performance was not as badly decremented after the reversal of targets and distractors, likely because older adults had not learned the original configuration of targets and distractors as well as younger adults had initially.

Implications and Directions for Future Research

This paper examined a recent set of research making claims that cognitive ability can be negatively related to task performance within certain performance environments. We classified the research into two general themes: (a) counterintuitive findings that “less is more” in terms of lower-ability people showing better performance (or less decline) than higher-ability people in tasks characterized by high psychological pressure (the pressure-to-perform paradigm) or rules that cannot be easily learned (the proceduralized learning paradigm); (b) counterintuitive findings that lower-ability people are more adaptable during skill acquisition in a changing task environment (the adaptive performance paradigm).

The counterintuitive claims in each of these research areas can be explained with resource theory in a manner that integrates well with past research. Specifically, the pressure-to-

perform paradigm suggests that task complexity, cognitive ability, and other factors that provide the performer with attentional resources (e.g., motivation, task salience) together determine whether processes are resource-limited or data-limited. Similarly, our interpretation of the proceduralized learning paradigm suggests that people with ample attentional resources are better able to identify and apply learning strategies in a manner that is most efficient and effective given the situation (i.e., data-limited or resource-limited). We also discussed the applicability of resource theory and skill acquisition theory to the adaptive performance paradigm, where resource theory is applied to longitudinal or dynamic performance. Specifically, people with ample attentional resources are expected to engage in more resource-limited processing and to acquire skills more rapidly; this generally results in greater performance success – and therefore greater loss of skill and performance when tasks change significantly. We acknowledge that “attentional resources” are relatively ill defined because of their multiple determinants (i.e., ability, motivation, situational factors), yet this general level of description of adaptive performance –along with resource theory reinforcing the positive contribution of cognitive ability to skilled task performance – provides a useful way to connect a vast history of previous research on complex task performance to the conclusions reached in the pressure-to-perform and procedural learning paradigms.

To highlight the importance of questioning the conclusions reached in the “less is more” paradigm, we consider operational environments where complex skills are used. In the context of personnel selection, this paradigm seems to point to the benefit of hiring *lower* ability people to work in high-pressure environments whenever the rules for optimal performance are not easily verbalized (e.g., as stockbrokers conducting complex and fast-paced trades, or servers in busy restaurants with complex menus and customer flows). The “less is more” paradigm also suggests

that higher cognitive ability would have no benefit for adaptive performance under the complex and pressure-filled circumstances of military combat; in fact high ability might be thought to handicap performance for fear of over-thinking and functional fixedness and higher ability people – more than lower ability people – would be targeted for remedial training to become more adaptive (e.g., as recommended by Lang & Bliese, 2009).

The “less is more” paradigm does not agree with our intuition regarding the benefits of cognitive ability, but more importantly, the scientific record, as summarized by meta-analytic data across a range of jobs that vary in complexity levels (as determined by job analysis), has provided strong support for cognitive ability as a consistently strong and positive correlate of successful performance in complex environments (including high stress and dynamic environments, Schmidt & Hunter, 1998). Nonetheless, the research reviewed remains important for drawing attention to the many challenges associated with understanding skilled and adaptive performance, and it inspires five specific recommendations for lines of future research.

Recommendation #1: Investigate a Range of Tasks and Ability Levels

Research falling under the “less is more” paradigm has focused mainly on the performance of either higher- or lower-ability people on either very easy or very difficult tasks. Much of the research we reviewed used median-split or extreme-group designs to examine individual differences in cognitive ability (Beilock & Carr, 2005; Gimmig et al., 2006, and supplemental analyses in Lang & Bliese, 2009; for an exception see regression analyses by Beilock & DeCaro, 2007). These types of experimental designs are generally not recommended because, although they can make a gross determination of whether or not an effect exists (Cortina & DeShon, 1998), they are likely to accentuate, attenuate, or otherwise distort the effects that are found in random and representative samples of people and tasks (MacCallum,

Zhang, Preacher, & Rucker, 2002; Preacher, Rucker, MacCallum, & Nicewander, 2005).

Moreover, undergraduate samples were used exclusively in this research, which necessarily restricts the range of cognitive ability considered, and perhaps the range of skills and domain-specific experience that can be investigated.

Including a wide range of tasks that vary in difficulty and a wide range of people that vary in their abilities is important because, as we have emphasized, skilled task performance is a function of *both* the resources available to the performer (i.e., individual differences in cognitive ability) *and* the characteristics of the task (Norman & Bobrow, 1975; Zeaman & House, 1967). Researching the effects of psychological task pressure and task changes, and more generally how individual differences and task characteristics affect task performance, requires knowledge about the attentional/ability resources that underlie skilled performance for the tasks selected. There are useful strategies for doing so, where extensive pilot testing can help determine or scale the relative complexity and consistency of given tasks or items, as determined by various sources of data. Substantively, many critical task features affect pressure and task performance in complex environments, including the modality and pace of the task, relationship between task components, the flexibility allowed in exercising given strategies, and the nature and detail of task feedback (Oswald, Hambrick, & Jones, 2007). Empirically, average performance and/or average error rates can be an indicator of task difficulty. When the resources are available to obtain large samples, item response theory can be applied to characterize task difficulty in terms of how well a task discriminates performance across people (Hambleton, Swaminathan, & Rogers, 1991). Within-person analysis could also be performed to compare whether within-person differences in task difficulty over time is as consistent as is implied by similar between-person differences.

In sum, the research that has been conducted to date on the relationship between ability and skilled performance under different conditions (e.g., high/low pressure) provides important insight into how higher- and lower-ability people dedicate attentional resources for task execution. These effects support what has long been known about the allocation of attentional resources for resource-limited and data-limited processes (Norman & Bobrow, 1976). We now face the challenge of generalizing these findings to complex problem solving and adaptive performance in vocational, avocational, and educational settings, which requires expanding the field of inquiry to a broader range of task and person characteristics.

Recommendation #2: Incorporate a Breadth of Ability, Personality and Motivational Determinants of Performance

In addition to research examining a broader range of task difficulty and ability levels, broadening the range of determinants of skilled performance that are examined is also warranted. Personality traits, motivation, goal setting, alertness, and other non-ability variables are critical additions to research in this domain because they are known to contribute to performance above and beyond the contributions of cognitive ability. Studies conducted under the research paradigms we reviewed are generally conducted in laboratory settings; these are settings where the task itself was not the likely incentive for participants to sign up for the study, where participants had situational pressures to conform and engage in the task once they agreed to participate, and where individual differences in personality and motivation were unmeasured and in a sense controlled for via random assignment to experimental conditions. In daily life, however, performance is not only a function of what people *can* do, it is a function of what people *will* do, in other words, performance is a function of the tasks they want to engage in and the goals they seek to accomplish (Borman, White, Pulakos, & Oppler, 1991). Therefore,

personality, goal orientation, and motivation will influence skilled and adaptive performance outside of laboratory environments in a manner that is likely to be distinct from the laboratory setting, if only because of the different tasks and goals that motivate different people.

Research on the effects of non-ability traits on adaptive performance has already shown promising results. For instance, LePine et al. (2000) found that, after controlling for cognitive ability, people higher on the personality trait of dependability were less able to adapt effectively to changes on a decision-making task. As another example, a study examining performance on difficult math problems (Mattarella-Micke, Mateo, Kozak, Foster, & Beilock, 2011) demonstrated that higher-ability people improved their performance under higher levels of arousal (cortisol levels) – but only when they had low levels of math anxiety. Under high levels of math anxiety, arousal decreased performance for higher-ability people. For people low in ability, increased arousal did not affect performance positively or negatively, probably because the problems were already too difficult for them (i.e., data-limited) – but this is *not* in our view a sign of adaptability or “success under stress.” Instead, there is a four-way interaction implied by this research: task performance depends on task complexity, cognitive ability, cortisol levels, and perceptions of the environment as anxiety producing..

Motivation is an especially interesting construct in the context of skilled performance because it may serve to reduce performance differences between higher and lower ability people. Furthermore, motivation is a malleable construct that can be influenced by interventions (e.g., positive feedback and encouragement, external rewards, structure), as opposed to more distal and stable ability and personality traits. When motivation is high in lower-ability individuals, they might persist and engage in a task long enough to identify and apply some of the underlying rules required for some degree of successful task accomplishment. Task accomplishment, in turn,

can lead to further motivation, task engagement, and task persistence. Although research has long suggested that motivation will be especially important when people have the ability or skill to accomplish the task in the first place (i.e., the task is resource-limited; Kanfer & Ackerman, 1989), we know less about how motivation might facilitate or impede the acquisition or choice of task strategies or how it interacts with (e.g., enhances or neutralizes) performance pressure.

A motivational trait examined in the context of the performance-under-pressure paradigm is goal orientation or regulatory focus, which refers to the desire to engage in tasks and learn from them (i.e., a promotion focus) or the desire to avoid tasks in order to avoid mistakes and embarrassment (i.e., a prevention focus). Recent research suggests that regulatory focus may moderate the relationship between ability and performance such that any mismatch between a person's regulatory focus and the nature of the task or situation will generally lead to fewer cognitive resources available for task completion (Worthy, Markman, & Maddox, 2009). For example, people who are high in prevention focus will tend to be more cognitively taxed when they are in situations where the goal is learning (i.e., training in an organization or academic environments).

Recommendation #3: Investigate Performance Processes

Research conducted in the “less is more” paradigm has focused attention on different problem-solving strategies employed by people who vary in their cognitive ability levels and perform tasks in different performance contexts (Beilock & DeCaro, 2007; DeCaro et al., 2009). Because the automatic cognitive processes involved in procedural tasks differ fundamentally from the controlled processes involved in explicit learning (Maddox & Ashby, 2004), the proceduralized learning paradigm provides a unique perspective for generating research that examines and models performance strategies and outcomes based on automatic versus controlled

performance processes. An example is found in DeCaro et al. (2009), who modeled levels of performance accuracy expected given different strategies for approaching the categorization tasks described earlier (e.g., using one, two, or three dimensions or the optimal strategy of figuring out the rules for the information integration task).

This line of research is also valuably supplemented by qualitative data on strategy use during task execution, to be compared with theoretical predictions and performance data (as was done by Beilock & DeCaro, 2007). Researchers can conduct focus groups and interviews to obtain information about how tasks and skill acquisition strategies are perceived and learned; researchers can then investigate how these perceptions relate to performance processes and outcomes, as well as stable characteristics of the performer (e.g., ability, personality, motivation). In future research, qualitative data can answer questions and raise new questions about the role of volition in performance. Unlike performance in most experimental settings, volition is a critical aspect of real world performance, where people select and prioritize multiple tasks and goals, and they choose and develop strategies for balancing them. Qualitative information would help answer some key questions raised previously: Can people identify situations in which certain problem-solving strategies are optimal? Does strategy identification and execution depend on people's cognitive ability? Given that multiple strategies are identified, why are some strategies viewed as more appealing to pursue than others?

Recommendation #4: Extend Research and Analytic Strategies to Examine Adaptive Performance

Research questions concerning the relationship between ability and adaptive performance are not straightforward. In line with the previous critique of Lang and Bliese (2009), future research designs on adaptive performance should ideally allow for modeling performance

decrements during task changes (transition adaptation) in terms of the change in task characteristics, concomitant changes in people's performance strategies and their individual differences (both static and time-varying). In experimental designs, because task characteristics remain constant across people even when tasks change, researchers have inferred that observed performance declines result from people who adopt maladaptive strategies on the new task. But a critical methodological problem competes with this substantive interpretation. Specifically, changing a task not only changes task characteristics and task strategies; it also changes the scale and the scores for what typical performance on the task will be.

An exaggerated example illustrates the general point: If the first task in a task-change study contained 100 tanks in close proximity that were easy to shoot, and the second task contained one tank that was difficult to find, let alone shoot, then *regardless* of a person's ability to switch strategies and adapt to changing task conditions, scores would drop dramatically in shifting from the first task to the second. Thus, even if the schedule for awarding points for task behaviors is the same on both tasks, the scores across the two tasks are not on a comparable metric, and the meaning of the slope across tasks and ability levels is questionable. A regression analysis predicting performance on the first trial of the second task from cognitive ability, the last trial of the first task, and their interaction might have been more illuminating and relatively more straightforward than the complex analysis undertaken by Lang and Bliese involving a hierarchical linear model with discontinuous slopes. These types of regression analysis would avoid the problem of arbitrary metrics, and the interaction term directly examines whether high-ability people have more to unlearn during task changes. Analyses at the level of subtasks might also be of interest, namely to determine whether rates of change and recovery are different across subtasks, and whether they correlate with one another. Covariates could also be incorporated into

these analyses to examine other non-ability moderators of change and recovery, such as psychological stress, conscientiousness, and goal orientation. When the metric is justifiably similar across tasks, regression models can incorporate discontinuities between tasks, such as piecewise regression that involves a regression lines for each task and a parameter for the transition point between them (e.g., Cudeck & Haring, 2007).

Moreover, unforeseen task changes must be interpreted relative to both a *level* and a *rate* of prior task performance, as well as an asymptote or plateau on prior performance that some people may have reached but others have not (assuming monotonic increases in performance). It may also be the case that there are multiple tasks to execute more or less at the same time, such that changes in performance on one task influence changes in performance on another task either positively or negatively (e.g., through task relatedness, or task interference). At a minimum, without examining adaptation in fine-grained detail, task difficulty can be inferred on the basis of means and sample variances of performance over time. For instance, previous skill acquisition research has reached the general conclusion that people's levels of performance converge over time when they are performing relatively simple tasks (higher mean, lower variance), and they diverge over time for more difficult tasks (lower mean, higher variance; Ackerman & Woltz, 1994). This principle can be used to understand whether performance on a task is (or can be) proceduralized for a sample of learners.

Adaptive performance is an important area that is ripe for additional research, and because adaptation is a dynamic process that unfolds over time, longitudinal research is most appropriate for its examination. Lang and Bliese (2009) developed a conceptually powerful conceptual framework for studying adaptive performance, with their delineation of performance immediately following a task change (transition adaptation) and the rate of gain in subsequent

performance (reacquisition adaptation). We recommend that future research on adaptive performance in complex and changing environments use a hybrid of the Lang and Bliese framework, which models transitions, with the resource theory framework, which readily incorporates critical person, task, and situational characteristics that relate to automatic and controlled processing during performance episodes over time (Ackerman, 1988). This type research could be tied to the development of educational, training, and employment interventions that improve learning and performance processes and outcomes.

Recommendation #5: Apply Theory to Design Training for Adaptive Performance

In addition to identifying the determinants of adaptive performance, researchers are currently investigating how best to train people to become adaptive learners and performers. *Adaptive transfer* refers to how flexibly people can apply skills learned in training to contexts and tasks that extend beyond the training environment (Bell & Kozlowski, 2010). Principles that guide the design of training environments to encourage adaptive transfer are based on the seminal ideas of Schmidt and Bjork (1992): Introducing difficulty germane to the content being learned (e.g., spaced versus massed practice, spaced feedback schedules, variation of training content) may decrement immediate performance in training, but will result in better long-term retention on tasks to which training is appropriate to generalize. Although these principles may seem at odds with theories of transfer-appropriate processing (i.e., specific mapping of training to performance content/contexts to maximize post-training performance; Morris, Bransford, & Franks, 1977) the reverse is actually true in this case. Rather than focusing on the direct transfer of training content to the same or similar contexts, principles of adaptability are focused on developing the relevant mental processes during training that will be needed at transfer (e.g., strategic knowledge and problem solving skills; Schmidt & Bjork, 1992). In support of these

ideas, research finds that people trained on easy tasks have more difficulty adapting what they have learned to a more difficult version of the task. Conversely, when trained on a difficult version of a task, people can more easily transfer what was learned to the easier task (Doane, Alderton, Sohn, & Pellegrino, 1996).

Many questions remain unanswered in this research paradigm, however, including how various person characteristics (i.e., stable individual differences) interact with task or situation characteristics that encourage adaptive transfer (i.e., Aptitude-Treatment Interactions or ATIs;), and how much these interactions depend on the domain of performance. There is research on ATIs suggesting, for example, that people lower in ability learn complex material better when the training environment is relatively structured whereas people higher in ability are actually hindered by structure (Snow, 1989). Research on skilled performance often does not manipulate structure and measure individual differences jointly, and we do not know how well ATI findings on structure generalize when the criterion of interest is adaptive transfer versus knowledge acquisition. Bell and Kozlowski (2008) and Carter and Beier (2010) suggest that ability is indeed a positive predictor of adaptive transfer. Moreover, training environments that maximize adaptive transfer promise to be complex, requiring active participation from learners (i.e., increased learner control, unstructured, variety in practice, spaced practice, only intermittent feedback; Bell & Kozlowski, 2010; Schmidt & Bjork, 1992). Because of this complexity, it is even more important to understand not only ability, but also the personality, and motivational components that lead to successful performance when training for adaptive transfer.

Conclusion

We reviewed the most recent claims that “less is more” in settings requiring complex task performance (Beilock & Carr, 2005; DeCaro et al., 2008; Gimmig et al., 2006; Lang & Bliese,

2009) and juxtaposed these claims against the solid history of theory and research involving individual differences in cognitive ability, situational differences in task complexity, skill acquisition, and skilled task performance. The research we have reviewed would be more compelling if it appeared to generalize to vocational, avocational, or academic environments or if it otherwise modified our scientific understanding of the nature or process of human cognition (e.g., Ackerman, 1988; Kane & Engle, 2000; Kanfer & Ackerman, 1989; Norman & Bobrow, 1975; Rosen & Engle, 1997). Ultimately, our review has reached a conclusion that does not support the “less is more” claims or their generalization; instead, our review is strongly aligned with one of the most consistent findings in over a century of psychological research: Cognitive ability exerts a main effect such that the smarter you are, the better you will perform on just about any complex task, all else being equal. Regardless of the paradigm from which this tenet originates, research should build upon the tradition of investigating skilled performance in a relatively broad context, because skilled performance is certainly not a sole function of cognitive ability; skilled performance is a function of situational factors and many other individual differences such as those reflected by personality traits, motivation, task knowledge and experience (Campbell, Gasser, & Oswald, 1996; Campbell, McCloy, Oppler, Sager, 1993). These determinants differ in their importance, depending on tasks and situations that differ with respect to their data-limited and resource-limited processes.

References

- Ackerman, P. L. (1987). Individual differences in skill learning: An integration of psychometric and information processing perspectives. *Psychological Bulletin*, 102, 3 – 27.
- Ackerman, P. L. (1988). Determinants of skill acquisition: Cognitive abilities and information processing. *Journal of Experimental Psychology: General*, 117, 288-318.
- Ackerman, P. L., Beier, M. E., & Boyle, M. O. (2005). Working memory and intelligence: The same or different constructs? *Psychological Bulletin*, 131, 30-60.
- Ackerman, P. L., & Woltz, D. J. (1994). Determinants of learning and performance in an associative memory/substitution task: Task constraints, individual differences, volition, and motivation. *Journal of Educational Psychology*, 86, 487-515.
- Anderson, J. R. (1982). Acquisition of cognitive skill. *Psychological Review*, 89, 369-406.
- Barrett, L. F., Tugade, M. M., & Engle, R. W. (2004). Individual differences in working memory capacity and dual-process theories of the mind. *Psychological Bulletin*, 130, 553-573.
- Beilock, S. L., & Carr, T. H. (2005). When high-powered people fail: Working memory and “choking under pressure” in math. *Psychological Science*, 16, 101-105.
- Beilock, S. L., & DeCaro, M. S. (2007). From poor performance to success under stress: Working memory, strategy selection, and mathematical problem solving under pressure. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 33, 983-998.
- Bell, B. S., & Kozlowski, S. W. J. (2008). Active learning: Effects of core training design elements on self-regulatory processes, learning, and adaptability. *Journal of Applied Psychology*, 93, 296-316.
- Bell, B. S., & Kozlowski, S. W. J. (2010). Toward a theory of learning-centered training design: An integrative framework of active learning. In S. W. J. Kozlowski & E. Salas (Eds.),

- Learning, training, and development in organizations* (pp. 263-300). New York: Routledge.
- Binet, A., & Simon, T. (1916). *The development of intelligence in children*. Baltimore: Williams & Williams.
- Borman, W. C., White, L. A., Pulakos, E. B., Oppler, S. H. (1991). Models of supervisory job performance ratings. *Journal of Applied Psychology*, 76, 863–872.
- Campbell, J. P., Gasser, M. B., & Oswald, F. L. (1996). The substantive nature of job performance variability. In K. R. Murphy (Ed.), *Individual differences and behavior in organizations* (pp. 258–299). San Francisco: Jossey-Bass.
- Campbell, J. P., McCloy, R. A., Oppler, S. H., & Sager, C. E. (1993). A theory of performance. In N. Schmitt & W. Borman (Eds.), *Personnel selection in organizations* (pp. 35-70). San Francisco: Jossey-Bass.
- Carey, B. (2004, December 21). When pressure is on, good students suffer. *The New York Times*, pp. D7.
- Carter, M., & Beier, M. E. (2010). The effectiveness of error management training with working-aged adults. *Personnel Psychology*, 63, 641-675.
- Cortina, J. M., & DeShon, R. P. (1998). Determining relative importance of predictors with the observational design. *Journal of Applied Psychology*, 83, 798–804.
- Cudeck, R., & Haring, J. R. (2007). The analysis of nonlinear patterns of change with random coefficient models. *Annual Review of Psychology*, 58, 615-637.
- DeCaro, M. S., & Beilock, S. L. (2010). The benefits and perils of attention control. In B. Bruya (Ed.), *Effortless attention: A new perspective in the cognitive science of attention and action* (pp. 51-73). Cambridge, MA: MIT Press.

- DeCaro, M. S., Carlson, K. D., Thomas, R. D., & Beilock, S. L. (2009). When and how less is more: reply to Tharp and Pickering. *Cognition*, *111*, 415-421.
- DeCaro, M. S., Thomas, R. D., Albert, N. B., & Beilock, S. L. (2011). Choking under pressure: Multiple routes to skill failure. *Journal of Experimental Psychology: General*, *140*, 390-406. doi: 10.1037/a0023466
- DeCaro, M. S., Thomas, R. D., & Beilock, S. L. (2008). Individual differences in category learning: Sometimes less working memory capacity is better than more. *Cognition*, *107*, 284-294.
- Doane, S. M., Alderton, D. L., Woo Sohn, Y., & Pellegrino, J. W. (1996). Acquisition and transfer of skilled performance: Are visual discrimination skills stimulus specific? *Journal of Experimental Psychology: Human Perception and Performance*, *22*, 1218-1248.
- Gimmig, D., Huguet, P., Caverni, J.-P., & Cury, F. (2006). Choking under pressure and working memory capacity: When performance pressure reduced fluid intelligence. *Psychonomic Bulletin & Review*, *13*, 1005-1010.
- Gottfredson, L. S. (1997). Why g matters: The complexity of everyday life. *Intelligence* *24*, 79-132.
- Griener, P. A., Snowdon, P. A., & Schmitt, F. A. (1996). The loss of independence in activities of daily living: The role of low normal cognitive function in elderly nuns. *American Journal of Public Health*, *86*, 62-66.
- Hambleton, R. K., Swaminathan, H., & Rogers, H. J. (1991). *Measurement methods for the social science series: Fundamentals of item response theory*. Newbury Park, CA: Sage.
- Hunter, J. E., & Hunter, R. F. (1984). Validity and utility of alternative predictors of job

- performance. *Psychological Bulletin*, 96, 72–98.
- Just, M. A., & Carpenter, P. A. (1992). A capacity theory of comprehension: Individual differences in working memory. *Psychological Review*, 99, 122-149.
- Kahneman, D. (1973). *Attention and effort*. Englewood Cliffs, NJ: Prentice-Hall.
- Kane, M. J., & Engle, R. W. (2000). Working-memory capacity, proactive interference, and divided attention: Limits on long-term memory retrieval. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 26, 336-358.
- Kane, M. J., Hambrick, D. Z., & Conway, A. R. A. (2005). Working memory and fluid intelligence are strongly related constructs: Comment on Ackerman, Beier, and Boyle (2005). *Psychological Bulletin*, 131, 66-71.
- Kanfer, R., & Ackerman, P. L. (1989). Motivation and cognitive abilities: An integrative/aptitude-treatment interaction approach to skill acquisition. *Journal of Applied Psychology Monograph*, 74, 657-690.
- Kuncel, N. R., Hezlett, S. A., & Ones, D. S. (2001). A comprehensive meta-analysis of the predictive validity of the Graduate Record Examinations: Implications for graduate student selection and performance. *Psychological Bulletin*, 127, 162–181.
- Lang, J. W. B., & Bliese, P. D. (2009). General mental ability and two types of adaptation to unforeseen change: Applying discontinuous growth models to the task-change paradigm. *Journal of Applied Psychology*, 94, 411-428.
- LePine, J. A., Colquitt, J. A., & Erez, A. (2000). Adaptability to changing task contexts: effects of general cognitive ability, conscientiousness, and openness to experience. *Personnel Psychology*, 53, 563-593.
- Maddox, W. T., & Ashby, F. G. (2004). Dissociating explicit and procedural-learning based

- systems of perceptual category learning. *Behavioural Processes*, 66, 309-332.
- MacCallum, R. C., Zhang, S., Preacher, K. J., & Rucker, D. D. (2002). On the practice of dichotomization of quantitative variables. *Psychological Methods*, 7, 19-40.
- Mattarella-Micke, A., Mateo, J., Kozak, M. N., Foster, K., & Beilock, S. L. (2011). Choke or thrive? The relation between salivary cortisol and math performance depends on individual differences in working memory and math-anxiety. *Emotion*. Advance online publication. doi: 10.1037/a0023224.
- Morris, C. D., Bransford, J. D., & Franks, J. J. (1977). Levels of processing versus transfer appropriate processing. *Journal of Verbal Learning and Verbal Behavior*, 16, 519-533.
- Navon, D. (1984). Resources – a theoretical soup stone? *Psychological Review*, 91, 216-234.
- Neisser, U. (Ed.). (1998). *The rising curve: Long-term gains in IQ and related measures*. Washington, DC: American Psychological Association.
- Neisser, U., Boodoo, G., Bouchard Jr., T. J., Boykin, A. W., Brody, N., Ceci, S. J., Halpern, D. F., Loehlin, J. C., Perloff, R., Sternberg, R. J., & Urbina, S. (1996). Intelligence: Knowns and unknowns. Report of a task force established by the American Psychological Association. *American Psychologist*, 51, 77-101.
- Nissen, M. J., & Bullemer, P. (1987). Attentional requirements of learning: Evidence from performance measures. *Cognitive Psychology*, 19, 1-32.
- Norman, D. A., & Bobrow, D. B. (1975). On data-limited and resource-limited processes. *Cognitive Psychology*, 19, 1-32.
- Oberauer, K., Schulze, R., Wilhelm, O., & Süß, H. M. (2005). Working memory and intelligence – their correlation and relation: Comment on Ackerman, Beier, and Boyle (2005). *Psychological Bulletin*, 131, 61-65.

- Oswald, F. L., Hambrick, D. Z., & Jones, L. A. (2007). Keeping all the plates spinning: Understanding and predicting multitasking performance. In D.H. Jonassen (Ed.), *Learning to solve complex scientific problems* (pp. 77-97). Mahwah, NJ: Erlbaum.
- Park, G., Lubinski, D., & Benbow, C. P. (2007). Contrasting intellectual patterns predict creativity in the arts and sciences: Tracking intellectual precocious youth over 25 years. *Psychological Science, 11*, 948-952.
- Preacher, K. J., Rucker, D. D., MacCallum, R. C., & Nicewander, W. A. (2005). Use of the extreme groups approach: A critical reexamination and new recommendations. *Psychological Methods, 10*, 178-192.
- Rogers, W. A. (1992). Age differences in visual search: Target and distractor learning. *Psychology and Aging, 7*(4), 526-535.
- Rosen, V. M., & Engle, R. W. (1997). The role of working memory in retrieval. *Journal of Experimental Psychology: General, 126*, 211-227.
- Saunders, T., Driskell, J. E., Johnston, J. H., & Salas, E. (1996). The effect of stress inoculation training on anxiety and performance. *Journal of Occupational Health Psychology, 1*, 170-186.
- Schmeichel, B. J. (2007). Attention control, memory updating, and emotion regulation temporarily reduce the capacity for executive control. *Journal of Experimental Psychology: General, 136*, 241-255. doi: 10.1037/0096-3445.136.2.241
- Schmidt, F. L., & Hunter, J. E. (1998). The validity and utility of selection methods in personnel psychology: Practical and theoretical implications of 85 years of research findings. *Psychological Bulletin, 124*, 262-274.

- Schmidt, F. L., & Hunter, J. (2004). General mental ability in the world of work: Occupational attainment and job performance. *Journal of Social and Personality Psychology*, 86, 162-173.
- Schmidt, R. A., & Bjork, R. A. (1992). New conceptualizations of practice: Common principles in three paradigms suggest new concepts for training. *Psychological Science*, 3, 207-217.
- Shiffrin, R. M., & Schneider, W. (1977). Controlled and automatic human information processing: II. Perceptual learning, automatic attending, and a general theory. *Psychological Review*, 84, 127-190.
- Snow, R. E. (1989). Aptitude-treatment interaction as a framework for research on individual differences in learning. In P. L. Ackerman, R. J. Sternberg, & R. J. Glaser (Eds.), *Learning and individual differences: Advances in theory and research* (pp. 13 – 59). New York: Freeman Press.
- Tharp, I. J., & Pickering, A. D. (2009). A note on DeCaro, Thomas and Beilock (2008): Further data demonstrate complexities in the assessment of information-integration category learning. *Cognition*, 111, 411-415.
- Unsworth, N., & Engle, R. W. (2007). The nature of individual differences in working memory capacity: Active maintenance in primary memory and controlled search from secondary memory. *Psychological Review*, 114, 104-132.
- Wood, R. E. (1986). Task complexity: Definition of a construct. *Organizational Behavior and Human Decision Processes*, 37, 60-82.
- Worthy, D. A., Markman, A. B., & Maddox, W. T. (2009). What is pressure? Evidence for social pressure as a type of regulatory focus. *Psychonomic Bulletin and Review*, 16, 344-349.
- Zeaman, D., & House, B. J. (1967). The relation of IQ and learning. In R. M. Gagne (Ed.),

Learning and individual differences (pp. 192-212). Columbus, OH: Merrill.

Figure 1. Example of resource-performance functions. Dashed lines represent resource-limited regions of the process; solid lines represent data-limited regions. Curve A represents a relatively more resource-limited process where performance will be dependent on effort except at high levels of effort; Curve B represents a relatively more data-limited process. Adopted from Figure 2 in Norman and Bobrow (1975, p. 49).

Figure 2. Examples of the interaction of cognitive ability, task difficulty, and a pressure manipulation on accuracy. Panel A is adapted from Figure 1 in Beilock and Carr (2005, p. 423; cognitive ability was operationalized as working memory capacity in this study). Panel B shows hypothesized results for tasks that are extremely easy, of intermediate difficulty, and extremely difficult.

Panel A: “Adaptability” interpretation (Lang & Bliese, 2009)

Panel B: Implication of “adaptability” across multiple task changes

Panel C: Implication of “adaptability” based on ability determinants of skill acquisition

Figure 3. Example of the relations between cognitive ability and skill acquisition. Panel A is adapted from Lang and Bliese’s Figure 4 (2009, p. 423). Panel B is the implications of those findings over multiple trials. Panel C shows hypothesized changes based on theory and research on the relation between ability and skill acquisition.