Chapter 4

General Discussion

Understanding adaptive behavior is the goal of both the Selective Optimization with Compensation (SOC; Baltes & Baltes, 1990) and the Adaptive Toolbox (Gigerenzer et al., 1999) approaches. This dissertation profited from the unification of these two perspectives in an effort to understand how cognitive aging determines the use of decision strategies. In this discussion I briefly reiterate the argument for the unification of these two views, give an overview of the knowledge gained in this thesis from connecting the concerns of the two, and point out some possibilities for further research.

Where We Started From

Selective Optimization with Compensation

"Win some, lose some", so the saying goes. Striking a balance between losses and gains is, according to the SOC framework, the key to *successful aging* (Baltes & Baltes, 1990). For example, in old age, to behave adaptively, one may try to compensate for losses in the speed with which cognitive operations may take place with the gains in knowledge originating from years of experience. This can result for instance in the use of different, compensatory strategies or more careful selection of environments in which to act. Moreover, SOC proposes that successful aging involves the selection of actions that fulfill a specific goal given a person's resources (e.g., cognitive capacity) and environmental demands.

Research on aging has described well the gains and losses in intellectual resources and how these relate to behavioral performance in fairly low level domains, such as memory (Baltes, Staudinger, & Lindenberger, 1999; Schaie, 1994). In contrast, there is no comprehensive theory of environments and how changes in intellectual functioning are related to cognitive performance in different settings. Consequently, the need for a theory of environments and its relation to behavior across the life span is clear.

The Adaptive Toolbox Approach

The adaptive toolbox (Gigerenzer et al., 1999) and the adaptive decision maker frameworks (Payne et al., 1993) share with the SOC framework the assumption that, to

perform adaptively, individuals have to strike a balance between their personal resources and the demands imposed by a task. The adaptive toolbox approach's solution to how this is achieved is the principle of ecological rationality, which holds that simple mechanisms can profit from environmental structure to perform well in particular settings. Hence, the adaptive toolbox program strives to identify different types of environments in terms of quantifiable statistics and propose mechanisms that take advantage of such structures to make correct and efficient decisions.

The study of ecological rationality has advanced our understanding of the fit between strategies' performances and environmental structure. However, the adaptive toolbox approach and decision making research in general have yet to provided a satisfying explanation of the intellectual resources underlying strategy use and how the life span pattern of gains and losses in intellectual functioning determines the use of strategies in different environments.

In conclusion, the connection made in this dissertation between the SOC and adaptive toolbox approaches emerged from the shared goal of understanding adaptive behavior as a function of 1) individual intellectual resources and 2) environment characteristics. The work presented profited from this intersection in its effort to understand how basic cognitive components underlie the use of decision strategies, and how age-related changes in these components relate to adaptivity of strategy use in different environments.

What We Have Learned

Two main questions were posed in this dissertation. The first concerned how the ability to select strategies as a function of environmental structure changed with the cognitive decline associated with increased age. The second question regarded the ability of applying strategies effectively and how this differs between younger and older adults. What have we learned from posing these questions?

Younger and Older Adults Select Decision Strategies Adaptively

Studies 1 and 2 investigated adaptivity in strategy selection concerning samples of younger adults, while Study 3 did the same concerning an older population. All three studies involved presenting participants with one of two environmental structures in which either the use of information-intensive strategies or more information-frugal strategies was favored. The participants' goal in all three studies was to decide which of two diamonds was more expensive, based on a set of cues (up to eight cues per diamond). Additionally, the role of cognitive capacity in strategy selection was investigated using correlational methods.

The three studies provided additional support for the adaptive toolbox approach by showing that people can adaptively select strategies as a function of environmental structure. Overall, participants tended to show search behavior indicative of more information-intensive search in a compensatory (in which all cues had the same predictive value) compared to the noncompensatory environment (in which all cues had different predictive values): There was considerable variance in information search that could be explained by environment. Similarly, concerning strategy use, there were medium effects of environment on strategy distributions in the different studies: Simpler strategies were more often used in the appropriate noncompensatory environment, while a majority of participants chose more information-intensive strategies in the compensatory environment. Because this pattern was found in all three experiments, these results support the idea that both younger and older adults can choose strategies adaptively as a function of environment structure.

Older Adults Use Simpler Strategies Compared to Younger Adults

Concerning age differences in information search and strategy use, it was found that older adults took longer to make decisions and viewed less information than younger adults. In addition, the distribution of strategies differed between young and older adults, with older adults more often using simpler, more information-frugal strategies, than younger adults. Individual differences in working memory capacity, speed, and reasoning explained most age-related variance in strategy selection, suggesting that the main reason for the overall tendency of older adults to use simpler strategies was older adults' decline in cognitive mechanics. Nevertheless, it must be emphasized that in a compensatory environment, which favors the use of more information-intensive strategies, the tendency of older adults to use simpler strategies compared to younger adults was small. In contrast, older adults tended to use simpler strategies more often than younger adults in the noncompensatory environments, which rewarded the use of simpler strategies. These results suggest that not only can older adults select strategies adaptively but also, in some conditions, they may outperform younger adults in strategy selection. Nevertheless, despite the overall adaptiveness of older adults' strategy selection behavior, the average decision accuracy of older adults was poorer than that of younger adults. Chapter 3 investigated whether age differences in strategy application could explain this discrepancy.

Older Adults Apply Decision Strategies Less Effectively Compared to Younger Adults

In Chapter 3, a neurocomputational approach was presented which built on the adaptive toolbox approach to decision making (Gigerenzer et al., 1999) and formal modeling

of aging (Li et al., 2000, 2001) to predict effects of age-related cognitive decline on the effectiveness of application of decision strategies. The rationale underlying the approach was that age-related changes in neuromodulatory processes impact cognition at the level of its basic information processing components, such as working memory and processing speed. In turn, these age-related changes produce age differences at the behavioral level, including the effectiveness of application of decision strategies.

Study 4 empirically tested the predictions originating from the neurocomputational approach, which included 1) differences between young and older adults' mean performance when using decision strategies, with older adults making on average more application errors than younger adults, 2) an age by strategy difficulty effect, with the performance of older adults showing a larger decrement with more cognitively demanding strategies compared to younger adults, and 3) larger intra-individual variability in performance with increased age. The experiment made use of younger and older adults trained to use an information-frugal and an information-intensive strategy, and evaluated how accurate the two age groups were in applying the two decision mechanisms. The results indicated that older adults more often selected an option not prescribed by the two strategies and that their performance was more variable across similar sets of trials compared to younger adults. However, no age by strategy difficulty effect was found, which is consistent with the idea that older adults used a simplified, less cognitively demanding version of the information-intensive strategy.

Overall, these results suggest that age-related cognitive decline impacts strategy use at the level of the effectiveness with which strategies are applied, with older adults being worse off than younger adults. Nevertheless, age differences in performance did not show a dramatic disadvantage of older compared to younger adults, suggesting that decision making abilities may still be relatively well preserved in old age. In addition, the ability of older adults to find for an information-intensive strategy a less cognitively demanding alternative reveals the adaptive character of their decision making behavior.

Scissors Have Two Blades: Adapting to Individual and Environment Characteristics

The Selective Optimization with Compensation approach (Baltes & Baltes, 1990) has emphasized the need to adapt behavior as a function of changes in personal resources over the life span. On the other hand, the adaptive toolbox approach (Gigerenzer et al., 1999) has emphasized that individuals adapt their behavior to environment structure. The work presented here is in line with both, having shown that individuals 1) use decision strategies well-matched to their current cognitive abilities that change over the life span and 2) adapt

their strategy use to the different task characteristics, such as the statistical structure of environments.

In conclusion, the work presented echoes Simon's (1957) vision of mind and environment as blades of a pair of scissors. As such, it emphasizes the adaptive nature of human behavior, perpetually cutting a balance between individual resources and environmental characteristics.

What We Still Need to Learn

The work presented in this thesis provided an approach for understanding the mechanisms underlying the link between cognitive aging and the use of decision strategies. Nevertheless, a considerable amount of work lies ahead. In the following sections I outline the main issues arising from the work reported in this thesis and provide some suggestions for future research.

Do People Select Environments Adaptively?

Simple strategies do well in many environments (e.g., Gigerenzer et al., 1999; Hertwig et al., 1999). However, it is not clear that these are environments in which individuals often make decisions. Consequently, one line of research should investigate the statistical structure of environments in which younger and older adults routinely perform decisions. It may be the case that simple strategies provide particularly satisfying outcomes in a number of domains. Moreover, even in those cases in which simple strategies are not the most accurate they may perform nearly as well as more cognitive demanding ones (see Fasolo et al., in press, for an example in the preferential choice domain).

More importantly, having a firm grasp of the different types of naturally occurring environments in which people make decisions will allow researchers to investigate how younger and older adults allocate their resources; in particular, *to what extent individuals choose environments as a function of their personal characteristics*. For example, it would be sensible for someone who must rely on simpler strategies to seek environments where these provide good payoffs. In sum, future research should make clear whether people are able to select environments adaptively.

Towards a Unified Computational Model of Strategy Selection and Application

Simply showing a relation between measures of cognitive capacity and strategy use should not represent the end point in the effort to specify the "the capacities that the rule exploits" (Gigerenzer, 2004, p. 67). On the contrary, these results should encourage more

detailed models of strategy selection processes, namely, at the computational level. Hence, the results suggesting that age-related differences in working memory and speed of processing determined strategy use provides a starting point for computational modeling of age differences in strategy use. For example, one should attempt to use established frameworks, such as connectionist or hybrid systems (Anderson & Lebiere, 1998), to implement decision strategies and use parameters that are known to relate to measures of working memory and speed to model age differences. Although such an approach was taken in Chapter 3, this could be expanded to include aspects of strategy selection beyond the application components already considered.

Additionally, existing models of strategy selection (e.g., Rieskamp & Otto, submitted; Siegler & Lemaire, 1997) may gain by adopting a bottom up approach that links basic research on the cognitive components of intellectual functioning, such as working memory research, to more complex cognitive abilities such as the use of decision strategies. Only by adopting fairly detailed models that include basic memory and attentional components can one aim to achieve an overall understanding of the mental processes underlying strategy use and associated age-related changes.

The Mysterious Path from Brain to Behavior

The issue of how brain produces behavior has been a major conundrum in the human sciences and doubt has been expressed concerning the current state of affairs: "The current situation is that we have good and improving theories of some aspects of language and mind, but only rudimentary ideas about the relation of any of this to the brain" (Chomsky, 2000, p. 116). One main concern associated with current brain research is its focus on mapping of cognitive function rather than testing of cognitive theories (Ochsner & Liberman, 2001). However, recent approaches have dealt successfully with this problem and made clear that the goal of any neurologically informed approach must be to understand how brain processes relate to theories of cognition and, ultimately, behavioral predictions (e.g., Anderson et. al., 2004).

Adopting such an approach in the domain of decision making and aging should prove particularly fruitful, as brain data could directly inform cognitive theories of strategy use, allowing for instance a better formulation of computational models of such processes. Moreover, a thorough understanding of age differences in strategy use may *necessarily* require gathering brain data, as behavioral measures may not capture the richness of cognitive aging phenomena. For example, it has been shown that older adults demonstrating behavioral performances equivalent to younger groups evidence more diffuse brain activation patterns,

which has been interpreted as revealing that with increased age more brain tissue needs to be recruited for achieving the same level of performance (cf. Reuter-Lorenz, 2002). Applying the same logic to age differences in the application of decision strategies, one would predict that older adults with behavioral performances equivalent to younger adults should show more diffuse brain activation patterns. Furthermore, one would expect this to be particularly evident when more information-intensive strategies are considered. Future work along these lines would provide a better understanding of how cognitive aging affects decision making at the neural, information processing, and behavioral levels.

Applied Potential of Understanding the Aging Decision Maker

The main theoretical goal of this thesis was to contribute to the understanding of the relation between decision making and cognitive aging. However, there is applied potential in the knowledge gained from applying the adaptive toolbox approach to the study of age-related change in decision making. Training older adults to use certain strategies is one way of making them perform more successfully in their environment (Kramer & Willis, 2002). However, for such a project to be successful one must 1) know which strategies provide accurate or good-enough solutions to a problem and 2) which of these strategies older adults can apply correctly. The study of ecological rationality provides the answer to the first issue, while research on the application of decision strategies aims to provide an answer to the second. Such work could be particularly useful in designing web-based systems for deciding between options. Web based decision-support systems usually involve a large number of options and associated attributes that make the process of deciding between alternatives cumbersome (Fasolo et al., in press). For example, in the domain of health, which is one of the three main areas of interest for older adults who use the web (White et al., 1999), web based systems leave something to be desired concerning their usability by older adults (Kurniawan & Zaphiris, 2001). A firm understanding of which strategies provide accurate decisions in the health domain and whether older adults are able to use them would provide a good way of improving their decision performance and, ultimately, their quality of life.

Conclusion

The adaptive toolbox (Gigerenzer et al., 1999) and the adaptive decision maker (Payne et al., 1993) approaches see decision making as the result of a balance between individual resources and task characteristics. Likewise, the SOC framework (Baltes & Baltes, 1990) sees successful aging as the result of balancing gains and losses in cognitive abilities and the demands and resources provided by the environment.

The work presented in this dissertation reflects these positions by sketching a view of the aging decision maker has that of an individual who, to use strategies adaptively, has to consider the structure of decision environments as well as personal limitations stemming from age-related cognitive decline. The results suggest that older individuals adjust their decision behavior both as a function of personal resources, such as cognitive capacity, and task characteristics, such as the statistical structure of environments. Hence, one is lead to conclude that the aging decision maker is nonetheless an adaptive one.