The Life Span Development of Decision Making

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Declaration

I, Anika Karina Josef (born May 9th, 1987 in Lörrach, Germany), hereby declare the following:

(i) This dissertation is based on four manuscripts, two published, two in preparation. I contributed to these papers substantially and independently and have been primarily responsible for the ideas, data collection, analyses, and writing of the papers for which I am first author. The author contributions for Mata, Josef, & Hertwig (2016) are described in the published paper. For the fourth manuscript (Josef, Kellen, Pachur, Hertwig, & Mata, submitted), the first of the two studies is based on my master's thesis. This characterization of my contributions is in agreement with my co-authors' views.

(ii) I only used the resources indicated.

(iii) I marked all citations.

Anika K. Josef

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Abstract

Individuals of all ages are often confronted with situations varying in their complexity and situational characteristics. Normal aging is associated with changes in cognitive capacities such as learning and memory but also notable alterations in physical fitness, health, and the social environment. These changes most likely affect not only the necessary cognitive tools but also the perception of gains and losses in relation to available resources and personal goals when making decisions. This dissertation shows that age differences in decision making cannot be understood without considering the fit between the individual resources and the characteristics of the choice environment. It comprises three papers studying the effect of aging on the propensity to take risks as well as one paper on inference decisions in choice ecologies that differ in memory demand.

The first paper investigates longitudinal changes in risk-taking propensity across the life span. It shows that the propensity to take risks varies as a function of age and domain. Interestingly, different conceptions of change suggest that risk-taking propensity has trait-like properties similar to those found in major personality traits such as the Big Five. The second paper studies the psychological mechanisms of age- and domain-differences in risk-taking propensity. It finds that individual differences in the perceptions of costs and benefits, but not control beliefs, account for the prominent age-related but domain-variant change in risk-taking propensity. The third paper presents a cross-cultural investigation of life span changes in risk-taking propensity. It suggests that age-related changes in risk taking are associated with local characteristics: Countries in which hardship (i.e., homicide rate, gross domestic product, income/gender inequality) is largest show least changes in risk-taking propensity over the life span. Finally, the fourth paper summarizes empirical studies on the effects of memory demand on age differences in inference decisions. It displays that individual memory ability is crucial for the maintenance of adequate decision outcomes in choice environments that pose high demands on

memory. Overall, these findings emphasize that in order to predict life span changes in decision making, one needs to take the interaction between the individual and the environment into account. Developmental phenomena such as changes in decision making can be understood as individual efforts to adapt one's performance to both internal and external changes such as in the environment surrounding them or their own motivations and cognitive capacity.

General Introduction

The populations of nations around the globe are aging. In developed societies, life expectancy is rising by an average of 2.5 years per decade, and there is no visible end to this trend (Vaupel, 2010). An inevitable consequence of the growing life span is that an expanding number of elderly people will be forced to work longer and will therefore have an increasing responsibility to make decisions affecting their own as well as the well-being of others. Financial decisions of older investors, for example, now have a higher impact on the global economy than ever before (Agarwal, Driscoll, Gabaix, & Laibson, 2009; Gamble, Boyle, Yu & Bennett, 2014).

In everyday life, we are often confronted with situations which are varying in their cognitive demand or that involve some degree of risk or uncertainty. Many times, decision environments are complex, involve risks and/or pose extensive demands on dwindling cognitive resources such as memory ability. Thus, it remains a lifelong endeavor to adapt to different situational demands in order to make good decisions and to uphold the own wellbeing in domains as diverse as health, pensions, and interpersonal relationships. How do older adults deal with the constant cognitive demands in our decision environments? How do changes that come along with aging alter goals and motivations that, eventually, determine changes driving our preferences and behavior? Understanding how aging affects decision making is an essential field of research, which is important for policy makers that aim to uphold the overall welfare of our aging societies.

Life Span Theories on Human Development

Human development – from young up to older ages – comprises constant multidimensional changes and lifelong adaptive processes to internal biological, cognitive as well as external changes in the environment (Baltes & Baltes, 1990; Carstensen, 1995). It entails the constant interplay of often opposing and simultaneous changes in these resources – trajectories of growth (i.e. gains, such as the acquisition of a language) and decline (i.e. losses, age-related decline in physical fitness). Some dimensions of development may expand while others shrink as individuals develop. For example, when children enter elementary school, they may learn new strategies to solve more sophisticated intellectual problems, but at the same time lose the ability to get completely lost in play. While young age is mostly characterized by the acquisition of new skills, older age is associated with sizable decreases in cognitive capacities such as memory and learning ability (Chasseigne, Ligneau, & Grau, 2003; Eppinger, Hämmerer, & Li, 2011; Lindenberger, 2014) but also notable alterations in physical fitness, health, and in the social environment (Fredrickson & Carstensen, 1990; Cartensen, 1995; Carstensen, Isaakowitz, & Charles, 1999; Salthouse, 2010). Therefore, with age, losses in many different types of developmental resources gradually overweigh present gains. As a result, older adults shift away from behavior supporting the allocation of resources and gains. Instead, they switch to behavior that balances the maintenance of a normal level of functioning in face of losses. This motivation may differ depending on the domain of functioning or the task at hand. Understanding developmental changes in actions and behavior thus means identifying age-related changes in individuals, their environments, and their interaction.

The Selective Optimization with Compensation theory (SOC; Baltes & Baltes, 1990) predicts how individuals adapt to evident changes in their resources. It distinguishes between several pathways of developmental regulation tailored to uphold continuing growth and adequate levels of functioning in the face of impeding or present age-related losses: Selection, optimization, and compensation. Selection refers to the adaptation and limitation to behaviors and domains in which to allocate personal resources. For example, deciding to cease taking risks in challenging recreational activities can prevent the negative experience of physical harm in such situations. Optimization describes a shift in focus towards the maximization of gains to increase positive emotions and the own well-being. With increasing age, for instance, older people put relatively more weight to emotionally meaningful goals, activities, emotional satisfaction, and their interpersonal relationships (Carstensen, 1995; Carstensen et al., 1999). Compensation implies changing the ways to acquire personal goals such that they match the changed internal or external resources. For instance, when it becomes increasingly difficult to remember several items, older people may shift from internal memory strategies to external aids (i.e., a shopping list). Taken together, successful aging requires people to orchestrate their available resources by applying these mechanisms in face of the challenges and demands produced by different environments.

Life Span Development of Decision Making

Decision making is the study of how individuals identify and choose among several alternatives based on individual values and preferences. Decisions can take place in a multitude of different choice environments. For example, financial decisions about retirement investments or health decisions about drugs with possible side effects are risky because they can result in either gains or losses. Moreover, many choice environments are complex because they pose extensive demands on memory and learning ability. That is, in many decision situations relevant information is not conveniently presented but needs to be recalled from memory. How does aging change the way individuals make decisions in these situations? What factors determine decisions in one situation opposed to another? Answers to these questions are crucial for building an understanding of the life span development of decision making.

The concept of ecological rationality makes predictions about how individuals make decisions in different choice environments. According to this perspective, there is no domain-general answer to how age-related changes affect decision making (Gigerenzer, Todd, & The

ABC Research Group, 1999; Mata, Pachur, von Helversen, Hertwig, Rieskamp, & Schooler, 2012). The impact of age-related changes depends strongly on the characteristics of the choice environment and how these interact with the resources and goals of the decision maker. Such characteristics can operate on different levels and can present themselves as both qualitative differences/demands between life domains, such as decisions concerning health, financial or social issues, and via the cognitive affordances of a specific decision task (e.g. memory). With respect to what we have learned about the SOC approach to human development, this means that changes brought about by aging may affect regulatory processes and likely become evident in decision making. To better understand age-related changes in decision making, one needs to take into account the characteristics of the choice environment.

This dissertation framework summarizes work covering empirical investigations of age-related changes in decision making. It adopts an ecological rational perspective and views the findings reported as the result of the fit between the individual, its resources, and the choice environment. The first section summarizes life span changes in the propensity to take risks and summarizes three manuscripts. The second part summarizes empirical investigations of the role of memory demand for adult age differences in decision making and summarizes one manuscript.

Part I – The Propensity for Risk Taking Across the Life Span

One prominent characterization of risk-taking propensity is the tendency of an individual to engage in behavior that bears the chance of losses (e.g. physical harm) as well as gains (e.g. excitement). An important debate in psychology concerns the issue of whether an individual's risk taking is stable across choice domains or whether it is heavily influenced by situational characteristics (Schoemaker, 1993; Yechiam & Ert, 2011). Several theoretical frameworks make predictions about stability and changes in risk taking across the life span as well as its domain-specificity.

First, trait views of risk taking favor domain-general patterns of age differences in risk taking. That is, risk-taking propensity is conceptualized as a domain-general construct which is biologically determined and, thus, potentially generalizable across domains. Results of behavioral genetics studies suggest that risk taking has substantial and reliable genetic underpinnings, with heritability estimates based on twin studies ranging between 20% and 60% of variance explained (Anokhin, Golosheykin, Grant, & Heat, 2009; Cesarini, Dawes, Johannesson, Lichtenstein, Sandewall, & Wallace, 2009). Similarly, some personality theories in psychology have characterized risk-taking propensity as a trait that shows stable relative differences between individuals across multiple measurement points spanning years (Steinberg, 2008; Zuckermann & Kuhlman, 2000). However, the conception of risk taking as a trait does not imply that it cannot change over time. General personality traits with moderate rank stability, such as openness to new experiences, show reliable mean-level change (e.g., decline) across adult life (Roberts, Walton, & Viechtbauer, 2006). Such changes are also consistent with behavioral ecology's conception of risk. From this viewpoint, risk taking can be seen as a behavioral strategy or functional adaptation to an individual's current state (Sih & Del Guidice, 2012). In young adulthood, for example, risk behaviors are instrumental in gaining access to potential mating partners via resource control and status. Consequently, risky behaviors can be expected to be more prevalent among young males (Daly & Wilson, 1997) who face higher reproductive competition than young females. Later in the life cycle, on the contrary, individuals place higher value on other objectives such as guarding their own lives because the offspring's survival depends on parental and in particular maternal care, and defense (Campbell, 1999). In addition, risk taking should be particularly pronounced among those young individuals who have lower expectations about the future (Wolf, von Doorn, Leimar, & Weissing, 2007), lower life expectancy (Wilson & Daly, 1997), and that live in more competitive environments (Belsky, Schlomer, & Ellis, 2012).

In contrast to trait views, cross-situational conceptions of risk taking emphasize its domain-specific nature. According to these approaches, risk taking can differ considerably across domains because of the different costs and rewards associated with specific risk ecologies (Blais & Weber, 2006). In other words, inter- and intra-individual differences in risk-taking propensity may stem from varying perceptions of costs and benefits across domains and time. For example, life span changes in cognitive ability (Dohmen, Falk, Huffman, & Sunde, 2009) and affective experience (Carstensen, 2006) could impact how the benefits and costs of risk-taking behavior are perceived (Peters, Hess, Västfjäll, & Aumann, 2007). Moreover, it is possible that risk taking remains necessary or attractive across the life span in some domains, translating into domain-specific trajectories of risk propensity with some showing steeper decline than others. For example, while individuals may be willing to forego certain risky activities with increasing age–such as reckless driving–other forms, such as interpersonal exchange associated with social support may become increasingly needed across the life span. This multi-faceted and flexible interplay between an individual's age and her propensity to take risks may constitute an adaptive strategy: It avoids unnecessary harm thus managing and maintaining physical well being and health when physical losses in some domains are accumulating (Baltes & Baltes, 1990).

Which perspective is correct? Can risk-taking propensity be thought of as a trait that captures individual differences across domains and over time? Or alternatively, is risk taking a domain-specific response pattern that varies systematically with age and in different choice ecologies?

Stability and Change of Risk-Taking Propensity in Different Life Domains

Josef, A. K., Richter, D., Samanez-Larkin, G. R., Wagner, G. G., Hertwig, R. & Mata, R. (2016). Stability and change in risk-taking propensity across the adult life span. *Journal of Personality and Social Psychology*. Advance online publication. doi:10.1037/pspp0000090

Several conceptually and empirically distinct approaches to study stability and changes in personality traits may help to answer these questions: First, differential stability refers to the consistency of rank ordering of individuals over time. High differential stability is supportive for high individual trait stability. Key personality traits (i.e. the Big Five) show considerable rank-order stability but low levels of stability in youngest and oldest ages (Briley & Tucker-Drob, 2014; Roberts & DelVeccio, 2000). Second, mean-level stability refers to the consistency in the average level of traits across the life span and reflects the general pattern of change for large numbers of individuals. For example, average levels of personality traits such as openness to experiences and extraversion have shown reliable decreases with age (Lucas & Donnellan, 2011; Roberts, et al., 2006; Specht, Egloff, & Schmukle, 2011). Third, individual-level stability refers to the consistency of a trait at the level of the individual person. Correlated changes of several variables can be helpful to understand mechanisms of change and to gather greater insight into the individual dynamics of the development of a trait.

The first manuscript analyzed data from a large and representative longitudinal data set of respondents aged 18 to 85 years obtained from the German Socioeconomic Panel Study (SOEP, www.leibnitz-soep.de). The survey included a question on general risk-taking propensity in nine waves of assessment spanning 10 years. Six questions on risk-taking propensity in different life domains (i.e., financial, driving, recreational, occupational, health, and social) were included in three waves each five years apart. Two behavioral experiments, a monetary gamble task and a trust game were assessed in one year of the panel study each. We analyzed general and domain-specific risk-taking propensity (*N* > 40,000 and *N* > 11,000) as well as behavioral measures of social and nonsocial risk taking (*N* = 646 and *N* = 433) to test the different conceptions of change used in the personality literature and the convergence of findings in self-report and behavioral measures of risk.

The results suggest that risk-taking propensity has characteristics similar to a personality trait that is subject to change. First, the relative stability of risk-taking propensity is very similar to that of major personality variables (i.e., the Big Five). Across all domains investigated, the stability followed an inverted U-shaped pattern with lowest stability estimates in very young and older ages. Second, we showed that individual-level change over time is significantly associated with individual-level changes in the Big Five but not with changes in income. Positive associations were observed between within-person change in extraversion and openness to experiences with risk-taking propensity; negative associations were present between within-person change in conscientiousness, neuroticism, and agreeableness and within-person changes in risk-taking propensity. Third, the results for mean-level changes echo the results reported by previous studies in showing that aging, albeit differences in the life domain trajectories, reduces self-reported risk-taking propensity. These findings also coincide with studies showing that the average levels of personality traits such as openness to experiences, or extraversion decrease with age. Interestingly, risk-taking propensity in the social domain showed to be relatively stable across the life span. The pattern obtained for social and financial risk-taking propensity matched that obtained from cross-sectional data of behavioral measures of the monetary gamble task (financial) and the trust game (social). The correlations between self- reports and behavioral measures of risk were, however, very small. These results have important implications for the conception of risk taking, in general, but also for the measurement validity of behavioral and self-report measures for the construct of risk. Most notably, despite the strong associations in the characteristics of change between risk-taking propensity and the Big Five personality traits, the domain-specific mean-level changes pose the question of what could be potential (psychological) mechanisms behind these different trajectories.

Psychological Mechanisms of Life Span Changes in Risk-Taking Propensity

Josef, A. K., Drewelies, J., Hertwig, R., & Mata, R. (2016). *Age differences in risk-taking propensity are related to perceptions of risk and reward but not perceived control.* Working paper.

The results of the first manuscript resonate well with previous work which showed that, on average, the life span trajectories of risk-taking propensities vary significantly as a function of the life domain investigated (e.g. Rolison, Hanoch, Wood, & Liu, 2013). The steepest declines were found in recreational and occupational risk-taking propensity while the declines were least pronounced in financial, health, and social risk-taking propensity. What are the psychological mechanisms behind these domain- and age-differences? According to the risk-return approach of risk taking, individual and domain-differences in risk taking are a function of psychological variables such as how people perceive the costs and its benefits of risk taking (Hanoch, Johnson, & Wilke, 2006; Weber, Blais, & Betz, 2002). For example, previous research showed that women take fewer risks compared to men because they perceive risk costs to be higher and risk gains to be lower. Since aging is associated with a general decline in resources (i.e. experienced cognitive decline, reductions in physical fitness and decreases in social network size), experiencing such decline likely alters the perceptions of costs and benefits of risks in different domains of life (Bonem, Ellsworth, & Gonzalez, 2015). Moreover, older adults may sense a concurrent decline in perceived control, especially in those domains of life that are most affected by these changes and adjust their level of risk taking accordingly. The second manuscript investigated the role of risk perceptions (costs and benefits) and control beliefs for age- and domain-specific changes in risk-taking propensities.

The manuscript used cross-section data from an independent representative sample of the German population (*N* = 1,786) between 20 and 75 years of age. In addition to the risk-taking propensity items used in the German Socioeconomic Panel, the survey assessed separate items on risk perception, expected benefits, and control beliefs in the six life domains (i.e., financial, driving, recreational, occupational, health, and social). The results replicate the prominent age-related and domain-specific decline in risk-taking propensity. Strongest age-related declines were found in the recreational, occupational domain, and in car driving while the weakest declines were found in health, financial, and social risk-taking propensity. Further, the results suggest that measures of risk perception and expected benefits, but not control beliefs, account for this prominent decline. These results make important advances in understanding the psychological mechanisms behind age-related and domain-specific changes in the propensity to take risks.

Cross-Cultural Differences in Life Span Changes in Risk-Taking Propensity

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Viewed from a life history point of view, risk taking can be considered a trait that serves a functional role (i.e. an adaptation to internal or external changes of the individual) and that is genetically determined. That is, risk taking can be seen in terms of a reproductive strategy which is more prominent among males than females and more prevalent among younger relative to older individuals (Wilson & Daly, 1997). Moreover, changes may occur as a function of ecological circumstances, such as the level of harshness in an environment. Especially environments in which available resources are scare and that are therefore associated with increased competition, may force individuals to choose risk taking as a survival strategy. Similarly, research in personality literature reports significant variation in personality development as a function of the timing of normative life events in different countries (Bleidorn et al., 2013). That is, personality development at least partly results from people's experience with local ecologies. Is the prominent decline in risk-taking propensity across the adult life span a universal phenomenon? Or, alternatively, do local characteristics such as the level of hardship influence the relationship between age and risk taking?

Manuscript three is based on cross-sectional survey data of 77 countries (N = 147,118) around the globe from the World Value Survey (www.worldvaluesurvey.org). The survey included one (domain-general) item on individual risk-taking propensity. To capture exposure to hardship in each country, we computed a composite measure of homicide rate, gross domestic product, income equality, infant mortality, life expectancy at birth, and gender equality. The results show that in the majority of countries investigated, risk-taking propensity declines with age. However, there was also a significant variation of the shape of change with some countries showing steeper declines than others. Importantly, the measure of hardship for each country correlated with the steepness of decline in risk-taking propensity across the life span. In countries in which resources are scare the age-related decline was least pronounced. These results are consistent with life history theory, which predicts that risk taking is an essential strategy for survival and reproduction in harsh environments, and is so, irrespective of age. They are also in line with an ecological perspective on personality development and risk taking as a trait that shows substantial adaptations to environmental characteristics across the life span.

Interim Summary

The research described has important implications for theories of risk taking. First, manuscript one suggests that risk taking can be considered a trait with a level of rank-order stability across individuals that is only slightly below that of major personality dimensions. That is, the pattern reported echo the inverted U-curved pattern of stability from young to old adulthood that has been reported for major personality factors. Risk-taking propensity is least stable in very young and older ages. This trajectory is largely consistent with the idea that personality traits are shaped by life experiences. Lower stability is to be expected in developmental periods involving significant biological, cognitive, and social changes/demands.

Second, manuscript one and two demonstrate that, on average, risk-taking propensity declines over the life span. The shape of change, however, is domain-dependent. Interestingly, the social domain showed to be relatively stable across the life span. These results are consistent with Socioemotional Selectivity Theory (Carstensen, 1995). This life span theory of motivation makes predictions about social and emotional involvement across the life span. It supports the notion that as time horizons shrink with age, individuals choose to invest more resources into emotionally meaningful goals and behaviors. For example, past research has shown that social and emotional information remains prioritized with respect to broader life goals across adulthood (Carstensen et al., 1999). In addition, despite their decreasing social network size, there is evidence that older individuals continue to be socially engaged more frequently and more emotionally with their closest relationships compared to younger adults (Fredrickson & Carstensen, 1990). Manuscript two makes one step towards the investigation of qualitative differences between the domains and the found life span trajectories and shows that individual and age-related changes in perceptions of costs and benefits of risky behavior can act as psychological mechanisms behind the prominent decreases. This is in accordance with ideas on life span development in general and the idea that a change in the balance of gains and losses concerning the own resources may translate into psychological perceptions of risk taking in different life domains.

Third, manuscript one finds associations between individual-level changes in major personality traits and individual-level changes in risk-taking propensity but no associations between changes in situational variables such as income. That is, individual increases in extraversion and openness to experiences showed to increase individual risk-taking propensity. Increases in conscientiousness, neuroticism, and agreeableness, in turn, were associated with decreases in individual risk-taking propensity. Correlations of individual-level change in income did not show to have substantial influence on individual-level changes in risk-taking propensity over time. Thus, on the individual level, changes in personality show stronger associations with risk-taking propensity than changes in the economic circumstances such as income.

Lastly, manuscript three presents efforts towards a global perspective on the development of risk-taking propensity by investigating its cross-cultural variations. We can show that the correlation between age and risk-taking propensity varies across different countries and that this variation is a function of the affordances of the local ecologies. These findings are in line with results from personality psychology reporting that personality development is a product of experience with the characteristics of the local ecologies. The relationship between age and risk seems to reflect an individuals' adjustment to the characteristics of local ecologies and cannot be understood without reference to the demands and affordances of the environment.

Overall, these results suggest that risk taking is not a purely situation-specific response pattern. Instead, it should be considered a trait-like construct that is consistent in different settings and that changes as a function of its functional role in different environments across the life span.

What Remains Open – Important Questions for Future Research

The Relationship Between Risk-Taking Propensity And Personality

Regrettably, the developments of risk-taking tendencies and personality traits have long been investigated separately, including sensation seeking and impulsivity. The work summarized here makes important advances in understanding the relationship between the two constructs. Next, I will address a few ideas for future research that will inspire both further theoretical and empirical work on the link between the development of personality and risk taking.

The Early Origins of Individual Risk-Taking Propensity

Personality research reports that differences in temperament and behavioral tendencies between children are already evident in very early stages of their lives. In particular, behavioral styles at the age of 3 years were found to be predictive of self-reports on personality at the age of 18 years in the largest longitudinal study on this issue to date (Caspi & Silva, 1995). Children that were impulsive, restless, and distractible at the age of 3 years were also those that were reckless, careless, and that favored dangerous and exciting activities at the age of 18 years. Our work shows parallels between risk-taking propensity and major personality traits such as openness to experiences and extraversion, among others. The developmental origins of risk-taking propensity, however, are only poorly understood. Future work may profit from examining the stability of early facets of risk taking propensity in children up until young adulthood. Further, studying the development of risk-taking propensities from early childhood will allow investigating the mechanisms of change in risk taking such as intergenerational (genetic) transmission of attitudes from parents to children as well as their social mechanisms such as learning from the family and social environment (Dohmen, Falk, Huffman & Sunde, 2012; Necker & Voskort, 2014; Zumbuehl, Dohmen, & Pfann, 2013).

Factors Moderating Continuity and Change in Risk-Taking Propensity

In order to properly understand developmental processes in risk-taking propensity across the life span, it is essential to further examine the mechanisms of processes of change. Existing literature on personality development has identified several factors that may be worth investigating in relation to developmental processes in risk-taking propensity. For example, major life events include normative transitions in life (e.g. puberty, first job, marriage), meaningful changes (e.g. birth of a child), or major unexpected individual life events (e.g. unemployment, death of a family member). There is evidence that such events invoke changes in personality (Specht et al., 2011). Likewise, previous work has shown that macroeconomic events like economic crisis and floods provoke differences in risk taking beyond the effect of age (Berlemann, Steinhardt, & Tutt, 2015; Malmendier & Nagel, 2011). We show that individual stability of risk-taking propensity in different life domains is lowest in very young and old ages. One reason for this overt change in risk-taking propensity may be that these phases in life are most affected by the transitions and life events described above. If such events are major catalysts of personality change one further step within the study of life span development of risk-taking propensity will be the investigation of their effect on individual risk-taking propensity. In particular, it will be interesting to see whether the influence of such events tears apart preexisting individual differences more dramatically or alternatively, makes individuals become more alike.

Late Life Development of Risk-Taking Propensity: The Role of Distance to Death

A substantial body of evidence suggests that most pronounced declines in cognitive abilities, perceptual-motor speed, and crystallized are related to imminent death. For example, respondents who died within one year after assessment showed steeper decline in an investigation on life satisfaction relative to the others (Mroczek & Spiro, 2005). Time and time perception is an important component of many everyday life decisions because outcomes are not only uncertain but also take time to materialize. Socioemotional Selectivity Theory makes predictions about how the perception of time alters the selection and pursuit of social goals (Carstensen et al., 1999). That is, when time is perceived as limited, emotional goals are prioritized. Distance to death may thus constitute a further variable of interest worth investigating in relation to longitudinal changes in risk-taking propensity. Are individual differences in change in risk-taking propensity over time best described by chronological age or by distance to death? Is the rate of change influenced by distance to death? Are individual differences in changes related to real-world risk factors such as previous illnesses, extraordinary causes of death (e.g. car accidents), or even longevity?

Qualitative Differences Between Risk Ecologies

Adaptive Selection of Risk Environments

One robust finding is that aging reduces risk-taking propensity. The shape of change, however, varies as a function of life domain. More work is needed to provide further theoretical rationales for potential qualitative differences between the life domains investigated. One possibility for the evident domain-specific trajectories is that there are some domains or risky activities that can be avoided in different phases of life. For example, abstaining from climbing ladders or standing on chairs can reduce the risk of falls at home and may be an adaptive strategy in older age. It avoids unnecessary harm thus managing and maintaining physical well-being and health when physical losses in some domains are accumulating (Baltes & Baltes, 1990). This is consistent with the SOC theory, which predicts that individuals select environments or tasks in response to changes in their own resources. Going forward, studies that investigate specific risk-taking behaviors and assess the causes underlying the adoption or cessation of these behaviors across adulthood are warranted. Another promising avenue for research is to investigate systematic differences in age-related stereotypes and beliefs that are widespread in the population and can lead to systematic differences in behavior of older adults between domains (Konradt, & Rothermund, 2011).

Recall Processes of Self-Report Measures of Risk

Further work is necessary to understand the representations and associated retrieval processes that lead to the observed patterns of mean-level age differences in self-reported risk-taking propensity. Past research suggests that one can conceptualize elicited preferences as the output of human memory representations that contain knowledge related to these preferences. The preferences-as-memory (PAM) approach, for example, suggests that preferences are the product of the retrieval of relevant knowledge (attitudes, attributes, previous preferences, episodes, or events) from memory in an online fashion (Weber & Johnson, 2006). According to such views, factors such as the accessibility or the representativeness of specific risky behaviors can largely impact which information is retrieved from memory. Similarly, specific prompts or behaviors may prime memory retrieval that could lead to quite different patterns of self-reported risk taking in a given domain, or associated perceived costs and benefits depending on the age group investigated. When older adults reflect on risk taking in the recreational domain they think of long hikes in the forest, younger adults, in turn, think about extreme sports such as bungee jumping or cave diving.

Aging and Social Decision Making/Preferences

Our findings are likely to inspire new research on topics that have received relatively less attention like age differences in social decision making. In comparison to most other domains, social risk taking does not seem to undergo systematic age-related changes across the adult life span. This was also mirrored in the results on the trust game. These results are consistent with previous work showing relatively stable levels of trust from young to older ages (Rieger & Mata, 2013; Sutter & Kocher, 2007) and recent research showing a link between wisdom and age-related changes in economic and social decision making (Lim & Yu, 2015). Further work is needed to expand these results to obtain a more general statement on the effect of aging on social (risk) preferences. In particular, it would be interesting to summarize experimental evidence on social behavior and aging in relation to risk taking more extensively. To date, there is no systematic review of age differences in related measures such as donation behavior, altruism, public goods games, cooperation, dictator games, perceptions of trustworthiness, or prosocial behavior. Naturally, these research questions can be expanded to cross-cultural investigations to test whether especially social preferences differ depending on the culture and their value of (pro)social behavior.

Investigating the Link to Real-World Behavior

The work summarized is based on self-reports and does not allow investigating the links between risk preferences and real-world outcomes such as investment data or individual health status. To our knowledge, there has only been one past effort to use one wave of the SOEP database to predict real-world behavior in the financial domain (Dohmen, Falk, Huffman, Sunde, Schupp, & Wagner, 2011) but these efforts could be extended to include other waves of the SOEP. A limitation of both past work and any future efforts with these data will be that they do not include objective measures of respondents' real-world behavior. The SOEP, for instance, relies almost exclusively on self-report assessments of behavior rather than on observational or registry data. Recent studies have shown the feasibility of complementing self-report assessments with objective real-world assessments, such as health markers (Moffitt et al., 2011) or financial reports (Li et al., 2015). Future work with large representative longitudinal surveys should therefore combine self-report and behavioral measures with objective measures of risk-taking behavior, such as those associated with financial, health, recreational, occupational, or social behavior.

Empirical Associations Between Behavioral And Self-Report Measures

Further work is necessary to marshal the construct validity of risk taking. Convergent validity is the extent to which a measure correlates with other measures of the same construct. It is advanced by the empirical convergence of findings using different measurements as well as their empirical associations. Manuscript one finds that there are parallels between the trajectories of the self-report measures and the two behavioral measures. Specifically, the decline in self-reported risk-taking propensity in the financial domain was matched by behavior in the monetary gamble. Similarly, a relatively flat trajectory of risk-taking propensity in the self-reported social domain matched results obtained from the behavioral trust game. However, the cross-sectional correlations between self-report and behavioral results were small. Naturally, the small correlations between behavioral and self-report measures of trust could stem from confounds present in the specific behavioral games used, such as the trust game, because factors such as mentalizing abilities and altruistic preferences may trump or confound the role of risk-taking preferences (Rilling & Sanfey, 2011). More broadly, although our work raises the possibility that both self-report and behavioral measures capture similar aspects of mean-level changes in risk-taking propensity with increased age, further work is needed to quantify the overlap between the different measures (see Appelt, Milch, Handgraaf, & Weber).

Part II – Adult Age-Differences in Decision Making: The Role of Memory Demand

In everyday life, we often must make decisions in which some or all information is not available in the environment but rather needs to be recalled from memory. Therefore, the ability to encode, bind, and retrieve information specific to decision alternatives is often crucial for choosing the best among several options.

Our cognitive system undergoes systematic and profound changes across the life span (Lindenberger, 2014). Especially old age is characterized by decreases in cognition, in particular, cognitive control and memory functioning (Hoyer & Verhaeghen, 2006; Light, 1991). Specifically, the ability to create and retrieve links between single units of information undergoes substantial and continuous decreases with age (Cowan, Naveh-Benjamin, Kilb, & Saults, 2006; Naveh-Benjamin, 2000). Cognitive control mechanisms, essential for the upholding, strategic selection and evaluation of relevant information also follow a declining developmental trajectory (Shing, Werkle-Bergner, Li, & Lindenberger, 2008).

The link between memory and decision making has long been discussed, but what are potential effects of developmental changes of this essential cognitive ability on decision making as we grow older? Concurrent literature is consistent in showing that adult age differences in decision making performance are a function of the cognitive demands of the decision situation with generally lower levels of decision performance of older relative to younger adults (e.g. Bruine de Bruin, Parker, & Fischhoff, 2010; Finucane, Mertz, Slovic, & Schmidt, 2005). These deficits are most pronounced in decision situations that are cognitively demanding, such as when options' values have to be extracted and learned from feedback or when any pieces of information are presented (Finucance et al., 2005; Frey, Mata, & Hertwig, 2015; Henninger, Madden, & Huettel, 2010). As a result, limitations in memory ability may especially constrain the tools necessary for competent decision making in decision tasks with high memory demand because such situations pose additional cognitive load when previously learnt information has to be retrieved from memory (Bröder & Schiffer, 2003; 2006; Peters et al., 2007; Yoon, Cole, & Lee, 2009).

The idea that individuals possess a set of different strategies to solve cognitive tasks is proposed in research on memory (Touron, 2015), arithmetic (Siegler & Lemaire, 1997), and decision making (Beach & Mitchell, 1978; Gigerenzer & Goldstein, 1996; Payne, Bettman, & Johnson, 1988). The prerequisite is that individuals select decision strategies that are adapted to the demands of the task and their own cognitive capacities (Mata et al., 2012). This selection process constitutes a cost-benefit tradeoff between the accuracy of a strategy for the decision problem at hand and the effort associated with its execution. Previous research has shown that individuals are sensitive to a number of task characteristics such as time pressure and memory demands (Bröder & Schiffer, 2003), among others, and select decision strategies accordingly. Increasing memory demand has especially been associated with the selection of simpler decision strategies that are less cognitively demanding. It follows that one way to compensate for increasing age-related memory decline can be a shift in the tools or strategies selected such that they match changed internal resources (Gigerenzer, 2003). For example, when tasks with high memory demand tend to become more difficult with age, older adults switch to simpler, less cognitively demanding decision strategies to reduce cognitive load (Mata, Schooler, & Rieskamp, 2007).

How Memory Demand Influences Decision Accuracy and Strategy Selection

Josef, A. K., Kellen, D., Pachur, T., Hertwig, R., & Mata, R. (2016). *How cognitive aging affects decision making under increased memory demands*. Working paper.

Manuscript four comprises two studies that directly tested the effect of memory demands on adult age differences in decision making. To do this, a group of young and older adults was engaged in a personnel selection scenario in which they first learnt cue information about five different job candidates. Later then, they made decisions in a context in which consideration of all information was necessary for high decision performance. To vary memory demands, decisions were based on information retrieval from memory (high memory demand), or on information displayed in front of the decision maker (low memory demand). With this design, we were able to test the following hypotheses: First, older adults' decisions reach a lower level of accuracy than younger adults and the former rely more on simpler strategies than the latter. Both effects occur most strongly when demands on memory are high and when decision making demands a high degree of self-initiated processing in memory. Second, individuals' differential memory (i.e. associative and working memory ability) is a key element in the occurrence of individual and age differences in performance when tasks strongly call upon memory.

The results show that older adults' decisions, relative to those of younger adults, were most compromised when demands on memory were high. Age differences in decision making were relatively small under low memory demands when information was displayed on the screen. Individual differences in memory ability mediated the relationship between age, memory demand, and decision performance. These findings are in line with findings reported in the memory literature in suggesting that age differences increase with the degree of self-initiated processing during memory retrieval (Lindenberger & Mayr, 2014). Modeling of the strategies underlying decisions suggests that younger adults balance the high demand on memory by switching to a simpler non-compensatory strategy. Older adults do not seem to compensate but instead select idiosyncratic strategies more often. The latter do not fit the traditional framework of compensatory versus non-compensatory processing. Overall, the results may have important implications for the boundary conditions of age-related compensation mechanisms and adaptive strategy selection (i.e. the selection of simpler decision strategies to offset high cognitive demand). They also highlight the role of decision aids that may especially help older adults to make adequate decisions in cognitively challenging decision environments.

Interim Summary

This work makes important contributions to the emerging field of cognitive aging and decision making competence. It is consistent with predictions from the SOC theory on successful aging as well as an ecological rational perspective on aging and decision making: Age-differences in decision making were a function of task demand and the available cognitive resources of the age groups. In particular, individual memory ability seems to be a crucial factor for adequate decision making, especially in older ages. The means by which especially older adults solve the decision problem, their strategy selection, remains unclear. In what follows, I will give an outlook for important questions for future research studying the interaction between memory and decision making in developmental populations.

What Remains Open – Important Questions for Future Research

Further Insights Into Strategic Memory and Decision Making Processes

This work shows that the impact of changes in cognitive abilities on decision making strongly depends on the demands of the specific choice environment, here memory demands. The accuracy of decisions made by individuals of all ages is the result of how such demands interact with the selection of particular strategies. Yet, this work does not provide definite conclusions about the relevant memory components or processes underlying these deficits and the selection of strategies. There are several important aspects worth an investigation in future research.

The Relative Contribution of Associative and Working Memory

Previous work in the memory literature provides evidence for robust age-related deficits in retrieval of associative memories as well as the ability to strategically manipulate and integrate information successfully in working memory (Shing et al., 2008). The decision task in the studies described above relies on both memory components and therefore does not allow differentiating their relative contribution to the observed deficits. Is it that older adults rely more on false memories and, as a result, make more erroneous decisions or, alternatively, is it that they fail during the process of integration in working memory?

Studying age-related changes in the ability to execute decision strategies correctly and successfully may help to approach this issue. The rationale is that decision strategies proposed in the decision making literature can vary in their degree of cognitive demand (e.g. Beach & Mitchell, 1978). Compensatory decision strategies, like tallying for example, use all available information. Simpler decision strategies use only a subset of all possible information and are therefore less cognitively demanding. Existent literature reports that especially older adults have difficulties in using compensatory decision strategies relative to young adults (Mata, von

Helversen, & Rieskamp, 2010; Bruine de Bruin et al., 2007). By forcing participants to use specific strategies, future research can control the cognitive processes and provide evidence for predictors of age-differences in performance as a function of the cognitive complexity of these processes in different choice environments. That is, further experimental manipulations can replace the demand of online retrieval by information search on the screen (e.g. via mouse lab or eye-tracking; Renkewitz & Jahn, 2012; Scholz, von Helversen, & Rieskamp, 2015) and test the effects of information integration versus recall deficiencies for a particular strategy.

When Easy Comes Hard in Memory

Executing a compensatory decision strategy becomes more challenging the more information has to be recalled from memory. In line with the cost-benefit idea of strategy selection, individuals shift to non-compensatory strategies like take-the-best when cognitive capacities are limited (Bröder & Schiffer, 2006) or when the costs of information search are high such as in memory-based decisions (Bröder & Schiffer, 2003). Yet, previous research uncovered a potential drawback of the simple decision strategy take-the-best (Khader, Pachur, Meier, Bien, Jost, & Rösler, 2011). In particular, on the neuronal level, this supposedly simple strategy has shown to require selective control of posterior information storage areas necessary for successful recall and integration orchestrated by the dorsolateral prefrontal cortex (DLPFC). This cognitive control process may especially be challenging for older adults. It follows that future work is necessary to understand whether older adults necessarily benefit from the reduced information load of simpler non-compensatory decision strategies. Neuroimaging studies that compare the neuronal correlates of such strategies can help to shed light on this issue and age differences thereof.

Individualized Cost-Benefit Tradeoffs in Information Search

Contingency approaches to decision making propose that individuals select decision strategies that are adapted to the demands of the task and their cognitive capacities (Mata et al., 2012). Past research found that older adults engage in less information search prior to a decision (Mata & Nunes, 2010) and that individuals may trade-off the utility of more information versus the costs of retrieval when making decisions. Our modeling results show that especially older adults resort to strategies that, albeit still methodical, are more idiosyncratic, and do not fit the traditional framework of compensatory versus non-compensatory processing. One assumption could be that the individual cost-benefit tradeoffs for information search become highly individualized. That said, older adults may still integrate across some but not all cues and this number may differ by individual. Verbal protocols may be helpful for evaluating these individual benchmarks (Cokely & Kelley, 2009).

Potential for Targeted Decision Aids In Complex Decision Situations

We show that memory demand is one extreme condition that leads to pronounced decision making deficits between young and older adults. When information needs to be retrieved from memory especially older adults may fail during recall and/or integration of this information. However, we show that when information is conveniently presented on a screen, age differences in decision making are relatively small. These insights provide important opportunities for the development of interventions and decision aids, external memory cues, or interactive designs that support decision making. For example, such aids may increase salience of cues relevant for choice quality but keep low the demands for information recall and integration. Further work is necessary to better understand the circumstances under which the provision of such aids, or retrieval cues, can support decision making and provide guidance for a more structured decision making process.

Summary and Conclusion

The Selective Optimization with Compensation approach emphasizes the need to adapt behavior in response to changes in own resources over the life span. According to an ecological rational perspective in decision making, individuals adapt their behavior to the affordances of their choice environment. The work presented in this dissertation is in line with both perspectives. It shows that developmental phenomena such as changes in decision making can be understood as (efforts to) adaptive performances of individuals in response to changes in their own resources (e.g. cognitive capacity) as well as in the environment surrounding them. First, although showing descriptive characteristics of a personality trait, risk-taking propensities varied substantially by life domain. Individual differences in the perceptions of costs and benefits showed to be associated with such age- and domain-differences. Second, the relation between age and risk-taking propensity is related to the level of hardship in different countries with high levels leading to flatter age-risk curves. Third, age-differences in decision performance are a function of the demands imposed by a task. Memory abilities show to represent an important boundary condition adaptive performance in choice tasks. Overall, these findings emphasize that in order to predict life span changes in decision making, one needs to take the interaction between cognition, behavior, and environment into account.

References

Agarwal, S., Driscoll, J. C., Gabaix, X., & Laibson, D. (2009). The age of reason: Financial decisions over the life cycle and implications for regulation. *Brookings Papers on Economic Activity*, 51–101. doi:10.2307/25652729

Anokhin, A. P., Golosheykin, S., Grant, J., & Heath, A. C. (2009). Heritability of risk-taking in adolescence: A longitudinal twin study. *Twin Research and Human Genetics*, *12*, 366–371. doi:10.1375/twin.12.4.366

Appelt, K. C., Milch, K. F., Handgraaf, M. J., & Weber, E. U. (2011). The Decision Making Individual Differences Inventory and guidelines for the study of individual differences in judgment and decision making research. *Judgment and Decision Making, 6,* 252–262.

Baltes, P. B., & Baltes, M. M. (1990). Psychological perspectives on successful aging: The model of selective optimization with compensation. In P. B. Baltes & M. M. Baltes (Eds.), *Successful aging: Perspectives from the behavioral sciences* (pp. 1–34). New York: Cambridge University Press

Beach, L. R., & Mitchell, T. R. (1978). A contingency model for the selection of decision strategies. *Academy of Management Review*, *3*, 439–449.

Belsky, J., Schlomer, G. L., & Ellis, B. J. (2012). Beyond cumulative risk: Distinguishing harshness and unpredictability as determinants of parenting and early life history strategy. *Developmental Psychology*, *48*, 662–673. doi:10.1037/ a0024454

Berlemann, M., Steinhardt, M. F., & Tutt, J. (2015). Do natural disasters stimulate individual savings? Evidence from a natural experiment in a highly developed country. *CESifo Working Paper Series No. 5344*. Retrieved from http://ssrn.com/abstract=2607938

Blais, A.-R. E., & Weber, E. U. (2006). A domain-specific risk-taking (DOSPERT) scale for adult populations. *Judgment and Decision Making*, *1*, 33–47. Retrieved from http://journal.sjdm.org/06005/jdm06005.htm

Bleidorn, W., Klimstra, T. A., Denissen, J. J. A., Rentfrow, P. J., Potter, J., & Gosling, S. D. (2013). Personality maturation around the world: A cross-cultural examination of social-investment theory. *Psychological Science*, *24*(12), 2530–2540. doi:10.1177/0956797613498396

Bonem, E. M., Ellsworth, P. C., & Gonzalez, R. (2015). Age differences in risk: Perceptions, intentions and domains. *Journal of Behavioral Decision Making*. http://dx.doi.org/10.1002/bdm.1848

Briley, D. A., & Tucker-Drob, E. M. (2014). Genetic and environmental continuity in personality development: A meta-analysis. *Psychological Bulletin*, *140*, 1303–1331. doi:10.1037/a0037091.supp

Bröder, A., & Schiffer, S. (2003). Take the best versus simultaneous feature matching: Probabilistic inferences from memory and effects of representation format. *Journal of Experimental Psychology: General, 132*, 277–293. doi:10.1037/0096-3445.132.2.277

Bröder, A., & Schiffer, S. (2006). Stimulus format and working memory in fast and frugal strategy selection. *Journal of Behavioral Decision Making, 19*, 361–380. doi: 10.1002/bdm.533

Bruine de Bruin, W., Parker, A. M., & Fischhoff, B. (2007). Individual differences in adult decision- making competence. *Journal of Personality and Social Psychology, 92*, 938–956.

Bruine de Bruin, W., Parker, A. M., & Fischhoff, B. (2010). Explaining adult age differences in decision-making competence. *Journal of Behavioral Decision Making, 25*, 352–360. doi: 10.1002/bdm.712

Campbell, A. (1999). Staying alive: Evolution, culture, and women's intrasexual aggression. *Journal of Behavioral and Brain Science*, *22*, 203–252. doi:10.1017/S0140525X99371818

Carstensen, L. L. (2006). The influence of a sense of time on human development. *Nature*, *312*(5782), 1913–1915. doi:10.1126/science.1127488

Carstensen, L. L. (1995). Evidence for a life-span theory of socioemotional selectivity. *Current Directions in Psychological Science, 4*, 151–156. doi:10.1111/1467-8721.ep11512261

Carstensen, L. L., Isaacowitz, D. M., & Charles, S. T. (1999). Taking time seriously: A theory of socioemotional selectivity. *American Psychologist, 54*(3), 165-181. doi:10.1037/0003-066X.54.3.165

Caspi, A., & Silva, P. A. (1995). Temperamental qualities at age three predict personality traits in young adulthood: Longitudinal evidence from a birth cohort. *Child Development, 66*, 486–498. doi: 10.2307/1131592

Cesarini, D., Johannesson, M., Lichtenberg, P. A., Sandewall, Ö., & Wallace, B. (2010). Genetic variation in financial decision making. *The Journal of Finance*, *65*, 1725–1754. doi:10.1111/j.1540-6261.2010.01592.x

Chasseigne, G., Ligneau, C., & Grau, S. (2003). Aging and probabilistic learning in single- and multiple-cue tasks. Experimental Aging Research, *30,* 23–45. doi:10.1080/03610730490251469

Cokely, E. T., Kelley, C. M. (2009). Cognitive abilities and superior decision making under risk: A protocol analysis and process model evaluation. *Judgment and Decision Making, 4*, 20–33.

Cowan, N., Naveh-Benjamin, M., Kilb, A., & Saults, J. S. (2006). Life span development of visual working memory: When is feature binding difficult. *Developmental Psychology, 42,* 1089–1102.

Daly, M., & Wilson, M. (1997). Crime and conflict: Homicide in evolutionary psychological perspective. *Crime and Justice*, *22*, 51–100.

Dohmen, T., Falk, A., Huffman, D., Sunde, U., Schupp, J., & Wagner, G. R. G. (2011). Individual risk attitudes: Measurement, determinants, and behavioral consequences. *Journal of the*

European Economic Association, 9, 522–550. doi:10.1111/j.1542-4774.2011 .01015.x

Dohmen, T., Falk, A., Huffman, D., & Sunde, U. (2012). The intergenerational transmission of risk and trust attitudes. *Review of Economic Studies, 79*, 645–677. doi:10.1093/restud/rdr027

Dohmen, T., Falk, A., Huffman, D., & Sunde, U. (2009). Are risk aversion and impatience related to cognitive ability? *The American Economic Review*, *100*, 1238–1260. doi:10.1257/aer.100.3.1238

Eppinger, B., Hämmerer, D., & Li, S. C. (2011). Neuromodulation of reward-based learning and decision making in human aging. *Annals of the New York Academy of Sciences, 1235*, 1–17. doi:10.1111/j.1749-6632.2011.06230.x.

Finucane, M. L., Mertz, C. K., Slovic, P., & Schmidt, E. S. (2005). Task complexity and older adults' decision-making competence. *Psychology and Aging, 20*, 71–84. doi:10.1037/0882-7974.20.1.71

Fredrickson, B. L., & Carstensen, L. L. (1990). Choosing social partners: How old age and anticipated endings make people more selective. *Psychology and Aging, 5,* 335–347. doi: 10.1037/0882-7974.5.3.335

Frey, R., Mata, R., & Hertwig, R. (2015). The role of cognitive abilities in decisions from experience: Age differences emerge as a function of choice set size. *Cognition*, *142*, 60–80. doi:10.1016/j.cognition.2015.05.004

Gamble, K. J, Boyle, P. A., Yu, L., & Bennett, D. A. (2014). Aging and financial decision making. *Management Science, 61*, 2603–2610. doi:10.1287/mnsc.2014.2010

Gigerenzer, G. (2003). The adaptive toolbox and lifespan development: Common questions? In U. M. Staudinger & U. Lindenberger (Eds.), *Understanding human development: Dialogues with lifespan psychology* (pp.423–4359). Dordrecht: Kluwer.

Gigerenzer, G., Todd, P. M., & The ABC Research Group. (1999). *Simple Heuristics that Make Us Smart*. New York: Oxford University Press.

Gigerenzer, G., & Goldstein, D. G. (1996). Reasoning the fast and frugal way: Models of bounded rationality. *Psychological Review*, *103*, 650–669.

Hanoch, Y., Johnson, J. G., & Wilke, A. (2006). Domain specificity in experimental measures and participant recruitment: An application to risk-taking behavior. *Psychological Science*, *17*, 300–304. doi:10.1111/j.1467-9280.2006.01702.x

Henninger, D. E., Madden, D. J., & Huettel, S. A. (2010). Processing speed and memory mediate age-related differences in decision making. *Psychology and Aging, 25*, 262–270. doi:10.1037/a0019096

Hoyer, W. J., & Verhaeghen, P. (2006). Memory aging. In J. E. Birren & K. W. Schaie (Eds.), *Handbook of the psychology of aging (sixth edition)* (p. 209–232). San Diego: Elsevier.

Khader, P. H., Pachur, T., Meier, S., Bien, S., Jost, K., & Rösler, F. (2011). Memory-based decision making with heuristics involves increased activation of decision-relevant memory representations. *Journal of Cognitive Neuroscience, 23*, 3540–3554.

Konradt, A. E., & Rothermund, K. (2011). Contexts of aging: Assessing evaluative age stereotypes in different life domains. *The Journals of Gerontology Series B: Psychological Sciences and Social Sciences*, *66*, 547–556. doi:10.1093/geronb/gbr036

Light, L. L. (1991). Memory and aging: Four hypotheses in search of data. *Annual Review of Psychology, 42*, 333–376. doi:10.1146/annurev.ps.42.020191.002001

Li, Y., Gao, J., Enkavi, A. Z., Zaval, L., Weber, E. U., & Johnson, E. J. (2015). Sound credit scores and financial decisions despite cognitive aging. *PNAS Proceedings of the National Academy of Sciences of the United States of America, 112,* 65–69. http://dx.doi.org/10.1073/pnas .1413570112

Lim, K. T. K., & Yu, R. (2015). Aging and wisdom: Age-related changes in economic and social decision making. *Frontiers in Aging Neuroscience, 7*, 1–11. doi:10.3389/fnagi.2015.00120

Lindenberger, U. (2014). Human cognitive aging: Corriger la fortune? *Science, 346,* 572–578. doi:10.1126/science.1254403

Lindenberger, U., & Mayr, U. (2014). Cognitive aging: Is there a dark side to environmental support? *Trends in Cognitive Sciences, 18*, 7–15. doi:10.1016/j.tics.2013.10.006

Lucas, R. E., & Donnellan, M. B. (2011). Personality development across the life span: Longitudinal analyses with a national sample from Germany. *Journal of Personality and Social Psychology*, *101*, 847–861. doi:10.1037/a0024298

Malmendier, U., & Nagel, S. (2011). Depression babies: Do macroeconomic experiences affect risk-taking? *The Quarterly Journal of Economics*, *126*, 373–417. doi:10.1093/qje/qjq004

Mata, R., von Helversen, B., & Rieskamp, J. (2010). Learning to choose: Cognitive aging and strategy selection learning in decision making. *Psychology and Aging*, *25*, 299–309. doi:10.1037/0882-7974.22.4.796

Mata, R., & Nunes, L. (2010). When less is enough: Cognitive aging, information search, and decision quality in consumer choice. *Psychology and Aging*, *25*, 289–298. doi:10.1037/a0017927

Mata, R., Pachur, T., von Helversen, B., Hertwig, R., Rieskamp, J., & Schooler, L. (2012). Ecological rationality: A framework for understanding and aiding the aging decision maker. *Frontiers in Neuroscience, 6*, 1–19. doi:10.3389/fnins.2012.00019

Mata, R., Schooler, L. J., & Rieskamp, J. (2007). The aging decision maker: Cognitive aging and the adaptive selection of decision strategies. *Psychology and Aging, 22*, 796–810. doi:10.1037/0882-7974.22.4.796

Moffitt, T. E., Arseneault, L., Belsky, D., Dickson, N., Hancox, R. J., Harrington, H., . . . Caspi, A.

(2011). A gradient of childhood self- control predicts health, wealth, and public safety. *PNAS Proceedings of the National Academy of Sciences of the United States of America, 108,* 2693–2698. doi:10.1073/pnas.1010076108

Mroczek, D. K., & Spiro, A. III (2005). Change in life satisfaction during adulthood: Findings from the veterans affairs normative aging study. *Journal of Personality and Social Psychology, 88*, 189–202. doi:10.1037/0022-3514.88.1.189

Naveh-Benjamin, M. (2000). Adult age differences in memory performance: Tests of an associative deficit hypothesis. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 26,* 1170–1187. doi: 10.1037//0278-7393.26.5.117

Necker, S., & Voskort, A. (2014). Intergenerational transmission of risk attitudes – A revealed preference approach. *European Economic Review, 65*, 66–89. doi:10.1016/j.euroecorev.2013.10.005

Payne, J. W., Bettman, J. R., & Johnson, E. J. (1988). Adaptive strategy selection in decision making. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *14*, 534–552.

Peters, E. M., Hess, T. M., Västfjäll, D., & Auman, C. (2007). Adult age differences in dual information processes: Implications for the role of affective and deliberative processes in older adults' decision making. *Perspectives on Psychological Science*, *2*, 1–23. doi:10.1111/j.1745-6916.2007.00025.x

Renkewitz, F., & Jahn, G. (2012). Memory-indexing: A novel method for tracing memory processes in complex cognitive tasks. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 38*, 1622–1639. doi:10.1037/a0028073

Rieger, M., & Mata, R. (2013). On the generality of age differences in social and nonsocial decision making. *Journals of Gerontology, Series B: Psychological Sciences and Social*

Sciences, 70, 200–212. do:10.1093/geronb/gbt088

Rilling, J. K., & Sanfey, A. G. (2011). The neuroscience of social decision-making. *Annual Review of Psychology, 62,* 23–48. doi:10.1146/annurev.psych.121208.131647

Roberts, B. W., Walton, K. E., & Viechtbauer, W. (2006). Patterns of mean-level change in personality traits across the life course: A meta-analysis of longitudinal studies. *Psychological Bulletin*, *132*, 1–25. doi:10.1037/0033-2909.132.1.1

Roberts, B. W., & DelVeccino, W. F. (2000). The rank-order consistency of personality traits from childhood to old age: A qualitative review of longitudinal studies. *Psychological Bulletin*, *126*, 3–25. doi:10.1037/0033-2909.126.1.3

Rolison, J. J., Hanoch, Y., Wood, S., & Liu, P. J. (2013). Risk-taking differences across the adult life span: A question of age and domain. *The Journals of Gerontology Series B: Psychological Sciences and Social Sciences*, *69*, 870–880. doi:10.1093/geronb/gbt081

Salthouse, T. A (2010). Selective review of cognitive aging. *Journal of the International Neuropsychological Society, 16*, 754–760. doi:10.1017/S1355617710000706

Schoemaker, P. J. H. (1993). Determinants of risk-taking: Behavioral and economic views. *Journal of Risk and Uncertainty, 6,* 49–73. doi:10.1002/smj.4250140304

Scholz, A., von Helversen, B., & Rieskamp, J. (2015). Eye movements reveal memory processes during similarity- and rule-based decision making. *Cognition*, *136*, 228–246. doi:10.1016/j.cognition.2014.11.019

Siegler, R. S., & Lemaire, P. (1997). Older and younger adults' strategy choices in multiplica- tion: Testing predictions of ASCM using the choice/no-choice method. *Journal of Experimental Psychology: General*, *126*, 71–92.

Shing, Y. L., Werkle-Bergner, M., Li, S.-C., & Lindenberger, U. (2008). Associative and strategic components of episodic memory: A life span dissociation. *Journal of Experimental*

Psychology: General, *137*, 496–513. doi:10.1037/0096-3445.137.3.495

Sih, A., & Del Giudice, M. (2012). Linking behavioural syndromes and cognition: a behavioural ecology perspective. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *367*, 2762–2772. doi:10.1016/j.neubiorev.2011.03.015

Specht, J., Egloff, B., & Schmukle, S. C. (2011). Stability and change of personality across the life course: The impact of age and major life events on mean-level and rank-order stability of the Big Five. *Journal of Personality and Social Psychology*, *101*, 862–882. doi:10.1037/a0024950

Steinberg, L. (2008). A social neuroscience perspective on adolescent risk-taking. *Developmental Review*, *28*, 78–106. doi:10.1016/j.dr.2007.08.002

Sutter, M., & Kocher, M. G. (2007). Trust and trustworthiness across different age groups. *Games and Economic Behavior, 59*, 364–382. doi:10.1016/j.geb.2006.07.006

Touron, D. R. (2015). Memory avoidance by older adults: When „old dogs“ won't perform their „new tricks“. *Current Directions in Psychological Science, 24*, 170–176. do:10.1177/0963721414563730

Weber, E. U., Blais, A.-R. E., & Betz, N. E. (2002). A domain-specific risk-attitude scale: Measuring risk perceptions and risk behaviors. *Journal of Behavioral Decision Making*, *15*, 263–290. doi:10.1002/bdm.414

Weber, E. U. & Johnson, E. J. (2006). Constructing preferences from memory. The construction of preference. In Lichtenstein, S. & Slovic, P., (eds.), 397-410, New York, NY, Cambridge University Press, 2006.

Wilson, M., & Daly, M. (1997). Life expectancy, economic inequality, homicide, and reproductive timing in Chicago neighborhoods. *Bmj*, *314*, 1271–1274. doi:10.1136/bmj.314.7089.1271

Wolf, M., Doorn, von, S. G., Leimar, O., & Weissing, F. J. (2007). Life-history trade-offs favour the evolution of animal personalities. *Nature*, *447*, 581–584. doi:10.1038/nature05835

Vaupel, J. W. (2010). Biodemography of human ageing. *Nature*, *464*, 536–542. doi:10.1038/nature08984

Yechiam, E., & Ert, E. (2011). Risk attitude in decision making: In search of trait-like constructs. *Topics in Cognitive Science, 3*, 166–186. doi:10.1111/j.1756-8765

Yoon, C., Cole, C. A., & Lee, M. P. (2009). Consumer decision-making and aging: Current knowledge and future directions. *Journal of Consumer Psychology*, *19*, 2–16. doi:10.1016/j.jcps.2008.12.002

Zuckerman, M., & Kuhlman, M. D. (2000). Personality and risk-taking: Common biosocial factor. *Journal of Personality*, *68*, 1000–1029. doi:10.1111/1467-6494.00124

Zumbuehl, M., Dohmen, T., & Pfann, G. (2013). Parental investment and the intergenerational transmission of economic preferences and attitudes. *SOEPpapers 570*. Berlin: DIW Berlin.

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Stability and Change in Risk-Taking Propensity Across the Adult Life Span

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Stability and Change in Risk-Taking Propensity Across the Adult Life Span

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Can risk-taking propensity be thought of as a trait that captures individual differences across domains, measures, and time? Studying stability in risk-taking propensities across the life span can help to answer such questions by uncovering parallel, or divergent, trajectories across domains and measures. We contribute to this effort by using data from respondents aged 18 to 85 in the German Socio-Economic Panel Study (SOEP) and by examining (a) differential stability, (b) mean-level differences, and (c) individual-level changes in self-reported general ($N = 44{,}076$) and domain-specific ($N = 11{,}903$) risk-taking propensities across adulthood. In addition, we investigate (d) the correspondence between cross-sectional trajectories of self-report and behavioral measures of social (trust game; $N = 646$) and nonsocial (monetary gamble; $N = 433$) risk taking. The results suggest that risk-taking propensity can be understood as a trait with moderate stability. Results show reliable mean-level differences across the life span, with risk-taking propensities typically decreasing with age, although significant variation emerges across domains and individuals. Interestingly, the mean-level trajectory for behavioral measures of social and nonsocial risk taking was similar to those obtained from self-reported risk, despite small correlations between task behavior and self-reports. Individual-level analyses suggest a link between changes in risk-taking propensities both across domains and in relation to changes in some of the Big Five personality traits. Overall, these results raise important questions concerning the role of common processes or events that shape the life span development of risk-taking across domains as well as other major personality facets.

Keywords: differential stability, domain specificity, individual differences, life span development, risk taking

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Definitions of risk and risk taking abound (Aven, 2012; Schonberg, Fox, & Poldrack, 2011). This conceptual diversity may be partly responsible for ongoing debates regarding the construct of risk-taking propensity, including how to best measure it (Friedman, Isaac, Duncan, & Sunder, 2014; Schonberg et al., 2011) and whether to conceptualize it as a general or a domain-specific trait (Weber, Blais, & Betz, 2002). An important issue in this regard is the development of risk-taking propensity across the life span, including its stability and change across measures and domains (Mata, Josef, Samanez-Larkin, & Hertwig, 2011; Rieger & Mata, 2015). Crucially, any insights into life span changes in risk-taking propensity may depend on how change is conceptualized. Person-

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ality research has distinguished between different types of change, with conceptually and empirically distinct implications (Briley & Tucker-Drob, 2014; Roberts & DelVecchio, 2000). For example, differential stability, or rank-order stability, a defining feature of a trait, can be independent from mean-level or normative age-related changes in the same trait.

Past work on adult age differences in risk taking has focused on mean-level changes estimated from cross-sectional comparisons, thus precluding a direct investigation of other conceptualizations of stability/change (e.g., rank-order stability). In our work, we explore different conceptualizations of stability and change in risk-taking propensity across the adult life span by drawing on a unique data set from the German Socio-Economic Panel Study (SOEP) (Wagner, Frick, & Schupp, 2007). This multicohort study combines longitudinal self-report data on both general and domain-specific risk-taking propensity with cross-sectional behavioral measurements of risk taking. Specifically, we investigate (a) differential stability, (b) mean-level differences, and (c) individual-level differences in change in both general and domain-specific self-report measures of risk-taking propensity, and relate (d) mean-level changes in self-report to mean-level changes in behavioral measures of social and nonsocial risk taking. Our goal is to advance the understanding of risk taking by evaluating the role of both domain (e.g., financial, social) and measure (self-report vs. behavior) on the stability of risk-taking propensity across adulthood.

In what follows, we first provide an overview of some of the constructs of change that have been investigated in the personality literature. Second, we review previous work on risk-taking propensity against the background of different conceptualizations of change. Third, we describe the present study and the main research questions addressed.

Characterizing Life Span Changes in Personality

There are several conceptually and empirically distinct approaches to personality stability/change. We highlight three main types: differential stability, mean-level stability, and individual-level stability (Briley & Tucker-Drob, 2014; Roberts & DelVecchio, 2000). First, *differential stability* refers to consistency in the rank ordering of individuals over time. The idea that individuals differ systematically from one another and that those differences are maintained over time echoes the concept of a trait. A number of meta-analyses have found that key personality traits, the Big Five personality traits, show considerable rank-order stability (Briley & Tucker-Drob, 2014; Ferguson, 2010; Roberts & DelVecchio, 2000). However, differential stability of personality traits undergoes systematic changes across the life span, with correlations ranging from 0 in infancy to .7 in adulthood (Briley & Tucker-Drob, 2014). There is still debate concerning whether there is some decrease in stability at the end of the life span. Meta-analytic results show only a trend toward decreasing stability in old age (Briley & Tucker-Drob, 2014); but a few studies with large numbers of older individuals have found clear inverted U-shaped patterns in differential stability for all Big Five personality traits (Lucas & Donnellan, 2011; Specht, Egloff, & Schmukle, 2011; Wortman, Lucas, & Donnellan, 2012). From a developmental perspective, it seems reasonable to expect an inverted U-shaped pattern, because periods marked by significant biological, cognitive, or social changes—that is, young adulthood and old age—could lead to marked changes in phenotypes, including personality traits such as risk-taking propensity, and their adaptation to these changes at different phases of the life span.

Second, *mean-level stability* refers to consistency in the *average* level of traits over time, and thus reflects normative/general patterns that apply to large numbers of individuals. Importantly, personality traits with high differential (rank-order) stability show systematic mean-level changes across the life span. For example, a number of studies coincide in their finding that average levels of agreeableness and conscientiousness show increasing mean-level trends across the life span, whereas neuroticism and openness to experience, in contrast, show reliable mean-level decreases with age (Lucas & Donnellan, 2009, 2011; Roberts, Walton, & Viechtbauer, 2006; Specht et al., 2011). The mean-level developmental trends observed for personality traits are typically thought to be adaptive in the sense of improving individuals' capabilities to fulfill adult roles such as increased relationship stability and quality, or success at work, among others (i.e., the maturity principle of personality development; Caspi, Roberts, & Shiner, 2005). There is considerable debate, however, about the role of biological (Costa & McCrae, 2006) and social factors (Roberts, Wood, & Smith, 2005) in engendering mean-level personality change.

Third, *individual-level stability* refers to the consistency of a trait at the level of the individual person. One typical way of detecting this kind of stability is to test for individual differences in change in a growth-modeling context: Significant variance in slopes confirms the presence of exceptions to the normative (mean-level) trend for the sample. Note that, on the whole, a lack of mean-level change does not preclude individual-level variation or individual differences in change across time: A trait may increase across the life span in some individuals, but decrease in others, resulting in no overall mean-change at the group level despite significant individual-level changes (i.e., variance in slopes). One issue related to individual-level change is whether individual differences can be accounted for by other endogenous or exogenous variables, that is, specific predictors that may be associated with individual differences in change. For example, Chopik, Kim, and Smith (2015) show that within-person changes in optimism across the life span are systematically related to within-person changes in self-reported levels of health, consistent (albeit not conclusively) with the hypothesis that individual differences in the former are caused by the latter. The investigation of individual changes and their predictors (e.g., cognitive ability, health, life events) can thus be important for gaining greater insight into the individual dynamics of personality development across the life span.

The Concept of Risk-Taking Propensity and Potential Changes Across the Life Span

The literature offers various definitions of risk and risk taking (Aven, 2012; Schonberg et al., 2011). One characterization of risk-taking propensity is the tendency to engage in behavior that bears the chance of losses (e.g., financial losses, physical harm) as well as gains (e.g., financial gains, excitement). Disciplines such as economics and psychology have developed different measures of such tendencies (Appelt, Milch, Handgraaf, & Weber, 2011). In economics, for example, individual risk-taking propensity is often estimated from choices between monetary lotteries with varying probabilities of gains and/or losses (Holt & Laury, 2002; Markowitz, 1952). Other measures integrate the social context, with individual outcomes and their probabilities depending on another person (Ben-Ner & Halldorsson, 2010; Berg, Dickhaut, & McCabe, 1995; Fehr, Fischbacher, Schupp, Rosenbladt, & Wagner, 2002; Houser, Schunk, & Winter, 2010; Lönnqvist, Verkasalo, Walkowitz, & Wichardt, 2011; Nickel & Vaesen, 2012). In psychology, there have been two common approaches to measuring risk-taking propensity: The first employs behavioral measures of risk taking, including the monetary lotteries described above, but also tasks that try to capture learning and experience (e.g., Hertwig & Erev, 2009), such as *n*-armed bandit tasks (Bechara, Damasio, Damasio, & Anderson, 1994) or other sequential decision tasks (Lejuez et al., 2002). The second approach employs self-report measures to elicit individual risk preferences in hypothetical scenarios or real-world behavior (Nicholson, Soane, Fenton-O'Creevy, & Willman, 2005; Weber et al., 2002; Wortman et al., 2012).

There is ongoing debate about how these different behavioral and self-report measures relate to each other as well as to real-world behavior. Past work suggests that the behavioral and self-report measures are only weakly correlated, and that correlations to real-world behavior are, at best, small (Anderson & Mellor, 2009; Berg, Dickhaut, & McCabe, 2005; Dohmen et al., 2011; Friedman et al., 2014; Schoemaker, 1990). One potential contributor to the poor correlation between measures is the extent to which risk-taking propensity is specific to particular domains (Weber et al., 2002). Some empirical investigations of self-report measures suggest that it is possible to separate distinct factors of risk taking (i.e., social, financial, health) and that these factors can characterize risk-taking propensities of distinct groups of individuals (Hanoch & Gummerum, 2011). Hanoch, Johnson, and Wilke (2006), for example, demonstrated that targeted subgroups of individuals (e.g., investors or smokers) scored highest in risk-taking propensity in the respective risk domain (e.g., financial or health) relative to other life domains. Partly because of the lack of systematic quantitative reviews estimating the links between different risk measures and domains, it remains unclear whether domain specificity can fully account for the small correlations observed among risk-taking measures and real-world outcomes.

In this study, we examine whether life span changes unfold in similar ways across different domains and measures of risk taking, thus providing further insights into the anatomy of risk taking. In the following, we briefly review past research based on the three conceptualizations of change outlined above. We focus on research on adulthood and aging rather than early and adolescent development, which has received considerable attention elsewhere (Braams, van Duijvenvoorde, Peper, & Crone, 2015; Defoe, Dubas, Figner, & van Aken, 2015; Figner, Mackinlay, Wilkening, & Weber, 2009; Harden, Quinn, & Tucker-Drob, 2012; Shulman, Harden, Chein, & Steinberg, 2015; Steinberg, 2008).

Rank-Order Stability in Risk-Taking Propensity

As mentioned above, there is evidence for an inverted U-shaped link between age and rank-order stability in many personality traits. This pattern could represent the effects of biological, cognitive, or social changes that occur at both ends of the life span (Lucas & Donnellan, 2011; Specht et al., 2011). Does this pattern extend to risk-taking propensity? Does it generalize across domains? Findings of domain-specificity in rank-order stability functions could provide insights into different causes in the development of risk taking in different domains of life.

Data on the rank-order stability of risk taking propensity are scarce and little to nothing is known about changes across the life span. Only very few studies have examined behavioral measures of risk across longer time spans (see Chuang & Schechter, 2015, for an overview). Even at short time spans, however, the rank-order stability of behavioral measures seems to vary considerably across measures and studies. Some studies have found evidence for moderate rank-order stability of behavioral measures over short periods of time of days or weeks (Harrison, Johnson, McInnes, & Rutström, 2005; Lejuez et al., 2002), whereas other studies have reported poor rank-order stability across short delays and between different risk measures collected at the same measurement occasion (Anderson & Mellor, 2009; Berg et al., 2005; Dave, Eckel, Johnson, & Rojas, 2010; Friedman et al., 2014; Reynaud & Couture, 2012; Schoemaker, 1990; Szrek, Chao, Ramlagen, & Peltzer, 2012). The few published studies using longer delays suggest low to moderate rank-order stability (Anokhin, Golosheykin, Grant, & Heath, 2009; Chuang & Schechter, 2015; Lönnqvist et al., 2011).

More studies have used self-report data to assess risk taking or related constructs, such as sensation seeking and impulsivity that show moderate levels of stability over time (Collado, Felton, MacPherson, & Lejuez, 2014; Niv, Tuvblad, Raine, Wang, & Baker, 2012; Roth, Schumacher, & Brähler, 2005; Zuckerman & Kuhlman, 2000). For self-reported risk-taking propensity measures, studies suggest high rank-order stability across short intervals (Blais & Weber, 2006) and medium to high levels of rank-order stability across longer periods of years (Sahm, 2012). However, most studies have typically focused on adolescents (Niv et al., 2012), have not included large numbers of older adults, or failed to provide analyses of developmental issues (Benjamin et al., 2012; Chuang & Schechter, 2015; Jung & Treibich, 2014; Mandal & Roe, 2014). Consequently, little is known about patterns of rank-order stability in risk taking across the adult life span, and nothing about the domain-specificity of such patterns.

Mean-Level Differences in Risk-Taking Propensity

Biological theories view the propensity for risk taking as a behavioral strategy or functional adaptation to maximize reproductive success (Campbell, 1999; Mishra, 2014; Sih & Del Giudice, 2012). Risk taking thus serves an adaptive function that may vary across the life span. According to behavioral ecology, in young adulthood, risk behaviors may be instrumental in gaining access to potential mating partners via resource control and status. Consequently, risky and competitive behaviors can be expected to be more prevalent among young males than among females and older individuals (Daly & Wilson, 1997; Mishra, 2014). Later in the life cycle, individuals are expected to place higher value on objectives such as guarding their own lives because their offspring's survival depends on parental and, in particular, maternal care and defense (Campbell, 1999). Behavioral ecology would further predict that patterns of life span changes in risk taking vary as a function of domain to the extent that different domains are more or less instrumental to survival and reproductive success across adulthood. To our knowledge, however, there has been no explicit theorizing about domain-specific differences in the life span trajectory of risk taking.

The bulk of empirical research on risk taking across adulthood has investigated mean-level changes. Findings based on behavioral measures of risk taking have been mixed, with some measures indicating a reduction in risk taking with age and others showing no differences or even increases. Most notably, recent meta-analyses report more pronounced age differences in behavioral risk tasks that require learning of the relationship between outcomes and probabilities such as in the Iowa Gambling Task (IGT) or the Balloon Analogue Risk Task (BART) relative to standard gamble paradigms (Best & Charness, 2015; Mata et al., 2011). This heterogeneity as a function of measures also mirrors results from research summarized in a meta-analysis on adolescent risk taking (Defoe et al., 2015). Against this background, there is considerable interest in task characteristics (e.g., memory and learning demands) that may engender specific patterns of age differences in behavioral measures of risk taking (Frey, Mata, & Hertwig, 2015). Another avenue has been to investigate self-reported risk taking, for which results seem more consistent, showing a decrease in risk-taking propensity across adulthood (Bonem, Ellsworth, & Gonzalez, 2015; Mata, Josef, & Hertwig, in press; Roalf, Mitchell, Harbaugh, & Janowsky, 2012; Rolison, Hanoch, Wood, & Liu, 2014; Rosman, Garcia, Lee, Butler, & Schwartz, 2013; Schwartz et al., 2013). Importantly, investigations of age differences in self-reported risk-taking propensity in different domains suggest that the overall reduction in risk-taking propensity plays out somewhat differently as a function of domain (e.g., financial, health, social). That is, financial and recreational risk-taking propensity showed steeper declines relative to risk-taking propensity in the social, ethical and health domains (Rolison et al., 2014).

It is important to note that this work on mean-level changes in risk taking has been conducted using cross-sectional designs. To our knowledge, there has been no assessment of longitudinal change in self-reported risk-taking propensity as a function of domain. Consequently, it remains unclear whether the cross-sectional findings generalize to longitudinal change in risk-taking propensity. Finally, the link between self-report and behavioral patterns of risk taking across adulthood remains to be studied. Some studies have investigated this link in young populations and provide evidence for only small correlations between the two types of risk measures (Mishra, Lalumière, & Williams, 2010; Szrek et al., 2012). It remains unclear whether self-report and behavioral measures capture similar mean-level changes in risk taking across the life span, and do so similarly across domains.

Individual-Level Differences in Risk-Taking Propensity

A number of hypotheses have been formulated on the link between individual differences in risk taking and other individual characteristics. Classic economic theories suggest that situational characteristics, such as fluctuations in individual's wealth (Bernoulli, 1954; Brunnermeier & Nagel, 2008; Chiappori & Paiella, 2011), play an important role in individual differences on risk taking. More recently, there has been an attempt to ground theories of individual differences in economic behavior in personality theory (Borghans, Duckworth, Heckman, & Weel, 2008). In line with these efforts, various studies have investigated the relation between risk taking and the Big Five personality factors. Although the results are mixed, there is some evidence that individual differences in personality may be related to risk-taking behavior: Risk taking has been found to be positively associated with Openness to Experience, Extraversion, and Sensation Seeking; and negatively associated with Agreeableness and Neuroticism (Becker, Deckers, Dohmen, Falk, & Kosse, 2012; Deck, Lee, Reyes, & Rosen, 2012; Mishra & Lalumière, 2011; Nicholson et al., 2005; Prinz, Gründer, Hilgers, Holtemöller, & Vernaleken, 2014). There are also some findings linking personality variables to performance on behavioral measures of risk taking, such as the Iowa Gambling or the Balloon Analogue Risk Task. Yet, the pattern of results is also mixed, partly due to the use of different personality and temperament measures as well as behavioral tasks (Hooper, Luciana, Wahlstrom, Conklin, & Yarger, 2008; Lauriola, Panno, Levin, & Lejuez, 2014; Suhr & Tsanadis, 2007). To our knowledge, however, there have been no attempts to directly link *change* in situational and personality variables to individual-level *change* in risk-taking propensity or to examine whether such effects vary across domains. Identifying parallels between the development of major personality traits and risk-taking propensity is an important step in relating these constructs.

The Present Study

Using an extensive longitudinal data set representative of the population living in Germany, we aim to assess stability in risk-taking propensity across adulthood, and the domain-generality (or specificity) thereof. To this end, we examine the following research questions: Are there systematic life span differences in (a) differential and (b) mean-level stability of both general and domain-specific self-report measures of risk-taking propensity? Are there (c) intraindividual differences in change in risk-taking propensity and what are their predictors? Also, (d) do any mean-level changes in self-reported risk-taking propensity correspond to those observed in behavioral measures of social and nonsocial risk taking? We thus examine the nature of risk taking by evaluating the role of both domain (e.g., financial, social) and measure (self-report vs. behavior) on stability of risk-taking propensity across adulthood.

We used longitudinal data from the German Socio-Economic Panel Study (SOEP; Wagner et al., 2007) to examine life span trajectories in self-reported domain-general and domain-specific risk-taking propensity. To our knowledge, this is the longest-term and most complete multicohort dataset available to model risk-taking trajectories across the life span using within-person data. First, from 2004 on, and for up to nine years, more than 44,000 SOEP respondents answered a question on their domain-general risk-taking propensity (Dohmen et al., 2011). Second, a subsample of more than 11,000 respondents answered six additional questions concerning their propensity to take risks in the driving, financial, recreational, occupational, health, and social domain in up to three waves at 5-year intervals (specifically, in 2004, 2009, and 2014). These data from a large number of individuals of different ages, followed up over time, allow us to discern between mean-level population trends, as investigated in cross-sectional studies, and individual differences in change in risk-taking propensity over time. Third, we were able to connect these rich data on risk-taking to individual personality measurements (i.e., the Big Five; Openness to Experience, Conscientiousness, Extraversion, Agreeableness, and Neuroticism) assessed in 2005, 2009, and 2013 (Lang, John, Lüdtke, Schupp, & Wagner, 2011) and other potentially relevant variables (e.g., current income) to investigate sources of individual differences in change in risk-taking in different domains across adulthood. Fourth, and finally, we compared results based on self-report measures with results from behavioral experiments, using data from two subsamples of SOEP respondents who participated in two behavioral tests thought to measure social and nonsocial forms of risk-taking behavior, respectively: a trust game assessed in 2004 ($N = 646$) and a monetary lottery assessed in 2005 ($N = 433$; Fehr et al., 2002; Holt & Laury, 2002; see Method for details).

Method

German Socio-Economic Panel (SOEP), 1984–2014

The German Socio-Economic Panel (SOEP, www.leibniz-soep.de) is a large longitudinal multicohort survey collected in households in Germany that has compiled data by means of face-to-face and computer-assisted personalized interviews (CAPI) since 1984 (Wagner et al., 2007). Private households are sampled to be representative of the population living in Germany in terms of several demographic and occupational characteristics and geographical region. Moreover, active efforts are made to maintain the representativeness of the sample by interviewing split-offs from the original households. For example, when a young person leaves the parental household, his or her new household becomes part of the study. The SOEP thus provides information about a large number of individuals over several time points and can be used to investigate the dynamics of important economic, social, and psychological variables across the life span. Approximately 20,000 individuals (11,000 households) were interviewed in each wave between 2004 and 2014. This includes both attrition and the inclusion of new respondents from refresher samples, which have been added to the original sample in each wave since 1984. Informed consent was obtained from all respondents before data collection in all waves. Because the SOEP assesses data from individuals in the same household, it is likely that data are more similar within households. We control for this nonindependence by clustering the survey data on the household level in our analyses.

Measures

Self-reported risk-taking propensity. A question on general risk-taking propensity was included in nine waves of the survey spanning 10 years (2004, 2006, 2008, 2009, 2010, 2011, 2012, 2013, and 2014). It was worded as follows: “Are you generally a person who is willing to take risks or do you try to avoid taking risks? Please tick a box on the scale, where the value *0* means *not at all willing to take risks* and the value *10* means *very willing to take risks*.” Six questions on risk-taking propensity in specific domains (driving, financial, recreational, occupational, health, and social) were included in three waves (2004, 2009, and 2014). The wording was as follows: “People can behave differently in different situations. How would you rate your willingness to take risks in the following areas? Please tick a box in each line of the scale!”

All seven items were rated on a 0–10 Likert-type scale from *not at all willing to take risks* to *very willing to take risks* (see Supplemental Materials for original items used). The items are part of the risk aversion scale that was first piloted in a pretest within a subset of the SOEP population in 2003 (Dohmen et al., 2011). Since their first administration in the main questionnaire in 2004, the items—particularly the general risk-taking propensity item—have been used in other scientific analyses on risk taking (e.g., Benjamin et al., 2012; Bonin, Dohmen, Falk, Huffman, & Sunde, 2007; Dohmen, Falk, Huffman, & Sunde, 2010; Lönnqvist et al., 2011; Szrek et al., 2012), where they have shown good internal consistency ($\alpha = .85$) and, to some extent, correlations with self-reported real-world risk behavior (Dohmen et al., 2011). Analyses on the dimensionality of risk-taking propensity suggest that a single-factor model captures the ratings reasonably well (see Supplemental Materials). Nevertheless, in our analyses, we opted to analyze each item separately to delineate domain-specific patterns of change and stability across adulthood.

For general risk-taking propensity, the longitudinal sample analyzed here consists of 44,076 individuals between 18 and 85 years of age ($M = 44.1$, $SD = 14.0$; 52% female), who were interviewed on their self-reported general risk propensity in up to nine waves of assessment between 2004 and 2014. For the six domain-specific risk propensity items, the longitudinal sample consists of $N =$ 11,903 individuals with the same age range ($M = 44.1$, $SD = 14.0$; 51% female) who answered domain-specific items in at least two of the three waves of assessment (domain-specific risk-taking propensity was assessed in 2004, 2009, and 2014).

Behavioral measures: Social and nonsocial risk taking. In addition, we analyzed behavioral data from subsamples of SOEP respondents between 18 and 85 years of age who participated in experiments assessing social (646 individuals, $M = 50.0$, $SD =$ 16.8; 51% female) and nonsocial behavioral measures of risk taking (433 individuals, $M = 48.8$, $SD = 17.5$; 52% female).

Nonsocial risk taking. In 2005, a subset of randomly selected (random route sampling method) respondents from the SOEP population played a lottery game presented in their homes on a survey computer as part of a pretest for the SOEP interview. Respondents were asked to make up to 20 choices between a risky lottery (win €300 or €0 with 50% probability, expected value €150) and a safe amount of money (Holt & Laury, 2002). The lottery stayed constant in all trials and the safe amount offered increased after each trial in which the lottery was chosen (€0–€190 in €10 increments). Individual risk preferences can thus be determined by identifying the trial in which a respondent switches from preferring the lottery to the safe amount (thus narrowing down the person’s certainty equivalent). Respondents who prefer a safe amount of money that is smaller than the expected value of the lottery is typically considered to be risk averse; respondents who choose the lottery even when the safety equivalent exceeds the expected value of the risk option (€150) are considered to be risk seeking.

Respondents’ choices were incentivized. Specifically, they were instructed that one in every seven participants would be randomly picked and win a monetary payment. The computer determined the value of the payment (which varied between €0 and €300) by randomly choosing one of the outcomes of the participant’s 20 decisions. All winners were paid by check after the experiment was completed.

Social risk taking. In 2004, a subset of respondents selected randomly from the SOEP population (sample F) participated in a trust game as part of the annual SOEP interview. Each respondent was assigned to one of two groups (Group 1 = Player 1; Group 2 = Player 2), endowed with 10 points, and instructed that he or she would participate in a "give and take" game that he or she would play with another anonymous respondent from the SOEP population. In total, $N = 1{,}295$ respondents participated in this experiment. $N = 646$ respondents were randomly assigned to Group 1, and $n = 649$ individuals to Group 2.

To play the game, both players decided how much of their endowment to transfer to their opponent (0–10 points). First, Player 1 decided how many points to transfer to Player 2 (measure of trust) and wrote a number between 0 and 10 on a sheet of paper. Each point transferred was then doubled as an income for Player 2. In response to this received income, Player 2 decided how many points of his or her endowment to back-transfer (measure of fairness) and wrote a number between 0 and 10 on a sheet of paper. This amount was then doubled as an income for Player 1. Both players received instructions about the incentive structure of the game before making their transactions: Each point they kept increased their own income by €1; each point they transferred increased the other's income by €2. Because the game was conducted as part of the SOEP interview at respondents' homes, no real-time interaction was possible. Endowments that Player 2 received from Player 1 were therefore automatically sampled from a simulation of Players in a pretest. All respondents were paid by check after the experiment. We used the number of points transferred by Player 1 (Group 1, $n = 646$) as a measure of trust and social risk taking (Fehr et al., 2002; Lönnqvist et al., 2011).

The Big Five. In 2005, 2009, and 2013 the SOEP used a short version of the Big Five personality inventory (BFI-S) to measure Openness to Experience, Conscientiousness, Extraversion, Agreeableness, and Neuroticism (Gerlitz & Schupp, 2005; John, Donahue, & Kentle, 1991; Lang et al., 2011). The BFI is a 15-item self-report questionnaire (three items per dimension) requiring a 1 (*does not apply at all*) to 7 (*applies perfectly*) rating. The shortened version of the BFI (used due to time limitations) has shown reasonably high correlations with the original version of the questionnaire (Donnellan & Lucas, 2008). It has also been used in scientific work on the life span development of personality traits (Donnellan & Lucas, 2008; Lucas & Donnellan, 2011; Specht et al., 2011). The scale was developed and validated within a pretest-sample of the SOEP population (see Lang et al., 2011, for information on internal consistency and test–retest reliability). To investigate correlated change between the Big Five personality traits and risk-taking propensity, we analyzed data from $N = 11{,}903$ respondents who answered both items on risk-taking propensity and completed the personality inventory.

Ethics Statement

The German Institute for Economic Research (DIW), Berlin, contracted TNS Infratest Sozialforschung GmbH and TNS Infratest GmbH & Cp. KG in Munich to carry out the SOEP survey "Leben in Deutschland (Living in Germany)." Data collection, processing, and storage were in full accordance with German data protection regulations. Research was overseen by the DIW scientific advisory board. The ethics committee of the Max Planck Institute for Human Development additionally approved the authors' use of the data for research purposes in accordance with German data protection regulations. German data privacy laws necessitate that all users sign a data user contract with the DIW Berlin. The survey data files are provided in anonymous form only. The institutes listed above do not provide third parties with any data that would permit individuals to be identified. The same applies to the follow-up surveys. Individual data from separate interviews are linked by a code number.

Analytic Approach

As outlined before, our analyses addressed the following research questions: Are there systematic life span differences in (a) differential and (b) mean-level stability of both general and domain-specific risk-taking propensity? Are there (c) intraindividual differences in changes and what are their predictors? Also, (d) do any mean-level changes in self-reported risk-taking propensity correspond to those observed in behavioral measures of social and nonsocial risk taking?

Differential stability of risk-taking propensity. To address question (a), we first calculated rank-order stability coefficients between each of the waves in which domain-general and domain-specific risk propensity was assessed. Specifically, we calculated test–retest correlations (r) across three waves (2004, 2009, and 2014) of assessment. These correlations reflect the degree to which the relative ordering of individuals within the sample was maintained over time.

Second, to investigate the effect of age on rank-order stability, we divided the domain-specific sample into 10 five-year age cohorts and calculated rank-order stability in these cohorts for the two 5-year periods (2004–2009; 2009–2014) and the 10-year period (2004–2014). Because the number of old individuals in the sample was limited, the oldest age group comprised individuals aged from 73 to 85 years. To quantify the effect of age, we fitted a locally smoothed regression line as well as a regression line fitted to all test–retest correlations from the different cohorts by predicting differential stability from age and age squared across the 10 cohorts. To control for the fact that the test–retest correlations stem from different time intervals, we included a cluster variable within a mixed-effects regression model framework.

Mean-level changes in risk-taking propensity. To answer question (b), we used latent growth curve models (McArdle & Nesselroade, 2003) to estimate change in domain-general and domain-specific risk-taking propensity across the life span. Specifically, we employed a separate latent growth curve model for each domain. Each domain was measured by one item at each measurement point. Each model included a latent intercept factor (i) and a latent slope factor (s). The latent intercept factor was fixed to 1 at each measurement point and reflected individual differences at the first point of measurement (2004). The latent slope factor (s) was fixed to 0 for the first measurement point and reflected the amount of mean-level linear change per time unit increase. Weights for the other measurement points were selected such that they reflected the estimated mean difference between two neighboring measurement points. Means and variances were estimated for both the slope and the intercept. Mean values of (i) represent the average risk-taking propensity at the population level. The variance in (i) shows whether individuals already differed at the first wave of assessment. Mean values of (s) represent the average rate of change. The variance in (s) shows whether individuals differed in their rates of change (see Figure 1A and 1B for a model representation of domain-general and domain-specific risk propensity).

We were particularly interested in estimating the effects of age. In addition, because theoretical predictions (Mishra, 2014) and empirical results (Byrnes, Miller, & Schafer, 1999) suggest sex differences in risk taking, we also estimated the effects of sex. To this end, we included sex (female = 1, male = 0) and age, age^2, age^3, as covariates and estimated linear, quadratic, and cubic effects of age on intercept and slope parameters. To test effects of age, sex, and their interactions on mean risk-taking propensity (i) and change thereof (s), we adopted a stepwise approach: Higher order terms of age and interactions of age and sex were included only if they were significant at $p < .05$ and increased model fit. We applied this method to intercept and slope separately. Age was mean-centered before higher order terms were calculated. Age and sex were included as linear predictors if their effect on intercept or slope was not significant in order to nevertheless show and discuss their effect for these particular risk domains. Model fit evaluation was based on full information maximum-likelihood estimates that allow for missing data across measurement points (Schafer & Graham, 2002). Because traditional chi-square model test statistics are influenced by sample size, we relied on additional measures of fit, such as comparative fit index (Bentler, 1990), root-mean-square error of approximation (Steiger, 1990), and standardized root-mean-square residual (Bentler, 1990) with cut-off values of CFI > .95, RMSEA < .06, and SRMR < .08 for reasonable model fit (Hu & Bentler, 1999).

Individual-level changes in risk-taking propensity. To answer question (c), we tested whether the latent growth curve models showed significant variation in levels of change on the individual level (significant estimates of slope variances). In addition, we investigated whether within-person changes in risk-taking propensity were associated with within-person changes in the variables of interest (i.e., the Big Five personality traits and income). Specifically, we estimated bivariate latent growth curve models in which a latent growth curve of each personality trait (Openness to Experience, Conscientiousness, Extraversion, Agreeableness, and Neuroticism) was linked to a latent growth curve of risk-taking propensity (general, driving, financial, recreational, occupational, health, and social) by correlating the respective intercepts and slopes (see Figure 2 for model representation). Correlations between intercept estimates can be interpreted in the same way as correlations from cross-sectional data, whereas correlations among slopes represent how two variables change together over development. The key parameter of interest in this parallel process model was thus the correlation between the slope factors of risk taking and personality/income. For example, positive correlated change would indicate that those respondents who show changes in risk-taking propensity show concordant changes in the respective personality trait. Because the rate of change is often correlated with initial status, we also included correlations between intercepts. To control for cross-sectional age differences, age (centered) was included as a covariate. We estimated models for each domain of risk taking with each personality trait separately. A similar model was used to investigate correlated changes with income. In these models, change in income at each measurement point was correlated with within-person change in risk-taking propensity.

Mean-level trajectory of behavioral measures of risk taking. To answer question (d), we used regression models of the cross-sectional data from the experiments conducted in 2004 and 2005 to estimate age-related mean-level change in social and nonsocial risk taking. Age was centered to the sample means. Again, higher order terms of age were included only if they were significant at $p < .05$, and linear effects of age were reported if the effect of the higher order terms was not significant. We computed Pearson product–moment correlations between behavioral and self-report measures of risk taking to assess the link between the two types of measures.

All analyses were run in R (R Core Team, 2015), and latent growth curve modeling was performed using the lavaan package (Rosseel, 2012).

Results

Differential Stability of Risk-Taking Propensity

Table 1 shows the test–retest correlations for domain-general and domain-specific risk propensity (from 2004–2009, 2009–2014, and 2004–2014) in the whole sample. For domain-general risk propensity, rank-order stability ranged between r = .45 and .53. For domain-specific risk-taking propensity, rank-order stability was likewise moderate to high, with rs ranging from .42 to .53 between 2004 and 2009, from .45 to .58 between 2009 and 2014, and from .38 to .50 between 2004 and 2014. These results show that individuals who reported high (or low) levels in risk-taking propensity remained relatively high (or low) in risk-taking propensity levels compared with others over time. To put these numbers in perspective, many personality variables have shown stabilities of more than .70 over periods of 1 to 5 years in adult samples (Briley & Tucker-Drob, 2014; Costa & McCrae, 1994). Mean stability in risk propensity was thus slightly lower than has been found for standard personality variables.

Figure 3 shows the effect of age on rank-order stability for different age cohorts, as measured by the test–retest correlations across the three waves of assessment (see also Table 2). Although there is some heterogeneity across domains, the typical pattern is lower test–retest correlations in young adulthood (18–30 years of age, r = .30–.40), rising to a plateau in middle adulthood (r = .40–.60), and decreasing again in older age (70–85 years of age, r = .25–30). Quadratic models of age best described the patterns obtained from the test–retest correlations, and locally smoothed lines deviated little from the quadratic model. The quadratic pattern matches results of studies on the stability of personality traits, with peak stability between the ages of 50 and 60 (Briley & Tucker-Drob, 2014; Specht et al., 2011). The inverted U-shaped pattern is typically attributed to social and biological changes that generally occur at both ends of the life span, leading to increased variation in phenotype in these phases. Findings in Figure 3 suggest that this pattern extends to risk-taking behavior and similarly across domains.

Mean-Level Changes in Risk-Taking Propensity

We used latent growth curve models with up to nine (domain-general) or three (domain-specific) measurement points to delin-

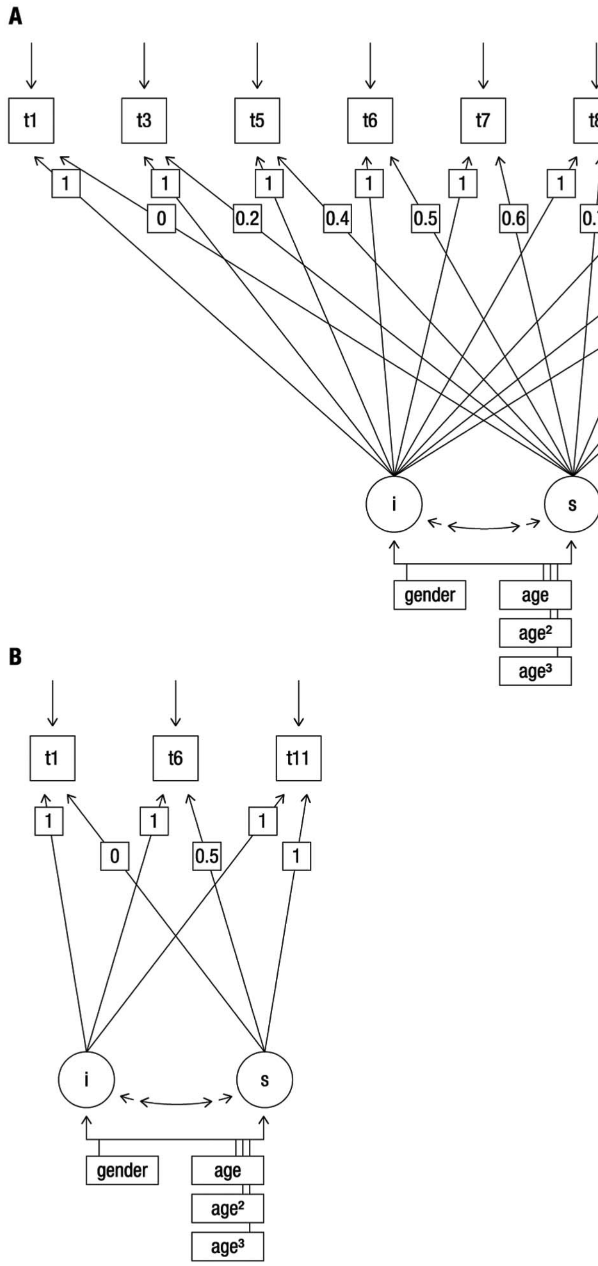

Figure 1. Model representation of the latent growth curve model used to analyze effects of age and sex on the mean level (intercept) and mean-level change (slope) of self-reported domain-general (A) and domain-specific (B) risk propensity (2004–2014). (A) At each measurement point (t1 to t11) one item was assessed. The latent intercept (*i*) is fixed to 1 on t1, t3, t5, t6, t7, t8, t9, t10, and t11 and refers to the estimated mean frequency of risk-taking propensity at t1. The latent slope (*s*) is fixed to 0.00 on t1, to 0.20 on t3, to 0.40 on t5, to 0.50 on t6, to 0.60 on t7, to 0.70 on t8, 0.80 on t9, to 0.90 on t10, and to 1 on t11 and refers to the estimated mean difference between two neighboring measurement points. Two-headed arrows represent correlations; single-headed arrows, regression coefficients. Gender, age, age^2, and age^3 were included as predictors of (*i*) and (*s*). (B) At each measurement point (t1, t6, t11) one item was assessed. The latent intercept (*i*) is fixed to 1 on t1, t6, and t11 and refers to the estimated mean frequency of risk-taking propensity at t1. The latent slope (*s*) is fixed to 0.00 on t1, to 0.50 on t6, to 1 on t11 and refers to the estimated mean difference between two neighboring measurement points. Two-headed arrows represent correlations; single-headed arrows, regression coefficients. Gender, age, age^2, and age^3 were included as predictors of (*i*) and (*s*).

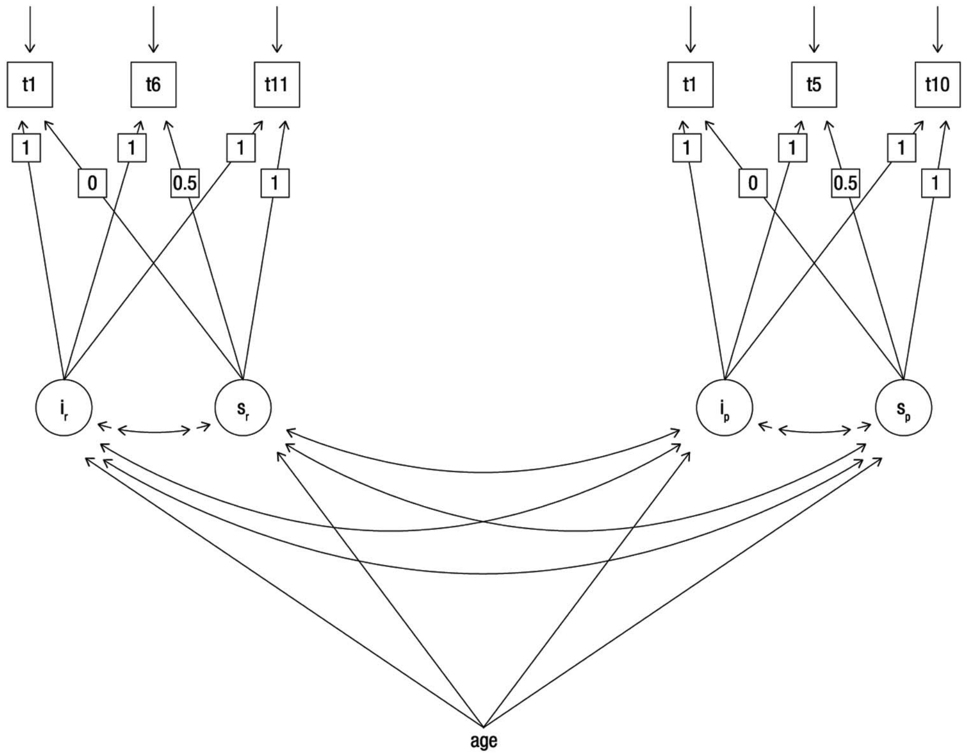

Figure 2. Bivariate latent growth curve model of risk-taking propensity and the Big Five personality traits. The observed variables t1, t6, and t11 (and t1, t5, and t10) represent the repeated measurements of risk-taking propensity (left) and the Big Five personality traits (right). Whereas risk-taking propensity was measured by one item, three items for each trait measured the Big Five. Therefore, for personality, the measurements at t1, t5, and t10 were again latent factors composed of these three items. Two-headed arrows represent correlations, single-headed arrows regression coefficients. The latent intercept (*i*) is fixed to 1 on t1, t5/t6, t10/t11 and refers to the estimated mean frequency of risk-taking propensity at t1. The latent slope (*s*) is fixed to 0.00 on t1, to 0.50 on t5/t6, and to 1 on t10/t11 and refers to the estimated mean difference between two neighboring measurement points. Age was included as predictors of - (*i*) and (*s*).

eate the effect of age and sex on mean level as well as mean-level change in domain-general (N = 44,076) and domain-specific risk-taking propensity (N = 11,903). Table 3 shows the parameter estimates. All parameters were standardized to the first measurement. Age was centered to the sample mean of 44.1 years of age. Parameter estimates are given in 10-year units. All models took nesting of individual data within households into account to correct for underestimation of standard errors due to clustered sampling. Column one of Figure 4 (intercept) depicts the life span trajectory of mean-level risk taking on a smoothed color density representation of a scatterplot of age and risk-taking propensity, obtained through a kernel density estimate (kernel width used for density estimation = 75). The second column (slope) of Figure 4 illustrates the effects of age and sex on slope estimates. The arrows in the third column (intercept + slope) represent a combined display of cross-sectional and longitudinal changes for separate 5-year cohorts.

Table 1
Differential Stability (r) of Risk-Taking Propensity

	(*r*)		
	04–09	09–14	04–14
General	.45	.53	.47
Driving	.53	.58	.50
Financial	.47	.50	.42
Recreational	.52	.56	.50
Occupational	.46	.49	.42
Health	.42	.45	.38
Social	.42	.46	.43

Note. All correlations were significant at $p < .001$.

Domain-General Risk-Taking Propensity

Cross-sectional effects. Overall, the results suggest that both age and sex affect mean-level domain-general risk-taking propensity (see Table 3, Figure 4a). Regarding age, the trajectory shows a decline in risk taking across adulthood, with an average decrease in risk-taking propensity of −0.17 points across 10 years. Females consistently reported lower levels of risk taking across the life span than males (−0.81 at the sample mean of 42.1 years of age). The steepest declines were evident between 20 and 30 years of age (−0.23 points decrease on the 11-point Likert scale).

Longitudinal effects. Age and sex also had a significant effect on mean-level change in risk-taking propensity over time (see

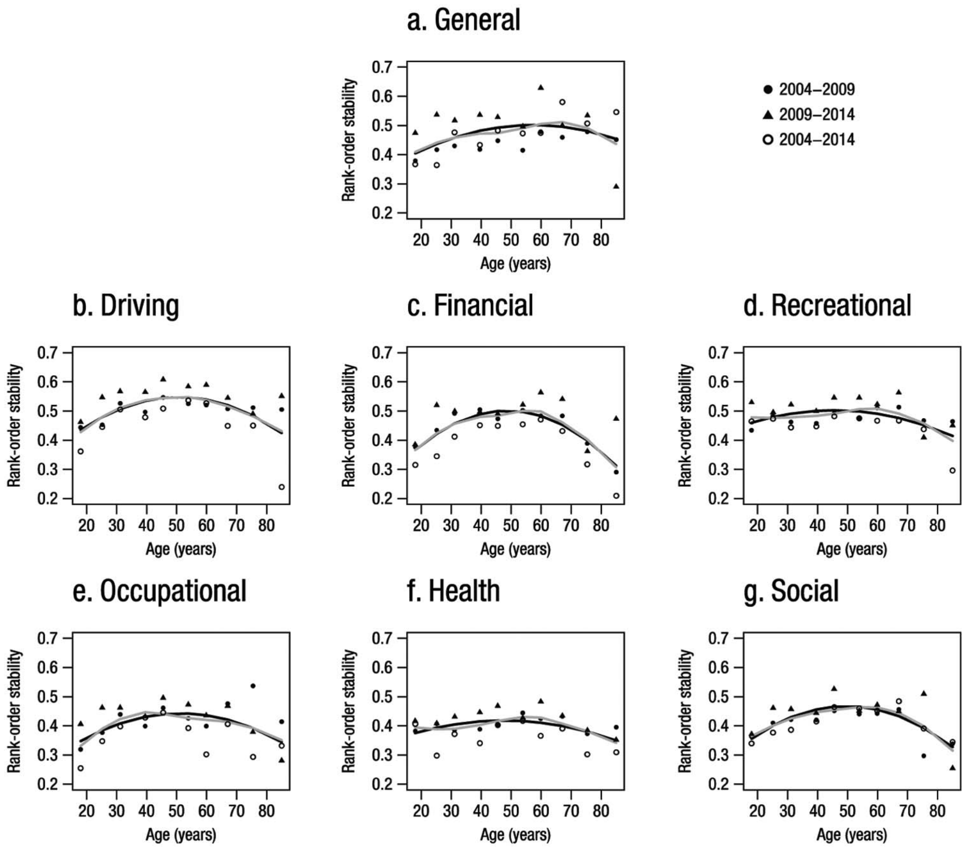

Figure 3. The effect of age on rank-order stability of risk-taking propensity.

Figure 4b, slope). Specifically, age had a quadratic effect on change in risk-taking propensity, with an overall decline across the life span: Decline in risk-taking propensity was shown to diminish until the age of about 60, after which change in risk-taking propensity showed larger decreases again. As Figure 4c (intercept + slope) shows, the cross-sectional results largely coincided with the longitudinal analysis, in that change in slope across the life span substantially corresponded with the cross-sectional pattern of mean-level change. Toward the end of the life span, however, slight deviations emerged between the longitudinal and cross-sectional results, with considerable stability in risk propensity for individuals older than 60 years but differences between cohorts (i.e., consecutive arrows for each 5-year cohort do not exactly match-up). One interpretation of this mismatch is that these findings represent "survivor" effects—that is, a type of cohort or attrition effect, whereby the least risk-taking respondents survive and continue to participate in the panel.

Domain-Specific Risk-Taking Propensity

Cross-sectional effects. Overall, the results show strong effects of age and sex on mean-level risk-taking propensity (see Table 3; Figure 4 column 1, intercept). Regarding age, the results show that mean risk-taking levels decreased across the life span in all domains. However, age-related changes followed different mean trends depending on the domain. In the social domain, risk-taking propensity followed a linear trend across the life span, decreasing −0.16 points on the Likert scale over 10 years (Figure 4s). In the driving domain, it showed a quadratic pattern of decline, with the highest risk-taking levels between 20 and 30 years of age and steady, but accelerating, decreases over the following decades. In the financial, recreational, occupational, and health domains, risk-taking propensity followed a cubic pattern across the life span (Figure 4g, 4j, 4m, and 4p): Financial and health risk-taking propensity showed only slight mean-level decreases until age 55 years but a steeper decrease in the following decades. Recreational risk-taking propensity showed continuous declines across the life span, but the steepest decline was evident until about 40 years of age. Occupational risk taking also showed a continuously declining pattern until the age of 65 years. Interestingly, the smallest mean-level decreases in risk-taking propensity emerged in the social domain (linear decrease of −0.16 points on the 11-point Likert scale per decade). Regarding sex, women consistently reported lower average levels of risk-taking propensity than men across all domains: −1.21 points lower in driving, −0.97 in financial, −1.02 in recreational, −0.83 in occupational, −0.85 in health, and −0.26 in social risk-taking propensity at age 42.1 (see Table 3).

Longitudinal effects. Figure 4 (column 2, slope) illustrates the effects of age and sex on mean-level change in domain-specific risk-taking propensity. The effects of age on change in risk-taking

Table 2
Regression Models Predicting Differential Stability of Risk-Taking Propensity From Age Across 10 Cohorts

Model	General		Driving		Financial		Recreational		Occupational		Health		Social	
R^2	.194		.358		.534		.287		.269		.225		.566	
	b	*p*	*b*	*p*	*b*	*p*	*b*	*p*	*b*	*p*	*b*	*p*	*b*	*p*
Intercept	.232 [.096]	.024	.180 [.089]	.055	.035 [.087]	.689	.339 [.065]	<.001	.139 [.090]	.135	.265 [.061]	<.001	.092 [.063]	.157
Age	.009 [.004]	.027	.015 [.004]	<.001	.020 [.004]	<.001	.007 [.003]	.017	.012 [.004]	.004	.007 [.003]	.021	.016 [.003]	<.001
Age^2	−.0001 [.00004]	.043	−.0002 [.00004]	<.001	−.0002 [.00004]	<.001	−.0001 [.00003]	.008	−.0001 [.00004]	.004	−.0001 [.0003]	.014	−.0002 [.00003]	<.001
Age^3														

Note. Models contain age^2 only if their effects on intercepts and slopes were significant at $p < .05$. Values in brackets indicate standard errors. The total *n* for this analysis is 30, which is the number of cohorts by the number of test–retest correlations. Effects of the interval (2004–2009, 2009–2014, 2004–2014) on mean-level trends were controlled for a by a cluster variable within a mixed-effects framework.

propensity in the occupational and recreational domain were best described by a cubic pattern. Change in occupational risk taking has its point of largest decrease at about 50 years of age. Change in recreational risk taking decreased across the life span but the smallest decreases were at about 40 years of age. For both domains, the longitudinal findings are largely consistent with the cross-sectional results: Changes in slope mapped onto the pattern of mean-level change (see Figure 4l/4o). For recreational risk-taking propensity, however, slight discrepancies emerged between cross-sectional and longitudinal change, possibly attributable to dropout of older adults or to older adults ceasing to engage in risky recreational activities. Importantly, age was not a significant predictor of changes in financial, health, and social risk-taking propensity, with individuals of all ages showing only very small but constant change in risk-taking propensity over time (change of −0.049 in financial, −0.006 in health, and + 0.009 in social risk taking over 10 years). For health risk-taking propensity, slight discrepancies between longitudinal and cross-sectional results emerged toward the end of the life span (Figure 4r; starting ~60 years of age). These results may again point to a survivor effect, with respondents who took fewest risks in these domains also living longer. In the domain of driving, change in risk-taking propensity was linear and generally increased over time at all ages but less so in older ages. One possible interpretation of this increase is that it reflects an effect of increased perceived competence in driving on risk taking: Over time, individuals may change their perceptions of risk or their individual level of perceived control over their driving skills and thus report riskier behavior; this tendency, however, diminishes in old age. Future work is necessary that replicates and tests this admittedly speculative interpretation.

Individual-Level Changes in Risk-Taking Propensity

Analysis of the latent growth curve models above suggested that there were considerable individual differences in change in risk-taking propensity (significant variance of slope estimates). We now examine to what extent individual differences in variation in change were associated with changes in personality and situational (i.e., income) variables. The rationale for these analyses is that understanding the covariates of change may help to understand the mechanisms underlying life span changes in risk-taking propensity.

We used bivariate latent growth curve models to estimate correlated change between domain-specific risk-taking propensity and variables of interest (i.e., the Big Five, income). Standardized estimates of covariance between slopes are shown in Table 4. The results show that within-person change in risk-taking propensity was positively associated with within-person change in Extraversion and Openness to Experience and negatively correlated with change in Conscientiousness, Neuroticism, and Agreeableness. These associations showed variation across domains, with no strong patterns of association between specific risk-taking domains and personality factors. For example, change in Openness to Experience was positively correlated with change in recreational (r = .28), occupational (r = .21), and social domains (r = .21) and

Table 3

Latent Growth Curve Models Describing the Effect of Chronological Age and Sex on Mean Level (Intercept) and Mean-Level Change (Slope) of Self-Reported Domain-Specific Risk Propensity

Model	General (N = 44,076)		Driving (N = 11,903)		Financial (N = 11,903)		Recreational (N = 11,903)		Occupational (N = 11,903)		Health (N = 11,903)		Social (N = 11,903)	
$\chi^2(df)$	2788.447 (69)		69.627 (5)		326.315 (7)		254.309 (5)		212.224 (5)		119.591 (7)		133.733 (3)	
CFI	.922		.990		.918		.958		.954		.968		.969	
RMSEA	.070		.045		.091		.089		.081		.050		.076	
SRMR	.048		.013		.029		.023		.022		.018		.022	
	b	*p*	*b*	*p*	*b*	*p*	*b*	*p*	*b*	*p*	*b*	*p*	*b*	*p*
Intercept														
Mean	4.943 [.035]	<.001	3.902 [.046]	<.001	3.047 [.039]	<.001	4.131 [.046]	<.001	4.345 [.049]	<.001	3.492 [.044]	<.001	3.503 [.039]	<.001
Variance	2.057 [.057]	<.001	2.948 [.132]	<.001	2.047 [.114]	<.001	2.514 [.135]	<.001	2.759 [.158]	<.001	2.205 [.163]	<.001	2.686 [.146]	<.001
Age	−.129 [.027]	<.001	−.412 [.024]	<.001	−.068 [.040]	.092	−.358 [.024]	<.001	−.338 [.053]	<.001	−.191 [.043]	<.001	−.161 [.024]	<.001
Age^2	.015 [.009]	.135	−.089 [.012]	<.001	−.045 [.011]	<.001	.015 [.015]	.319	−.095 [.017]	<.001	−.031 [.012]	.013		
Age^3	−.023 [.006]	<.001			−.017 [.007]	.002	−.047 [.011]	<.001	−.032 [.011]	.005	−.018 [.009]	.039		
Sex	−.806 [.037]	<.001	−1.206 [.054]	<.001	−.973 [.049]	<.001	−1.019 [.052]	<.001	−.834 [.056]	<.001	−.853 [.053]	<.001	−.257 [.053]	.732
Slope														
Mean	−.018 [.035]	.637	.205[.045]	.533	−.279 [.042]	<.001	−.158 [.051]	.002	−.475 [.058]	<.001	−.096 [.047]	.041	.028 [.045]	.533
Variance	1.234 [.085]	.085	1.545 [.251]	<.001	.781 [.224]	<.001	.861 [.259]	<.001	1.380 [.304]	<.001	.745 [.273]	.007	.659 [.278]	<.001
Age	.089 [.017]	<.001	−.057 [.028]	.042	−.049 [.026]	.063	−.104 [.054]	.052	−.178 [.061]	.004	−.006 [.027]	.732	.009 [.026]	.732
Age^2	−.030 [.011]	.004					−.060 [.017]	<.001	.042 [.020]	.034				
Age^3							.025 [.012]	.033	.027 [.014]	.042				
Sex	−.084 [.041]	.042	.215 [.061]	<.001	.126 [.058]	.031	.146 [.057]	.012	.144 [.058]	.013	.092 [.065]	.161	.006 [.063]	.929

Note. Model parameters were standardized relative to the first measurement (i.e., the mean of the intercept was set to 0, and the variance was set to 1). Models contain age^2 and age^3 as well as effects for sex only if their effect on intercepts and slopes were significant at $p < .05$. Age was mean-centered at sample mean age = 42.1; sex was dummy coded (1 = female, 0 = male). Values for age are given in 10-year units. Values in brackets indicate standard errors. CFI = comparative fit index; RMSEA = root-mean-square error of approximation; SRMR = standardized root-mean-square residual.

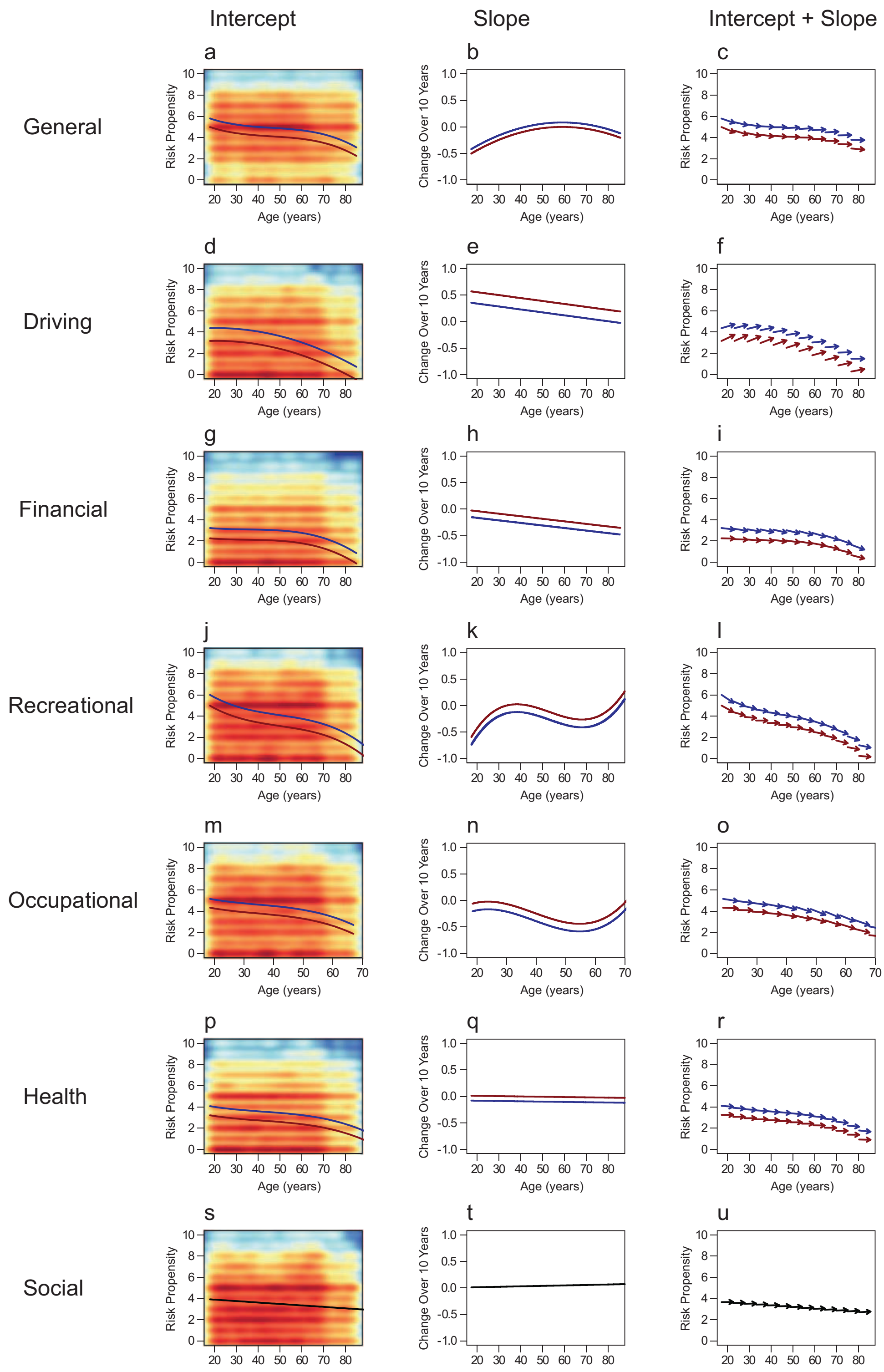

Figure 4. Age-differences in mean levels (intercepts) and mean-level changes (slopes). Arrows (intercept + slope) represent a combined display of age differences in intercepts and slopes for 11 different cohorts. Red line = female, blue line = male. Single black line = no sex difference. All curves in the Intercept plots (a, d, g, j, m, p, s) are plotted on a kernel density plot in which darker red colors indicate higher density of responses (kernel width used for density estimation = 75). General risk propensity (N = 44,076). Driving risk propensity (N = 11,903). Financial risk propensity (N = 11,903). Recreational risk propensity (N = 11,903). Occupational risk propensity (N = 11,903). Health risk propensity (N = 11,903). Social risk propensity (N = 11,903).

Table 4
Correlated Change: Correlations Among Slopes in Bivariate Latent Growth Curve Models of Risk-Taking Propensity, the Big Five Personality Traits, and Income

	General	Driving	Financial	Recreational	Occupational	Health	Social
Risk taking propensities							
General							
Driving	.54***						
Financial	.58***	.65***					
Recreational	.61***	.66***	.64***				
Occupational	.59***	.54***	.59***	.72***			
Health	.51***	.58***	.56***	.65***	.64***		
Social	.47***	.42***	.49***	.56***	.42***	.55***	
The Big Five							
Extraversion	.22**	.04	.03	.10	.15**	.10	.13*
Openness	.24***	.03	.04	.28***	.21***	.12*	.21*
Conscientiousness	.03	−.07	−.11	−.09	−.003	−.06	−.24***
Neuroticism	−.23***	−.01	−.04	−.19*	.06	−.02	−.23**
Agreeableness	−.11	−.12*	−.18*	−.28***	−.12*	−.10	−.02
Income	−.001	−.02	.05	−.08	−.01	.06	−.04

Note. Estimates were obtained from bivariate latent growth curve models and the respective correlation between slope estimates between a particular risk domain and the variable of interest (Big Five traits, income). Note also that the effects reported are ambiguous in direction as they represent correlations of changes.
* $p < .05$. ** $p < .01$. *** $p < .001$.

in general risk taking ($r = .24$). To put these numbers into perspective, intercorrelations of slope estimates between the different risk domains ranged between .42 and .72 (see Table 4).

In sum, these results suggest that within-person changes in standard personality factors are linked to within-person changes in risk-taking propensity, although less strongly than the changes found across risk-taking domains. In contrast, within-person changes in risk-taking propensity showed no significant associations with changes in individual income over time. Overall, these results suggest that—and this may be surprising from a classic economic expectation about the relationship between risk aversion and wealth—life span changes in risk-taking propensity are more closely related to life span changes in personality than to changes in economic factors such as income.

Life Span Trajectory of Social and Nonsocial Risk Taking in Behavioral Tasks

We used regression models to probe for age differences in the cross-sectional samples of respondents who completed behavioral risk measures (Fehr et al., 2002; Holt & Laury, 2002). Figure 5 shows the life span trajectories. In the monetary lottery, we found a significant quadratic relation between age and risk taking (i.e., choosing the risky over the safe option) with evident decreases in risk taking from about 30 years of age. Respondents aged between 18 and 30 years, switched from preferring the lottery to the safe amount when the latter amounted to, on average, €93.6; for respondents aged between 70 and 85 years, the safe amount preferred over the lottery shrank to about half this amount (€44.7). In the trust game, in contrast, we found linear effects of age but overall relatively stable levels of risk taking across the life span (i.e., entrusting money to the other party and hoping for reciprocation).

These results suggest that, similar to self-reported risk propensity, behavioral risk taking shows different trends across different economic tasks (see Table 5). Furthermore, the overall pattern of mean-level differences in risk taking in the respective domains roughly matches between self-report and behavioral measures. Most interestingly, for both self-report and behavioral measures, we find no discernable link between age and risk taking in the social domain. Note, however, that the correlations between the two types of measures are small. For the subset of individuals for whom we have data on both the trust game and self-reported risk-taking propensity ($N = 676$), we found only small correlations between self-report on risky (trust) behavior, rs = [.08–.18] in 2004. The correlation between domain-general risk-taking propensity and risky behavior in the gamble experiment collected in 2005 was only slightly higher, $r = .24$. With regard to correlations with the Big Five personality traits the pattern is similar, with highest correlations between openness to experience and behavior in the gamble experiment, $r = .15$ (see Table 6).

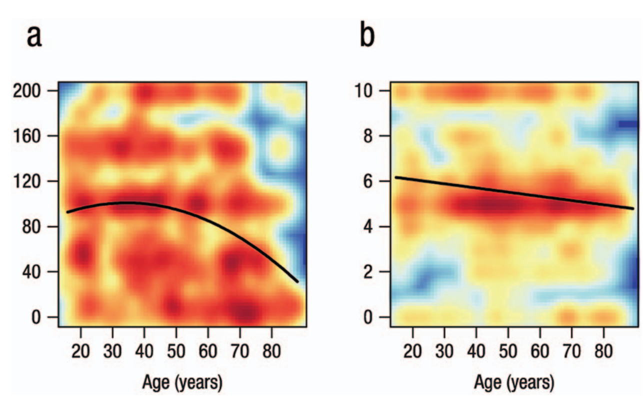

Figure 5. Age differences in mean-levels of behavioral risk taking (cross-sectional data). Single black line = no sex difference. (a) Lottery experiment ($N = 433$). (b) Trust experiment ($N = 646$).

Table 5
Regression Models Describing the Effect of Chronological Age and Sex on Economic Games Involving Social and Nonsocial Risks

	Lottery (N = 433)		Trust (N = 646)	
Model	b	p	b	p
Intercept	96.36 [4.958]	<.001	5.405 [.142]	<.001
Age	−7.597 [1.610]	<.001	−.205 [.060]	.001
Age^2	−2.803 [.943]	.003		
Age^3				
Sex	−5.36 [5.614]	.339	.078 [.200]	.696
AIC	4753		3044	
R^2	.064		.015	

Note. Sex was dummy coded (1 = female, 0 = male). Values in brackets indicate standard errors. Lottery = nonsocial risk, Trust = social risk. The age range of both samples was restricted to 18–85 years. Age was mean-centered at sample means. Values for age are given in 10-year units.

Discussion

How does risk-taking propensity change across adulthood? We examined this question by analyzing (a) differential stability, (b) mean-level differences, and (c) predictors of individual-level change in self-reported risk-taking propensity across adulthood, as well as (d) the correspondence between the life span trajectories of self-report and behavioral measures of social and nonsocial risk taking. We took advantage of data from a longitudinal multicohort survey of individuals between 18 and 85 years of age including subsamples of respondents who provided self-report ratings of general and domain-specific risk-taking propensity (driving, financial, recreational, occupational, health, social) and completed behavioral measures of social (trust game) or nonsocial risk taking (monetary gamble). Next, we discuss the results in light of the four main issues outlined above, discuss some of the limitations of the current investigation, and suggest broad implications and directions for future work.

Differential Stability of Risk-Taking Propensity

Differential stability represents the degree to which relative differences between individuals are preserved over time. To our knowledge, our study is the first to systematically investigate stability in rank-order positioning of self-reported risk propensity across adulthood. We also investigated differential stability in specific domains. The results echo the inverted U-curved pattern of stability from young to old adulthood that has been reported for major personality factors (i.e., Big Five; Briley & Tucker-Drob, 2014; Ferguson, 2010; Roberts & DelVecchio, 2000). Across all domains, stability coefficients in risk-taking propensity increased from young to middle adulthood before declining again in older age. This trajectory is largely consistent with the idea that lower stability is to be expected in developmental periods involving significant biological, cognitive, and social changes/demands.

More work is necessary to uncover the specific biological and environmental factors that lead to this particular life span pattern. One possible conclusion from our results is that life span differences in rank-order stability are relatively homogenous across risk-taking domains. Consequently, future studies may want to consider factors that are common to different areas of life—be they biological changes due to maturation and senescence or the adoption of specific social roles.

Mean-Level Changes in Risk-Taking Propensity

Our study is unique in capturing general and domain-specific risk taking longitudinally across multiple waves spanning up to 10 years. Importantly, our results allowed us to compare longitudinal and cross-sectional estimates of mean-level change in risk-taking propensity: The results suggest that cross-sectional and longitudinal data roughly coincide in showing a decrease in risk-taking propensity with increased age. Indeed, driving was the only domain that yielded a substantial discrepancy between cross-sectional and longitudinal trends (with the latter showing an atypical increase in risk taking over time). Consequently, taken as a whole, our results suggest that previous estimates obtained from cross-sectional data largely capture longitudinal changes in risk-taking propensity (Bonem et al., 2015; Dohmen et al., 2011; Roalf et al., 2012; Rolison et al., 2014; Rosman et al., 2013; Schwartz et al., 2013). Importantly, the normative decreases of mean-level trends in risk-taking propensity are consistent with what behavioral ecology would predict about age (and sex) differences in risk taking against the background of differential incentives for reproductive competition across the life span (and between the sexes; e.g., Daly & Wilson, 1997).

The pattern of normative age-related decline varied as a function of life domain, with some domains (e.g., social) proving relatively stable across adulthood. Future work needs to provide a theoretical rationale for potential qualitative differences between domains. One possibility is to determine the extent to which particular domains or risky activities should and can be avoided in different phases of life. For example, abstaining from climbing ladders or

Table 6
Correlations Between Self-Reported and Behavioral Measures of Risk

	Lottery		Trust	
Variable	r	n	r	n
Risk taking propensities				
General	.24***	433	.13**	646
Driving	—	—	.14*	322
Financial	—	—	.13*	322
Recreational	—	—	.17*	322
Occupational	—	—	.18*	322
Health	—	—	.08	322
Social	—	—	.17*	322
The Big Five				
Extraversion	.08	433	—	—
Openness	.15**	433	—	—
Conscientiousness	−.04	433	—	—
Neuroticism	.04	433	—	—
Agreeableness	−.09	433	—	—

Note. The lottery game was assessed together with the domain-general risk item in a pretest of the SOEP in 2005. We can therefore not provide correlations with the domain-specific risk-propensity items. The trust game was assessed in 2004 and allowed correlations with the domain-specific and the domain-general risk items but not the Big Five. n = cases used for the correlations.
* $p < .05$. ** $p < .01$. *** $p < .001$.

standing on chairs can reduce the risk of falls at home and may be an adaptive strategy in older age (Brandtstädter, Wentura, & Rothermund, 1999; Duke, Leventhal, Brownlee, & Leventhal, 2002). In contrast, interpersonal exchange is a key domain that people hardly can escape from with age. These results also fit ideas about social and emotional involvement across the life span, at large. That is, past research has shown that social and emotional information remains prioritized with respect to broader life goals across adulthood (Carstensen, 1995; Carstensen, Isaacowitz, & Charles, 1999). In addition, despite thinning of social network size, there is evidence that older individuals continue to be socially engaged more frequently and more emotionally with their closest relationships compared to younger adults (Fredrickson & Carstensen, 1990). Overall, it may be important to investigate whether patterns of stability in social risk taking are related to the cultural and biological roles of seniors as both recipients of social support (Baltes, 1997) and donors of care to progeny (Coall & Hertwig, 2010). More generally, going forward, studies that investigate specific risk-taking behaviors and assess the causes underlying the adoption or cessation of these behaviors across adulthood are warranted.

Individual-Level Changes in Risk-Taking Propensity

Identifying covariates of age differences in risk taking may offer insights into the mechanisms underlying change in risk propensity across the life span. We have contributed to this effort by assessing the link between change in risk-taking propensity and situational or psychological characteristics hypothesized to vary with risk taking: income (Dohmen et al., 2011) and personality (Becker et al., 2012; Borghans et al., 2008). Individual-level change in risk-taking propensity was weakly and not significantly correlated with within-person changes in income. However, within-person change in risk-taking propensity was moderately correlated with within-person change in some Big Five personality factors. More concretely, we found positive associations between within-person change in Extraversion and Openness to Experiences and negative associations between within-person change in Conscientiousness, Neuroticism, and Agreeableness and within-person change in risk-taking propensity.

One limitation of our work is that we did not analyze further variables that have been suggested to be associated with individual differences in risk taking, such as cognitive ability (Dohmen et al., 2010), numeracy (Reyna, Nelson, Han, & Dieckmann, 2009), affect (Peters, Hess, Västfjäll, & Auman, 2007), and risk perception (Bonem et al., 2015). The SOEP either does not include these variables or has not yet gathered enough longitudinal data (i.e., cognitive ability) for correlated changes to be estimated. Future work including additional measurements in the SOEP and use of other longitudinal surveys will be helpful in uncovering predictors of change in risk taking over time.

Life Span Trajectories of Self-Report and Behavioral Measures of Risk Taking

One of our goals was to assess whether self-report and behavioral measures of risk taking converged in the estimated patterns of life span mean-level trajectories in risk taking. We found that there were indeed parallels between the trajectories of the self-report measures and the two behavioral measures. Specifically, the decline in self-reported risk-taking propensity in the financial domain was matched by behavior in the monetary gamble. Similarly, a relatively flat trajectory of risk-taking propensity in the self-reported social domain matched results obtained from the behavioral trust game. However, when we estimated the cross-sectional correlations between self-report and behavioral results, we found that most correlations between self-report and behavioral measures were small. Naturally, the small correlations between behavioral and self-report measures of trust could stem from confounds present in the specific behavioral games used, such as the trust game, because factors such as mentalizing abilities and altruistic preferences may trump or confound the role of risk-taking preferences (Rilling & Sanfey, 2011). More broadly, although our work raises the possibility that both self-report and behavioral measures capture similar aspects of mean-level changes in risk-taking propensity with increased age, further work is needed to quantify the overlap between different behavioral and self-report measures (see Appelt et al., 2011; Friedman et al., 2014; Mishra & Lalumière, 2011; Szrek et al., 2012).

Limitations

One main limitation of our work is that we have not investigated the links between risk preferences and real-world outcomes. To our knowledge, there has only been one past effort to use one wave of the SOEP database to predict real-world behavior in the financial domain (Dohmen et al., 2011), but these efforts could be extended to include other waves. A limitation of both past work and any future efforts with these data will be that they do not include objective measures of respondents' real-world behavior. The SOEP, for instance, relies almost exclusively on self-report assessments of behavior rather than on observational or registry data. Recent studies have shown the feasibility of complementing self-report assessments with objective real-world assessments, such as health markers (Moffitt et al., 2011) or financial reports (Li et al., 2015). Showing predictive value of current risk-taking propensity measures for real-world behavior would remove potential doubts about the validity of the single-item measures in the present investigation. Future work with large representative longitudinal surveys should therefore combine self-report and behavioral measures with objective measures of risk-taking behavior, such as those associated with financial behavior.

Implications for Conceptions of Risk Taking and Future Research

What is risk taking? Our results may not afford a definite answer but they suggest some more and some less surprising regularities that a comprehensive theory of risk taking will have to meet. First, they suggest that risk taking is not a purely situation-specific response pattern and can, instead, be considered a trait with a level of rank-order stability across individuals that is only slightly below that of major personality dimensions (Briley & Tucker-Drob, 2014; Roberts & DelVecchio, 2000). Furthermore, like those personality dimensions, its pattern of differential stability obeys an inverted U-shape such that the periods of young adulthood and old age reveal least stability. Second, like other personality dimension—such as openness to experience—it shows mean-level decreases with age (Lucas & Donnellan, 2011; Specht, Egloff, & Schmukle, 2011). This, however, only holds as long as the risk-taking propensity is probed in an abstract and domain-general fashion. Notable variations in mean-level risk taking emerge across domains, such as in the relatively stable pattern of risk taking across the life span observed for the social domain. To what extent these variations stem from a stable trait but changing domain-specific perceptions of costs and benefits or rather from domain-specific traits with somewhat unique age trajectories remains an open question for future research. Third, and finally, we found that life span changes in risk-taking propensity are more closely related to life span changes in personality than to changes in economic circumstances such as income. All in all, these results highlight the need for a better understanding of the links between risk-taking propensities, personality structure, and the mechanisms or sources of personality development at large.

Although risk-taking tendencies have long been within the purview of personality theories, they have, regrettably, been investigated under different banners, including sensation seeking (Cross, Cyrenne, & Brown, 2013; Zuckerman & Kuhlman, 2000) and impulsivity (Cross, Copping, & Campbell, 2011; Sharma, Markon, & Clark, 2014). Understanding the relationship between the different constructs and how they are linked to major personality factors will require both theoretical and empirical work. As mentioned above, we see potential for convergence by examining the empirical links between major (i.e., Big Five) personality factors and risk-taking propensity. For example, there has been considerable progress in understanding individual differences in life events (Kandler, Kornadt, Hagemeyer, & Neyer, 2014; Specht et al., 2011), cognitive development (Klimstra, Bleidorn, Asendorpf, van Aken, & Denissen, 2013), and cross-cultural variation in social roles (Bleidorn et al., 2013). Such methods could also be applied to understanding the development of risk taking and to determine parallels between the development of Big Five personality factors and specific risk-taking behaviors. We have partly initiated this effort by investigating how age differences in risk taking vary across different countries and thus are a function of the affordances of local ecologies (Mata et al., in press), a message that matches previous results on the life span development of major personality dimensions (Bleidorn et al., 2013). Yet another possible future step in understanding the development of risk-taking propensity and links to other personality dimensions would be to assess the role of general proximal mechanisms that can account for global effects that we reported across domains and personality factors, including potential changes in neurotransmitter systems (Buckholtz et al., 2010; Düzel, Bunzeck, Guitart-Masip, Düzel, 2010) or hormonal profiles (Mehta, Welker, Ziliolic, & Carré 2015).

Conclusion

We investigated the stability and change in risk-taking propensity across the life span and found that risk taking can be thought of as a trait that changes significantly across the life span and similarly, albeit with exceptions, across different domains of life. Future work is now needed to uncover the underlying sources of domain-specificity in the development of risk-taking propensity and assessing more closely the empirical and theoretical links between risk taking and other personality factors.

References

Anderson, L. R., & Mellor, J. M. (2009). Are risk preferences stable? Comparing an experimental measure with a validated survey-based measure. *Journal of Risk and Uncertainty, 39,* 137–160. http://dx.doi.org/10.1007/s11166-009-9075-z

Anokhin, A. P., Golosheykin, S., Grant, J., & Heath, A. C. (2009). Heritability of risk-taking in adolescence: A longitudinal twin study. *Twin Research and Human Genetics, 12,* 366–371. http://dx.doi.org/10.1375/twin.12.4.366

Appelt, K. C., Milch, K. F., Handgraaf, M. J., & Weber, E. U. (2011). The Decision Making Individual Differences Inventory and guidelines for the study of individual differences in judgment and decision making research. *Judgment and Decision Making, 6,* 252–262.

Aven, T. (2012). The risk concept: Historical and recent development trends. *Reliability Engineering & System Safety, 99,* 33–44. http://dx.doi.org/10.1016/j.ress.2011.11.006

Baltes, P. B. (1997). On the incomplete architecture of human ontogeny. Selection, optimization, and compensation as foundation of developmental theory. *American Psychologist, 52,* 366–380. http://dx.doi.org/10.1037/0003-066X.52.4.366

Bechara, A., Damasio, A. R., Damasio, H., & Anderson, S. W. (1994). Insensitivity to future consequences following damage to human prefrontal cortex. *Cognition, 50*(1–3):7–15. http://dx.doi.org/10.1016/0010-0277(94)90018-3

Becker, A., Deckers, T., Dohmen, T., Falk, A., & Kosse, F. (2012). The relationship between economic preferences and psychological personality measures. *Annual Review of Economics, 4,* 453–478. http://dx.doi.org/10.1146/annurev-economics-080511-110922

Benjamin, D. J., Cesarini, D., van der Loos, M. J. H. M., Dawes, C. T., Koellinger, P. D., Magnusson, P. K. E., . . . Visscher, P. M. (2012). The genetic architecture of economic and political preferences. *PNAS Proceedings of the National Academy of Sciences of the United States of America, 109,* 8026–8031. http://dx.doi.org/10.1073/pnas.1120666109

Ben-Ner, A., & Halldorsson, F. (2010). Trusting and trustworthiness: What are they, how to measure them, and what affects them. *Journal of Economic Psychology, 31,* 64–79. http://dx.doi.org/10.1016/j.joep.2009.10.001

Bentler, P. M. (1990). Comparative fit indexes in structural models. *Psychological Bulletin, 107,* 238–246. http://dx.doi.org/10.1037/0033-2909.107.2.238

Berg, J., Dickhaut, J., & McCabe, K. (1995). Trust, reciprocity, and social history. *Games and Economic Behavior, 10,* 122–142. http://dx.doi.org/10.1006/game.1995.1027

Berg, J., Dickhaut, J., & McCabe, K. (2005). Risk preference instability across institutions: A dilemma. *PNAS Proceedings of the National Academy of Sciences of the United States of America, 102,* 4209–4214. http://dx.doi.org/10.1073/pnas.0500333102

Bernoulli, D. (1954). Exposition of a new theory on the measurement of risk. *Econometrica, 22,* 23–36. http://www.jstor.org/stable/1909829. http://dx.doi.org/10.2307/1909829

Best, R., & Charness, N. (2015). Age differences in the effect of framing on risky choice: A meta-analysis. *Psychology and Aging, 30,* 688–698. http://dx.doi.org/10.1037/a0039447

Blais, A.-R. E., & Weber, E. U. (2006). A domain-specific risk-taking (DOSPERT) scale for adult populations. *Judgment and Decision Making, 1,* 33–47. Retrieved from http://journal.sjdm.org/06005/jdm06005.htm

Bleidorn, W., Klimstra, T. A., Denissen, J. J. A., Rentfrow, P. J., Potter, J., & Gosling, S. D. (2013). Personality maturation around the world: A cross-cultural examination of social-investment theory. *Psychological Science, 24,* 2530–2540. http://dx.doi.org/10.1177/0956797613498396

Bonem, E. M., Ellsworth, P. C., & Gonzalez, R. (2015). Age differences in risk: Perceptions, intentions and domains. *Journal of Behavioral Decision Making*. http://dx.doi.org/10.1002/bdm.1848

Bonin, H., Dohmen, T., Falk, A., Huffman, D., & Sunde, U. (2007). Cross-sectional earnings risk and occupational sorting: The role of risk attitudes. *Labour Economics, 14,* 926–937. http://dx.doi.org/10.1016/j.labeco.2007.06.007

Borghans, L., Duckworth, A. L., Heckman, J. J., & Weel, B. (2008). The economics and psychology of personality traits. *The Journal of Human Resources, 43,* 972–1059.

Braams, B. R., van Duijvenvoorde, A. C., Peper, J. S., & Crone, E. A. (2015). Longitudinal changes in adolescent risk-taking: A comprehensive study of neural responses to rewards, pubertal development, and risk-taking behavior. *The Journal of Neuroscience, 35,* 7226–7238. http://dx.doi.org/10.1523/JNEUROSCI.4764-14.2015

Brandtstädter, J., Wentura, D., & Rothermund, K. (1999). Intentional self-development through adulthood and later life: Tenacious pursuit and flexible adjustment of goals. In J. Brandtstädter & R. M. Lerner (Eds.), *Action and self-development: Theory and research through the lifespan* (pp. 373–400). Thousand Oaks, CA: Sage. http://dx.doi.org/10.4135/9781452204802.n13

Briley, D. A., & Tucker-Drob, E. M. (2014). Genetic and environmental continuity in personality development: A meta-analysis. *Psychological Bulletin, 140,* 1303–1331. http://dx.doi.org/10.1037/a0037091

Brunnermeier, M. K., & Nagel, S. (2008). Do wealth fluctuations generate time-varying risk aversion? *The American Economic Review, 98,* 713–736. http://dx.doi.org/10.1257/aer.98.3.713

Buckholtz, J. W., Treadway, M. T., Cowan, R. L., Woodward, N. D., Li, R., Ansari, M. S., . . . Zald, D. H. (2010). Dopaminergic network differences in human impulsivity. *Science, 329,* 532. http://dx.doi.org/10.1126/science.1185778

Byrnes, J. P., Miller, D. C., & Schafer, W. D. (1999). Gender differences in risk taking: A meta-analysis. *Psychological Bulletin, 125,* 367–383. http://dx.doi.org/10.1037/0033-2909.125.3.367

Campbell, A. (1999). Staying alive: Evolution, culture, and women's intrasexual aggression. *Behavioral and Brain Sciences, 22,* 203–214. http://dx.doi.org/10.1017/S0140525X99001818

Carstensen, L. L. (1995). Evidence for a life-span theory of socioemotional selectivity. *Current Directions in Psychological Science, 4,* 151–156. http://dx.doi.org/10.1111/1467-8721.ep11512261

Carstensen, L. L., Isaacowitz, D. M., & Charles, S. T. (1999). Taking time seriously. A theory of socioemotional selectivity. *American Psychologist, 54,* 165–181. http://dx.doi.org/10.1037/0003-066X.54.3.165

Caspi, A., Roberts, B. W., & Shiner, R. L. (2005). Personality development: Stability and change. *Annual Review of Psychology, 56,* 453–484. http://dx.doi.org/10.1146/annurev.psych.55.090902.141913

Chiappori, P.-A., & Paiella, M. (2011). Relative risk aversion is constant: Evidence from panel data. *Journal of the European Economic Association, 9,* 1021–1052. http://dx.doi.org/10.1111/j.1542-4774.2011.01046.x

Chopik, W. J., Kim, E. S., & Smith, J. (2015). Changes in optimism are associated with changes in health over time among older adults. *Social Psychological and Personality Science, 6,* 814–822. http://dx.doi.org/10.1177/1948550615590199

Chuang, Y., & Schechter, L. (2015). Stability of experimental and survey measures of risk, time and social preferences: A review and some new results. *Journal of Development Economics, 117,* 151–170. http://dx.doi.org/10.1016/j.jdeveco.2015.07.008

Coall, D. A., & Hertwig, R. (2010). Grandparental investment: Past, present, and future. *Behavioral and Brain Sciences, 33,* 1–19. http://dx.doi.org/10.1017/S0140525X09991105

Collado, A., Felton, J. W., MacPherson, L., & Lejuez, C. W. (2014). Longitudinal trajectories of sensation seeking, risk taking propensity, and impulsivity across early to middle adolescence. *Addictive Behaviors, 39,* 1580–1588. http://dx.doi.org/10.1016/j.addbeh.2014.01.024

Costa, P. T., Jr., & McCrae, R. R. (2006). Age changes in personality and their origins: Comment on Roberts, Walton, and Viechtbauer (2006). *Psychological Bulletin, 132,* 26–28. http://dx.doi.org/10.1037/0033-2909.132.1.26

Costa, P. T., & McCrae, R. R. (1994). Set like plaster? Evidence for the stability of adult personality. In T. F. Heatherton & J. L. Weinberger (Eds.), *Can personality change?* (pp. 21–40). Washington, DC: American Psychological Association. http://dx.doi.org/10.1037/10143-002

Cross, C. P., Copping, L. T., & Campbell, A. (2011). Sex differences in impulsivity: A meta-analysis. *Psychological Bulletin, 137,* 97–130. http://dx.doi.org/10.1037/a0021591

Cross, C. P., Cyrenne, D. L. M., & Brown, G. R. (2013). Sex differences in sensation-seeking: A meta-analysis. *Scientific Reports, 3,* 2486.

Daly, M., & Wilson, M. (1997). Crime and conflict: Homicide in evolutionary psychological perspective. *Crime and Justice, 22,* 51–100. http://dx.doi.org/10.1086/449260

Dave, C., Eckel, C. C., Johnson, C. A., & Rojas, C. (2010). Eliciting risk preferences: When is simple better? *Journal of Risk and Uncertainty, 41,* 219–243. http://dx.doi.org/10.1007/s11166-010-9103-z

Deck, C., Lee, J., Reyes, J., & Rosen, C. (2012). Risk taking behavior: An experimental analysis of individuals and pairs. *Southern Economic Journal, 79,* 277–299. http://dx.doi.org/10.4284/0038-4038-2010.026

Defoe, I. N., Dubas, J. S., Figner, B., & van Aken, M. A. G. (2015). A meta-analysis on age differences in risky decision making: Adolescents versus children and adults. *Psychological Bulletin, 141,* 48–84. http://dx.doi.org/10.1037/a0038088

Dohmen, T., Falk, A., Huffman, D., & Sunde, U. (2010). Are risk aversion and impatience related to cognitive ability? *The American Economic Review, 100,* 1238–1260. http://dx.doi.org/10.1257/aer.100.3.1238

Dohmen, T., Falk, A., Huffman, D., Sunde, U., Schupp, J., & Wagner, G. R. G. (2011). Individual risk attitudes: Measurement, determinants, and behavioral consequences. *Journal of the European Economic Association, 9,* 522–550. http://dx.doi.org/10.1111/j.1542-4774.2011.01015.x

Donnellan, M. B., & Lucas, R. E. (2008). Age differences in the Big Five across the life span: Evidence from two national samples. *Psychology and Aging, 23,* 558–566. http://dx.doi.org/10.1037/a0012897

Duke, J., Leventhal, H., Brownlee, S., & Leventhal, E. A. (2002). Giving up and replacing activities in response to illness. *The Journals of Gerontology: Series B: Psychological Sciences and Social Sciences, 57,* 367–376. http://dx.doi.org/10.1093/geronb/57.4.P367

Düzel, E., Bunzeck, N., Guitart-Masip, M., & Düzel, S. (2010). Novelty-related motivation of anticipation and exploration by dopamine (NOMAD): Implications for healthy aging. *Neuroscience and Biobehavioral Reviews, 34,* 660–669. http://dx.doi.org/10.1016/j.neubiorev.2009.08.006

Fehr, E., Fischbacher, U., Schupp, J., von Rosenbladt, B., & Wagner, G. G. (2002). A nationwide laboratory examining trust and trustworthiness by integrating behavioral experiments into representative surveys. *Schmollers Jahrbuch: Zeitschrift fur Wirtschafts- und Sozialwissenschaften, 122,* 519–542.

Ferguson, C. J. (2010). A meta-analysis of normal and disordered personality across the life span. *Journal of Personality and Social Psychology, 98,* 659–667. http://dx.doi.org/10.1037/a0018770

Figner, B., Mackinlay, R. J., Wilkening, F., & Weber, E. U. (2009). Affective and deliberative processes in risky choice: Age differences in risk taking in the Columbia Card Task. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 35,* 709–730. http://dx.doi.org/10.1037/a0014983

Fredrickson, B. L., & Carstensen, L. L. (1990). Choosing social partners: How old age and anticipated endings make people more selective.

Psychology and Aging, 5, 335–347. http://dx.doi.org/10.1037/0882-7974.5.3.335

Frey, R., Mata, R., & Hertwig, R. (2015). The role of cognitive abilities in decisions from experience: Age differences emerge as a function of choice set size. *Cognition, 142(C),* 60–80. http://dx.doi.org/10.1016/j.cognition.2015.05.004

Friedman, D. R., Isaac, M. R., Duncan, J., & Sunder, S. (2014). *Risky curves: On the empirical failure of expected utility*. New York, NY: Routledge.

Gerlitz, J.-Y., & Schupp, J. (2005). Zur Erhebung der Big-Five-basierten Persönlichkeitsmerkmale im SOEP [The measurement of the Big Five personality traits in the SOEP]. *DIW Research Notes, 9/2005, 4*.

Hanoch, Y., & Gummerum, M. (2011). A comparison of the risk-taking behaviors of prisoners and non-prisoners. *Journal of Behavioral Decision Making, 24,* 431–442. http://dx.doi.org/10.1002/bdm.701

Hanoch, Y., Johnson, J. G., & Wilke, A. (2006). Domain specificity in experimental measures and participant recruitment: An application to risk-taking behavior. *Psychological Science, 17,* 300–304. http://dx.doi.org/10.1111/j.1467-9280.2006.01702.x

Harden, K. P., Quinn, P. D., & Tucker-Drob, E. M. (2012). Genetically influenced change in sensation seeking drives the rise of delinquent behavior during adolescence. *Developmental Science, 15,* 150–163. http://dx.doi.org/10.1111/j.1467-7687.2011.01115.x

Harrison, G. W., Johnson, E. J., McInnes, M. M., & Rutström, E. E. (2005). Temporal stability of estimates of risk aversion. *Applied Financial Economics Letters, 1,* 31–35. http://dx.doi.org/10.1080/1744654042000311576

Hertwig, R., & Erev, I. (2009). The description-experience gap in risky choice. *Trends in Cognitive Sciences, 13,* 517–523. http://dx.doi.org/10.1016/j.tics.2009.09.004

Holt, C. A., & Laury, S. K. (2002). Risk aversion and incentive effects. *The American Economic Review, 92,* 1644–1655. http://dx.doi.org/10.1257/000282802762024700

Hooper, C. J., Luciana, M., Wahlstrom, D., Conklin, H. M., & Yarger, R. S. (2008). Personality correlates of Iowa Gambling Task performance in healthy adolescents. *Personality and Individual Differences, 44,* 598–609. http://dx.doi.org/10.1016/j.paid.2007.09.021

Houser, D., Schunk, D., & Winter, J. (2010). Distinguishing trust from risk: An anatomy of the investment game. *Journal of Economic Behavior & Organization, 74,* 72–81. http://dx.doi.org/10.1016/j.jebo.2010.01.002

Hu, L., & Bentler, P. M. (1999). Cutoff criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives. *Structural Equation Modeling, 6,* 1–55. http://dx.doi.org/10.1080/10705519909540118

John, D., Donahue, E. M., & Kentle, R. L. (1991). *The Big Five Inventory: Versions 4a and 54*. Berkeley, CA: University of California Berkeley, Institute of Personality and Social Research.

Jung, S., & Treibich, C. (2014). *Is self-reported risk aversion time varying?* (PSE Working Papers n2014-12). Retrieved from https://halshs.archives-ouvertes.fr/halshs-00965549/

Kandler, C., Kornadt, A. E., Hagemeyer, B., & Neyer, F. J. (2014). Patterns and sources of personality development in old age. *Journal of Personality and Social Psychology, 109,* 175–191. http://dx.doi.org/10.1037/pspp000028

Klein, A. G., & Moosbrugger, H. (2000). Maximum likelihood estimation of latent interaction effects with the LMS method. *Psychometrika, 65,* 457–474. http://dx.doi.org/10.1007/BF02296338

Klimstra, T. A., Bleidorn, W., Asendorpf, J. B., van Aken, M. A. G., & Denissen, J. J. A. (2013). Correlated change of Big Five personality traits across the lifespan: A search for determinants. *Journal of Research in Personality, 47,* 768–777. http://dx.doi.org/10.1016/j.jrp.2013.08.004

Lang, F. R., John, D., Lüdtke, O., Schupp, J., & Wagner, G. G. (2011). Short assessment of the Big Five: Robust across survey methods except telephone interviewing. *Behavior Research Methods, 43,* 548–567. http://dx.doi.org/10.3758/s13428-011-0066-z

Lauriola, M., Panno, A., Levin, I. P., & Lejuez, C. W. (2014). Individual differences in risky decision making: A meta-analysis of sensation seeking and impulsivity with the Balloon Analogue Risk Task. *Journal of Behavioral Decision Making, 27,* 20–36. http://dx.doi.org/10.1002/bdm.1784

Lejuez, C. W., Read, J. P., Kahler, C. W., Richards, J. B., Ramsey, S. E., Stuart, G. L., . . . Brown, R. A. (2002). Evaluation of a behavioral measure of risk taking: The Balloon Analogue Risk Task (BART). *Journal of Experimental Psychology: Applied, 8,* 75–84. http://dx.doi.org/10.1037/1076-898X.8.2.75

Li, Y., Gao, J., Enkavi, A. Z., Zaval, L., Weber, E. U., & Johnson, E. J. (2015). Sound credit scores and financial decisions despite cognitive aging. *PNAS Proceedings of the National Academy of Sciences of the United States of America, 112,* 65–69. http://dx.doi.org/10.1073/pnas.1413570112

Lönnqvist, J.-E., Verkasalo, M., Walkowitz, G., & Wichardt, P. C. (2011). Measuring individual risk attitudes in the lab: Task or ask? An empirical comparison. *CESifo Working Paper No. 4663*.

Lucas, R. E., & Donnellan, M. B. (2009). Age differences in personality: Evidence from a nationally representative Australian sample. *Developmental Psychology, 45,* 1353–1363. http://dx.doi.org/10.1037/a0013914

Lucas, R. E., & Donnellan, M. B. (2011). Personality development across the life span: Longitudinal analyses with a national sample from Germany. *Journal of Personality and Social Psychology, 101,* 847–861. http://dx.doi.org/10.1037/a0024298

Mandal, B., & Roe, B. (2014). Risk tolerance among National Longitudinal Survey of Youth participants: The effect of age and cognitive skills. *Economica, 81,* 522–543.

Markowitz, H. (1952). Portfolio selection. *The Journal of Finance, 7,* 77–91.

Maslowsky, J., Jager, J., & Hemken, D. (2015). Estimating and interpreting latent variable interactions: A tutorial for applying the latent moderated structural equations method. *International Journal of Behavioral Development, 39,* 87–96. http://dx.doi.org/10.1177/0165025414552301

Mata, R., Josef, A. K., & Hertwig, R. (in press). Risk taking across the life span and around the world. *Psychological Science*.

Mata, R., Josef, A. K., Samanez-Larkin, G. R., & Hertwig, R. (2011). Age differences in risky choice: A meta-analysis. *Annals of the New York Academy of Sciences, 1235,* 18–29. http://dx.doi.org/10.1111/j.1749-6632.2011.06200.x

McArdle, J. J., & Nesselroade, J. R. (2003). Growth curve analysis in contemporary psychological research. In J. A. Schinka & W. F. Velicer (Eds.), *Handbook of psychology: Vol. 2. Research methods in psychology* (pp. 447–480). New York, NY: Pergamon Press. http://dx.doi.org/10.1002/0471264385.wei0218

Mehta, P. H., Welker, K. M., Zilioli, S., & Carré, J. M. (2015). Testosterone and cortisol jointly modulate risk-taking. *Psychoneuroendocrinology, 56,* 88–99. http://dx.doi.org/10.1016/j.psyneuen.2015.02.023

Mishra, S. (2014). Decision-Making under risk: Integrating Perspectives from biology, economics, and psychology. *Personality and Social Psychology Review, 18,* 280–307. http://dx.doi.org/10.1177/1088868314530517

Mishra, S., & Lalumière, M. L. (2011). Individual differences in risk-propensity: Associations between personality and behavioral measures of risk. *Personality and Individual Differences, 50,* 869–873. http://dx.doi.org/10.1016/j.paid.2010.11.037

Mishra, S., Lalumière, M. L., & Williams, R. J. (2010). Gambling as a form of risk-taking: Individual differences in personality, risk-accepting attitudes, and behavioral preferences for risk. *Personality and Individual Differences, 49,* 616–621. http://dx.doi.org/10.1016/j.paid.2010.05.032

Moffitt, T. E., Arseneault, L., Belsky, D., Dickson, N., Hancox, R. J., Harrington, H., . . . Caspi, A. (2011). A gradient of childhood self-control predicts health, wealth, and public safety. *PNAS Proceedings of the National Academy of Sciences of the United States of America, 108,* 2693–2698. http://dx.doi.org/10.1073/pnas.1010076108

Nicholson, N., Soane, E., Fenton-O'Creevy, M., & Willman, P. (2005). Personality and domain-specific risk taking. *Journal of Risk Research, 8,* 157–176. http://dx.doi.org/10.1080/1366987032000123856

Nickel, P. J., & Vaesen, K. (2012). Risk and trust. In S. Roeser, R. Hilerbrand, P. Sandin, & M. Peterson (Eds.), *Handbook of Risk Theory* (pp. 857–876). The Netherlands: Springer. http://dx.doi.org/10.1007/978-94-007-1433-5_34

Niv, S., Tuvblad, C., Raine, A., Wang, P., & Baker, L. A. (2012). Heritability and longitudinal stability of impulsivity in adolescence. *Behavior Genetics, 42,* 378–392. http://dx.doi.org/10.1007/s10519-011-9518-6

Peters, E., Hess, T. M., Västfjäll, D., & Auman, C. (2007). Adult age differences in dual information processes: Implications for the role of affective and deliberative processes in older adults' decision making. *Perspectives on Psychological Science, 2,* 1–23. http://dx.doi.org/10.1111/j.1745-6916.2007.00025.x

Prinz, S., Gründer, G., Hilgers, R. D., Holtemöller, O., & Vernaleken, I. (2014). Impact of personal economic environment and personality factors on individual financial decision making. *Frontiers in Psychology, 5,* 158. http://dx.doi.org/10.3389/fpsyg.2014.00158

R Core Team. (2015, March 9). *R: A language and environment for statistical computing*. Vienna, Austria: R Foundation for Statistical Computing. Retrieved from http://www.R-project.org/

Reyna, V. F., Nelson, W. L., Han, P. K., & Dieckmann, N. F. (2009). How numeracy influences risk comprehension and medical decision making. *Psychological Bulletin, 135,* 943–973. http://dx.doi.org/10.1037/a0017327

Reynaud, A., & Couture, S. (2012). Stability of risk preference measures: Results from a field experiment on French farmers. *Theory and Decision, 73,* 203–221. http://dx.doi.org/10.1007/s11238-012-9296-5

Rieger, M., & Mata, R. (2015). On the generality of age differences in social and nonsocial decision making. *The Journals of Gerontology: Series B: Psychological Sciences and Social Sciences, 70,* 200–214. http://dx.doi.org/10.1093/geronb/gbt088

Rilling, J. K., & Sanfey, A. G. (2011). The neuroscience of social decision-making. *Annual Review of Psychology, 62,* 23–48. http://dx.doi.org/10.1146/annurev.psych.121208.131647

Roalf, D. R., Mitchell, S. H., Harbaugh, W. T., & Janowsky, J. S. (2012). Risk, reward, and economic decision making in aging. *The Journals of Gerontology: Series B: Psychological Sciences and Social Sciences, 67,* 289–298. http://dx.doi.org/10.1093/geronb/gbr099

Roberts, B. W., & DelVecchio, W. F. (2000). The rank-order consistency of personality traits from childhood to old age: A quantitative review of longitudinal studies. *Psychological Bulletin, 126,* 3–25. http://dx.doi.org/10.1037/0033-2909.126.1.3

Roberts, B. W., Walton, K. E., & Viechtbauer, W. (2006). Patterns of mean-level change in personality traits across the life course: A meta-analysis of longitudinal studies. *Psychological Bulletin, 132,* 1–25. http://dx.doi.org/10.1037/0033-2909.132.1.1

Roberts, B. W., Wood, D., & Smith, J. L. (2005). Evaluating five factor theory and social investment perspectives on personality trait development. *Journal of Research in Personality, 39,* 166–184. http://dx.doi.org/10.1016/j.jrp.2004.08.002

Rolison, J. J., Hanoch, Y., Wood, S., & Liu, P. J. (2014). Risk-taking differences across the adult life span: A question of age and domain. *The Journals of Gerontology Series B, Psychological Sciences and Social Sciences, 69,* 870–880. http://dx.doi.org/10.1093/geronb/gbt081

Rosman, A., Garcia, M., Lee, S., Butler, S., & Schwartz, A. (2013). DOSPERT+M: A survey of medical risk attitudes in the United States. *Judgment and Decision Making, 8,* 470–481.

Rosseel, Y. (2012). "lavaan": An R package for structural equation modeling. *Journal of Statistical Software, 48,* 1–36. http://hdl.handle.net/1854/LU-3099674. http://dx.doi.org/10.18637/jss.v048.i02

Roth, M., Schumacher, J., & Brähler, E. (2005). Sensation seeking in the community: Sex, age, and sociodemographic comparisons on a representative German population sample. *Personality and Individual Differences, 39,* 1261–1271. http://dx.doi.org/10.1016/j.paid.2005.05.003

Sahm, C. R. (2012). How much does risk tolerance change? *Quarterly Journal of Finance, 2,* 1–38. http://dx.doi.org/10.1142/S2010139212500206

Schafer, J. L., & Graham, J. W. (2002). Missing data: Our view of the state of the art. *Psychological Methods, 7,* 147–177. http://dx.doi.org/10.1037/1082-989X.7.2.147

Schoemaker, P. J. H. (1990). Are risk-attitudes related across domains and response modes? *Management Science, 36,* 1451–1463. http://dx.doi.org/10.1287/mnsc.36.12.1451

Schonberg, T., Fox, C. R., & Poldrack, R. A. (2011). Mind the gap: Bridging economic and naturalistic risk-taking with cognitive neuroscience. *Trends in Cognitive Sciences, 15,* 11–19. http://dx.doi.org/10.1016/j.tics.2010.10.002

Schwartz, A., Yamagishi, K., Hirahara, N., Onishi, H., Barnes, J. I., Garcia, M., . . . Butler, S. (2013). Risk perception and risk attitudes in Tokyo: A report of the first administration of DOSPERT+M in Japan. *Judgment and Decision Making, 8,* 691–699.

Sharma, L., Markon, K. E., & Clark, L. A. (2014). Toward a theory of distinct types of "impulsive" behaviors: A meta-analysis of self-report and behavioral measures. *Psychological Bulletin, 140,* 374–408. http://dx.doi.org/10.1037/a0034418

Shulman, E. P., Harden, K. P., Chein, J. M., & Steinberg, L. (2015). Sex differences in the developmental trajectories of impulse control and sensation-seeking from early adolescence to early adulthood. *Journal of Youth and Adolescence, 44,* 1–17. http://dx.doi.org/10.1007/s10964-014-0116-9

Sih, A., & Del Giudice, M. (2012). Linking behavioural syndromes and cognition: A behavioural ecology perspective. *Philosophical Transactions of the Royal Society of London Series B, Biological Sciences, 367,* 2762–2772. http://dx.doi.org/10.1098/rstb.2012.0216

Specht, J., Egloff, B., & Schmukle, S. C. (2011). Stability and change of personality across the life course: The impact of age and major life events on mean-level and rank-order stability of the Big Five. *Journal of Personality and Social Psychology, 101,* 862–882. http://dx.doi.org/10.1037/a0024950

Steiger, H. (1990). Structural model evaluation and modification. *Multivariate Behavioral Research, 25,* 173–180. http://dx.doi.org/10.1207/s15327906mbr2502_4

Steinberg, L. (2008). A social neuroscience perspective on adolescent risk-taking. *Developmental Review, 28,* 78–106. http://dx.doi.org/10.1016/j.dr.2007.08.002

Suhr, J. A., & Tsanadis, J. (2007). Affect and personality correlates of the Iowa Gambling Task. *Personality and Individual Differences, 43,* 27–36. http://dx.doi.org/10.1016/j.paid.2006.11.004

Szrek, H., Chao, L.-W., Ramlagan, S., & Peltzer, K. (2012). Predicting (un)healthy behavior: A comparison of risk-taking propensity measures. *Judgment and Decision Making, 7,* 716–727.

Wagner, G. G., Frick, J. R., & Schupp, J. (2007). The German Socio-Economic Panel Study (SOEP): Scope, evolution and enhancements. *Journal of Applied Social Science Studies / Zeitschrift fur Wirtschafts- und Sozialwissenschaften, 127,* 139–169.

Weber, E. U., Blais, A.-R. E., & Betz, N. E. (2002). A domain-specific risk-attitude scale: Measuring risk perceptions and risk behaviors. *Journal of Behavioral Decision Making, 15,* 263–290. http://dx.doi.org/10.1002/bdm.414

Wortman, J., Lucas, R. E., & Donnellan, M. B. (2012). Stability and change in the Big Five personality domains: Evidence from a longitudinal study of Australians. *Psychology and Aging, 27,* 867–874. http://dx.doi.org/10.1037/a0029322

Zuckerman, M., & Kuhlman, D. M. (2000). Personality and risk-taking: Common biosocial factors. *Journal of Personality, 68,* 999–1029. http://dx.doi.org/10.1111/1467-6494.00124

Appendix

Overview of Assessment of Self-Report and Behavioral Measures of Risk

Variable	2004	2005	2006	2008	2009	2010	2011	2012	2013	2014	*N*
Risk propensities											
General	x		x	x	x	x	x	x	x	x	44,076
Driving	x				x					x	11,903
Financial	x				x					x	11,903
Recreational	x				x					x	11,903
Occupational	x				x					x	11,903
Health	x				x					x	11,903
Social	x				x					x	11,903
The Big Five											
Extraversion		x			x				x		11,903
Openness		x			x				x		11,903
Conscientiousness		x			x				x		11,903
Neuroticism		x			x				x		11,903
Agreeableness		x			x				x		11,903
Income	x	x	x	x	x	x	x	x	x	x	11,903
Experiments											
Lottery game		x									433
Trust game	x										646

Note. The lottery game was assessed in a pretest of the SOEP in 2005 and also included the domain-general risk-taking propensity item but not the domain-specific items.

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Manuscript 2

Age Differences in Risk-Taking Propensity
Are Related to Perceptions of Risk and Reward but not Perceived Control

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Abstract

Concordant evidence from survey and self-report measures suggests that the propensity to take risks decreases as a function of age but that the specific pattern differs across life domains. Yet, extant efforts to investigate the psychological mechanisms underlying these age-related changes or potential differences between domains are still scarce. Especially representative surveys, albeit providing a rich and representative data source, assess no psychological variables leaving open their explanatory power for such age-related trends. Using items from the risk aversion scale used in the German Socioeconomic Panel (SOEP), we investigated the extent to which changes in the perception of risks and benefits as well as perceived control may act as psychological mechanisms behind age-related changes in risk propensity. We conducted a representative survey (regarding sex, age, and education) of the population living in Germany and assessed risk-taking propensity, risk perception, expected benefits, and control beliefs associated with various domains of life, such as driving, financial, recreational, occupational, health, and social domains ($N = 1{,}786$). The results show that age is associated with (i) decreased self-reported risk propensity, (ii) perceived risk, and (iii) expected benefits of risky activities, but not perceived control. Changes in perceived risks and benefits, but not control beliefs, were able to account for the lifespan patterns in risk-taking propensity. Overall, our results support the view that domain-specific perceptions of benefits and risk vary across individuals and age cohorts and inform estimates of risk-taking propensity.

Keywords: risk taking, adult lifespan, domain specificity, risk perception, expected benefit, control belief

Age Differences in Risk-Taking Propensity Are Related to Perceptions of Risk and Reward but not Perceived Control

With life expectancy increasing around the globe, more and more older individuals are forced to reckon with risk and uncertainty in the financial, health, and other domains (Agarwal, Driscoll, Gabaix, & Laibson, 2009; Vaupel, 2014). A common view on aging is that it is accompanied with more caution and increased risk aversion (e.g., Botwinik, 1966; Calhoun & Hutchinson, 1981; Okun, 1976; Quetelet, 1842). This conforms with evidence from survey and self-report measures that show an overall decrease in risk-taking propensity with advancing age (Dohmen, Huffman, Schupp, Falk, Sunde, & Wagner, 2011; Mandal & Roe, 2014; Roalf, Mitchell, Harbaugh, & Janowsky, 2011; Rolison, Hanoch, Wood, & Liu, 2013; Rosman, Garcia, Lee, Butler, & Schwartz, 2013). Despite such a general trend of age-related decrease in self-reported risk propensity, patterns of age-related change vary considerably across domains, such as recreational, financial, or social domains (Bonem, Ellsworth, & Gonzalez, 2015; Josef, Richter, Samanez-Larkin, Wagner, Hertwig, & Mata, in press; Roalf et al. 2011; Rolison et al., 2013; Rosman et al. 2013; Schwartz et al., 2013). For example, while older individuals may forego certain dangerous recreational activities–say bungee jumping or mountain biking–other activities such as taking the risk of trusting and relying on others may remain indispensible or even increasingly important in older age, thus contributing to differential decline in risk-taking propensity across domains. Regrettably, investigations of the psychological mechanisms behind these age-related and domain-specific changes are still scarce (Bonem et al., 2015; Roalf et al., 2012; Rosman et al., 2013). Especially panel data sets provide a rich data source for the investigation of developmental trends of self-reported risk taking propensity but provide no variables to test the psychological background of such changes. We here aim to fill this gap and to provide an explanation as to *why* aging leads to, in general, decreased risk-taking propensity and does so differentially for separate life domains. In particular, we test the extent to which individual differences in the perceptions of risks, benefits and control can account for the domain-specific age-related patterns in risk taking using survey items adopted from the German Socioeconomic Panel Study (SOEP).

A cost-benefit approach to risk taking

The risk-return framework suggests that individual and domain differences in risk taking are a function of a risky behavior's perceived risks/costs and its expected benefits (Figner & Weber, 2011; Hanoch, Johnson, & Wilke, 2006; Weber, Blais, & Betz, 2002). To measure those perceptions across a number of risky behaviors in different life domains, Weber and colleagues developed a Domain-Specific Risk-Taking Scale in which risk taking is measured together with two additional scales assessing perceived risks and expected benefits of specific risky activities (DOSPERT; Blais & Weber, 2006; Weber et al., 2002). Using this questionnaire, previous research has found robust effects of individual differences in risk perceptions and expected benefits on self-reported risk taking. For example, women's overall lower level of risk taking shows to be linked to their higher risk perception and lower expectation of benefits of taking risks (Byrnes, Miller, & Schafer, 1999; Harris, Jenkins, & Glaser, 2006). Aging is associated with normal changes in resources, such as decline in cognitive and physical abilities and the social network (e.g. death of spouse). Experiencing such decline across domains, the overall behavior motivation may alter from a primary focus of accruing gains to preventing or slowing down losses (Baltes, 1997; Baltes & Smith, 2003). This change likely influences older individuals' expectations about the benefits and costs of engaging in certain behaviors. Consequently, the risk-return framework would suggest that changes in perceived costs and benefits could account for observed age and sex differences in risk-taking propensity in different domains of life.

How are perceptions and risk-taking behaviors conjoined? Risk taking and perceived benefits of a specific behavior are likely to be positively associated: Individuals are more prone to engage in risky behaviors that promise higher rewards. The link between the perception of how risky an activity is and the willingness to engage in it is less straightforward. Perceiving an activity to be risky may be negatively associated with risk taking because activities perceived to be highly risky may exceed an individuals' threshold for possible losses (Blais & Weber, 2006). Consequently, age-related decreases in risk taking may co-occur with increases in the perception of risks and feelings of vulnerability to negative outcomes (Bonem et al., 2015; Moser, Spagnoli, & Santos-Eggimann, 2011). At the same time, risk and reward are often positively correlated (Pleskac & Hertwig, 2014) and positive correlations between risk taking and risk perception have been observed in the literature (e.g., Johnson, McCaul, & Klein, 2002; Mills, Reyna, & Estrada, 2008, Weinstein, 1988). Individuals who engage in risky activities, say, unprotected sex or mountain biking may very well realize their potential costs but still engage in them because of their perceived benefits or because they underestimate the chance of possible negative consequences to themselves. For example, some older adults may be aware of the potential dangers associated with driving but still engage in it because of its perceived benefits (e.g., individual mobility). Alternatively, age may decrease risk perception due to changes in the available set of risky behaviors (e.g. older adults may not drive at night and keep more distance to other drivers and thus reduce their overall level of risk taking).

The role of control beliefs

Another psychological dimension that may underlie risk taking is the belief about the own ability to influence and control life circumstances, that is, the perceived level of control (Bandura, 2006; Skinner, 1996). This belief has been identified as an important determinant of risk perceptions (Slovic, 1987; Ruthig, Chipperfield, Bailis, & Perry, 2008). Individuals engaging in risky activities tend to perceive higher control over the respective behavior (Nordgren, van der Pligt, & van Harreveld, 2007). Since diverse physical and cognitive resources decline in old age (Lindenberger, 2014; Salthouse, 2010), older adults may sense a concurrent decline in perceived control in those domains most affected by declining resources

(Baltes & Smith, 2003). Alternatively, however, it has been argued that notwithstanding older age, individuals are able to maintain a relatively constant level of perceived control. They do so by adapting their strategies to exert control and adjusting their standards of comparison. Consequently, aging does not necessarily lead to reduced perceived control across the board (Heckhausen, Wrosch, & Schulz, 2010); instead, decline in perceptions of control vary across roles and domains (Krause, 2007; Lachman & Weaver, 1998; McAvay, Seeman, & Rodin, 1996). For example, Lachman and Weaver showed an increase in perceived control over work and finances with increasing age, but a decrease in control over one's relationship with children. This suggests that, depending on the domain, perceiving increasingly less control may be associated with a decreasing risk propensity in this domain. For instance, the less control people sense to have over their health with age (e.g., the development of cancer with age), the less they are willing to take risks (e.g., quit smoking; e.g. Windsor, Anstey, & Walker, 2008). Differences in risk-taking propensity between individuals and age groups may thus be prompted by concurrent differences in risk perceptions, expected benefits, and perceived control.

Age-related changes in risk-taking propensity

Concurrent research investigating age-related changes of self-reported risk-taking propensity has relied on two major sources of measurement to elicit risk preferences concerning different domains of life. One is via representative panel studies such as the German Socioeconomic Panel Study (SOEP, Wagner, Frick, & Schupp, 2007; Dohmen et al., 2011); the second is via the domain-specific risk-taking propensity scale (DOSPERT, Weber, Blais, & Betz, 2002). Both data sources show converging evidence for reduced risk-taking propensity with advancing age across different life domains (Dohmen et al., 2011; Mandal & Roe, 2014; Roalf et al., 2011, Rolison et al., 2013; Rosman et al., 2013). Studies using the DOSPERT support the notion of an age-related increase in risk perceptions along with decreased expected benefits of risky actions that may explain this prominent decline of self-reported risk propensity across the lifespan (Bonem et al., 2015; Roalf et al., 2011). Recent work using longitudinal panel data from the SOEP showed that the longitudinal changes in different age cohorts are largely consistent with the prominent cross-sectional changes in most domains of life (Josef et al., in press). Regrettably, this panel data is mute about the psychological mechanisms driving these changes leaving open a direct test of the explanatory role of such psychological variables for age-related changes in self-reported risk taking. No study has yet explored the role of perceived control on risk taking in different domains across the lifespan.

The current study aims to contribute to this issue. We collected an extensive cross-sectional data set representative of the German population and asked individuals of different ages to report their risk-taking propensity along with their risk perceptions across a number of domains (i.e., driving, financial, recreational, occupational, health, and social). The risk items used were adapted from a risk aversion scale used in the German Socioeconomic Panel Study (SOEP). Our overall goal is to quantify the extent to which age differences in perceptions of rewards, risks, and controllability can account for the declining but domain-specific mean-level changes of risk-taking propensity across the lifespan using such survey items.

Methods

Sample

We commissioned a survey company (Gesellschaft fuer Konsumforschung, one of the largest commercial market research institutes in Europe, www.gfk.de) to conduct face-to-face and computer-assisted personalized interviews (CAPI) in a representative sample (on age, sex and education) of the population living in Germany (see Table 1 for demographic characteristics). Survey participation was voluntary and participants did not receive monetary compensation for their participation. The Ethics Committee of the Max Planck Institute for Human Development approved the data collection procedure, data utilization for research purposes, and confirmed accordance with German data protection regulations. Because sample size in the initial sample for very young and very old ages were low ($N < 15$), we restricted our sample to an age range of 20-75 years of age ($M = 49.5$; $SD = 14.8$; 55% female) to avoid biasing estimates for extreme ages though outliers when estimating the age trajectories ($N = 1{,}786$; see Lucas & Donnellan, 2009, for a similar approach). More detailed information about the age distribution can be found in the Appendix (Table A1, Figure A1).

Items and procedure

Respondents were first asked to report risk-taking propensity separately for six different risk domains (driving, financial, recreational, occupational, health, and social risk taking) and on a general risk-taking propensity item. These items were adapted from those used in the risk aversion scale in the German Socio-Economic Panel (SOEP, www.leibniz-soep.de; see also Dohmen et al., 2011), a large-scale representative survey of the population living in Germany. This scale comprises one item for general risk taking and six items covering domain-specific risk-taking propensity in the domains mentioned above. Since their first administration in the SOEP in 2004, the items – particularly the general risk-taking propensity item–have been used in numerous scientific analyses on risk taking (e.g., Benjamin et al. 2012; Bonin, Dohmen, Falk, Huffman, & Sunde, 2009; Lönnqvist, Verkasalo, Walkowitz, & Wichardt, 2011; Szrek, Chao, Ramlagen, & Peltzer, 2012).

Following the risk items, participants were asked to report their perceived risk, expected benefits and control beliefs in each of the six life domains. The instructions for these items were adapted from the DOSPERT (German translation, see Johnson, Wilke, Weber, 2004) to reliably differentiate between risk taking and perceptions of risk. The instructions of the perceived-control items were adapted from Lachman and Weaver (1998). The order of items was not randomized and thus the same for each participant.

All items were accompanied by a 1–10 Likert scale, with the risk-taking propensity item running from *"not at all willing to take risks"* to *"very willing to take risks"*, and the remaining items from *"not at all risky/no benefits at all/no control at all"* to *"extremely* *risky/great benefits/everything under control"* (see also Supplemental Materials file for the original items used). All respondents answered *one item per domain* after having read the following instructions for each item:

(1) Risk taking: "People can behave differently in different situations. How would you rate your willingness to take risks in the following domains? For each one, please indicate your *likelihood of engaging in a risky activity or behavior* in this domain."

(2) Perceived risk: "People often see some risk in situations that contain uncertainty about what the outcome or consequences will be and for which there is a *possibility of negative consequences*. However, riskiness is a very personal and intuitive notion, and we are interested in your gut level assessment of risk. How would you rate your *intuitive notion of risk perception* in these different domains?"

(3) Expected benefits: "People often see some risk in situations that contains uncertainty about what the outcome or consequences will be and for which there is the possibility of negative consequences. Whether people engage in risky behavior or actions also depends on the expected benefits obtained from that behavior or action. For each of the following domains, please indicate the *benefits you would obtain from a risky behavior or action* in these domains."

(4) Control belief: "People often feel different levels of control over domains of life. How would you rate your personal level of perceived control in the domains listed below? Your answer represents your subjective estimate or *feeling of control* in this life domain."

Statistical analysis

We first estimated the cross-sectional patterns of risk-taking propensity, risk perception, expected benefits and perceived control from young to old age in the six different domains in our sample. For this purpose, we used multiple regression models in R (RCore Team, 2015). Specifically, we followed a stepwise approach when considering the role of different predictors, namely, age, sex, and their interactions on the dynamics of the dependent variable. First, we analyzed the relation of age by including age, age^2, and age^3 as covariates. Age was mean-centered and regression estimates therefore represent the dependent variable at the mean sample age (49.5 years of age). We decreased model complexity by testing for linear and quadratic age effects when the cubic effect was not significant and did not show significant improvement in model fit. We added sex as a covariate and the interaction of each of the age terms with sex to the model. We report the interactions of age and sex when they proved significant and provided significant increase in overall model fit.

Second, we tested whether the covariates *perceived risk*, *expected benefits*, and *control beliefs* can account for the age-related patterns in risk-taking propensity. To do this, we included these variables as well as their interactions with each of the age terms as additional predictors into multiple regression models when predicting self-reported risk-taking propensity.

The data file and R scripts documented in this manuscript are made publicly available (https://osf.io/gnkcu/).

Results

Lifespan trajectories of self-reported risk propensity

We obtained both effects of age and sex on domain-general and domain-specific risk-taking propensity (see Table 2). Figure 1 and 2 show the age patterns of the models reported in Table 2 superimposed on heat plots of the raw data obtained from kernel density estimates of the frequency of self-reported risk propensity for each age. Overall, age showed a negative correlation to self-reported risk-taking propensity levels in all domains. Domain-general risk-taking propensity showed a quadratic age-related pattern with lowest risk-taking propensity ratings towards the end of the lifespan. The pattern for the domain-specific risk items, followed different age trends depending on the life domain. The steepest linear declines were evident in the recreational domain (–0.61 points decrease on the Likert scale per decade), followed by the health and social domain (–0.27 points decrease in risk taking propensity per decade), and the financial domain (–0.24 points decrease in risk taking propensity per decade). Risk taking in the driving and occupational domain revealed a quadratic pattern of risk propensity across the lifespan. In particular, risk propensity in the driving domain showed slight increases until young adulthood (0.10 increase in risk-taking propensity until 30 years of age) followed by a steady decrease until old age (average of –0.43 points decrease per decade). Risk propensity in the occupational domain showed decreases from thirty years of age on: Mean-level differences were smallest between 20 and 30 years of age (–0.11 points decrease) relative to differences between the other decades (average of –0.61 points decrease). Independent of age trends, females reported on average lower levels of risk-taking propensity relative to males on all risk items. We also conducted similar analyses including a number of demographic control variables such as education, income, and occupational and marital status. All these led to a comparable pattern of results concerning the age and sex described above (see Supplemental Material Table S1).

Notwithstanding these differences in the domain-dependent trajectories of risk propensity, the most general phenomenon is that self-reported risk-taking propensity decreases, in different ways, with age. Therefore, it is not surprising that one observes moderate inter-correlations of ratings between the different domains (ranging from r = .35 to r = .57; see Table 3). This suggests that there is substantial joint variance in the cross-sectional ratings of risk taking propensity across the lifespan. Individuals that indicate to engage in risk in one domain also indicate to engage in risk in most other domains. Yet, correlations are slightly different in the different domains echoing the finding of domain-specific lifespan trajectories of risk taking propensity.

The explanatory role of perceptions

Figure 2 (column 2-4) illustrates the lifespan patterns of perceptions of risk, benefits, and controllability. Overall, the results show substantial effects of age and sex on self-reported risk perception and expected benefits of risk. More precisely, perceptions of risk and benefits show steady declines across the adult lifespan but the declines are also different across domains. For example, while risk perception and expected benefits in the occupational domain followed a quadratic function across the lifespan, most other domains showed a linear decrease with age. Regarding sex the results show that females report overall lower levels of perceived risks and expected benefit relative to males. The results for perceptions of control are quite different though (Figure 2, column 4). Here we obtained only small effects of age and sex on self-reports with the level of perceived control proving relatively stable across the lifespan (see Supplemental Materials Table S2-4 file for regression estimates of age and sex on risk perceptions, expected benefits, and perceived control). Note that there are also significant correlations between ratings in different domains for risk perceptions (*r*s = .39–.64), expected benefits (*r*s = .35–.53), and control beliefs (*r*s = .34–.53) indicating again substantial joint variance of these perceptions in different domains.

To learn more about the explanatory role of perceptions of risk, benefits and controllability for risk propensity across the lifespan, we run separate regression analyses including these variables as well as their interaction with age as covariates. Overall, the results show that the inclusion of measures of perception eliminates the effects of age and thus the typical age-related pattern on risk-taking propensity across domains. Yet, regression estimates show that this can solely be attributed to the impact of the predictors of risk perception and expected benefit. Control beliefs, in contrast, do not show to be a significant predictor for risk-taking propensity in any of the domains (Table 4). Additional analyses that considered each predictor independently support this conclusion: Perceptions of risk and benefits, by themselves, can be used to reduce or eliminate age effects; this is not the case for control beliefs. Note that risk perceptions and expected benefits, the two significant predictors, are not redundant, with correlations ranging from .13 to .55 across the different domains (see Supplemental Materials file, Table S5).

Discussion

There is converging evidence from self-report and representative panel data sets that aging goes along with domain-specific reductions in (self-reported) risk-taking propensity (Dohmen et al., 2011; Josef et al. in press; Mandal & Roe, 2014; Roalf et al., 2011; Rolison et al., 2013). The risk-return framework offers a psychological framework of domain- and age-related differences in risk-taking propensity and there are a few studies that show that risk perceptions and expected benefits change significantly with age (e.g. Bonem et al., 2015; Rosman et al., 2013). Regrettably, existent evidence from survey data is mute about the psychological mechanisms driving these changes. Our goal was to examine the extent to which perceptions of risk, expected benefits, and controllability are associated with the typical pattern of age-related decline in risk-taking propensity and with different patters of decline between domains. To this end, we analyzed cross-sectional data from a large representative survey of adults between 20 and 75 years of age from Germany (*N* = 1,786) using items adapted from the German Socioeconomic Panel Study (SOEP).

We found three major results consistent with results reported in previous studies. First, self-reported risk-taking propensity showed reliable mean-level decreases across the adult lifespan in both males and females. Second, the lifespan trajectories varied substantially depending on the domain, with some domains yielding flatter decline than others. Specifically, risk taking propensity in the social, financial, and health domain showed less pronounced declines across the adult lifespan relative to the recreational, occupational, and driving domains. Third, and most importantly, our results suggest that perceptions of risk and benefits, but not control beliefs, predict domain-dependent and age-related differences in risk-taking propensity. The association between these perceptions, however, was contrary to what has been found previously in the literature.

What explains both the default decline in the risk-taking propensity and somewhat domain-specific deviations from this default (Figure 2)? One possibility is that some domains more than others afford the individual to more easily abandon risky activities and substitute them with others, without compromising quality of life. Attenuating risks by crowding out increasingly daring with less daring activities (e.g., mountain biking is swapped for hiking) is, in principle, an adaptive strategy with increasing age. It avoids *unnecessary* harm, thus making it easier to manage and maintain physical well-being and health (Brandtstädter, Wentura, & Rothermund, 1999; Duke, Leventhal, Brownlee, & Leventhal, 2002). Crowding out specific activities could also explain why, in general, perception-of-risk ratings do not grow with age but rather tend to decline (Figure 2). An individual would perhaps, perceive mountain biking as increasingly riskier when he or she gets older. Hiking, in contrast, may be perceived as less risky. The same principle may apply to perceived control: Swapping biking with hiking may maintain a relative high level of control albeit perhaps at the cost of less satisfaction or perceived benefits. Crowding out activities, however, has limits. Mountain bikes and motorcycles can be sold but the same logic may not apply to all domains. For interpersonal exchanges, financial activities, and health-related decisions this may be more difficult. Take, for instance, social risk taking such as trusting others. Social interactions and support may, if anything, be even more important with increased age (Baltes, 1997; Okun & Schultz, 2003; Seeman, Lusignolo, Albert, & Berkman, 2001). These results also fit ideas about social and emotional involvement across the lifespan, at large. That is, past research has shown that social and emotional information remains prioritized with respect to broader life goals across adulthood (Carstensen, 1995; Carstensen, Isaacowitz, & Charles, 1999). In addition, despite thinning of social network size, there is evidence that older individuals continue to be socially engaged more frequently and more emotionally with their closest relationships compared to younger adults (Fredrickson & Carstensen, 1990).

What explains the somewhat different association between risk propensity and risk perceptions found in our present investigation? There is research arguing that preferences can be conceptualized as the product of memory representations and memory processes (Weber &

Johnson, 2006). That is, judgments about risks are formed by retrieving relevant knowledge about risks (e.g., attitudes, previous events, or activities) from memory. It is very likely that the quantity and quality of information that individuals have about risks in different domains of their life depends on the salience and accessibility of those particular risks in their environment and to their particular age group (Hertwig, Pachur, & Kurzenhäuser, 2005; Lichtenstein, Slovic, Fischhoff, Layman, & Combs, 1978). As noted above, depending on the domain, older people may substitute riskier and demanding activities, and the age-related and domain-specific changes in perceptions of risk, benefit and controllability are a function of the set of activities that are only partly overlapping for younger and older people and thus retrieved from memory. Another possibility is that older people continue (as much as possible) to engage in still the same activities but reduce their difficulty and risk levels (e.g., less demanding mountain bike tours), and the perceptions reflect these adjustments in difficulty. Still another possibility is that when individuals respond to questions related to their risk-taking propensity and perceptions thereof, they invoke age-related stereotypes and beliefs that are widespread in the population (Konradt, & Rothermund, 2011) rather than consulting their own behavior. In line with this idea, past research has shown that individuals have a much better representation about the risks faced by their own age group rather than the population at large (Benjamin, Dougan, & Buschena, 2001; Benjamin & Dougan, 1997).

Further work is necessary to uncover the memory and judgment mechanism that underlie the link between risk perceptions and risk taking across the lifespan. For example, in order to examine which of these or other mechanisms is the most likely one, future studies will need to go beyond our procedure and those of numerous previous studies, namely, to have respondents judge and possibly even generate specific activities. By only specifying relatively broad domains, one leaves it up to the respondent to decide on what mnemonic basis he or she aims to construct an answer (e.g., sampling actual behaviors from memory; sampling stereotypes; sampling extreme and rare behavior or common and frequent behavior).

Clearly, general versus specific items can trigger different sets of representations that may, in turn, lead to varying correlations between perceived risks and benefits (Mills et al., 2008; Gerrard, Gibbons, & Bushman, 1996) and perceived control (Ruthig et al., 2003). This difference in item specificity, in turn, may drive the relationship between risk taking and perception across the lifespan.

In sum, our and past results suggest a general declining trend in risk-taking propensity with age but also domain-specific changes in this default trajectory. What was largely unknown is what drives these commonalities and differences. We show that changes in perceived risks and benefits, but not control beliefs, were able to account for the observed domain-specific lifespan patterns in risk-taking propensity using items adapted from the German Socioeconomic Panel Study (SOEP). Uncovering the mechanisms underlying the perception of risks and benefits constitutes an important direction for future work necessary to understand the domain-specificity of age differences in risk taking.

References

Agarwal, S., Driscoll, J. C., Gabaix, X., & Laibson, D. (2009). The Age of reason: Financial decisions over the life cycle and implications for regulation. *Brookings Papers on Economic Activity*, 51–101. doi:10.2307/25652729

Baltes, P. B. (1997). On the incomplete architecture of human ontogeny: selection, optimization, and compensation as foundation of developmental theory. *American Psychologist*, *52*(4), 366–380. doi:10.1037/0003-066X.52.4.366

Baltes, P. B., & Smith, J. (2003). New frontiers in the future of aging: From successful aging of the young old to the dilemmas of the fourth age. *Gerontology*, *49*(2), 123–135. doi:10.1159/000067946

Bandura, A. (2006). Toward a psychology of human agency. *Perspectives on Psychological Science*, *1*(2), 164–180. doi:10.2307/40212163

Blais, A.-R., & Weber, E. U. (2006). A Domain-Specific Risk-Taking (DOSPERT) scale for adult populations. *Judgment and Decision Making, 1*(1), 33-47.

Benjamin, D. J., Cesarini, D., van der Loos, M. J. H. M., Dawes, C. T., Koellinger, P. D., & Magnusson, P. K. E. (2012). The genetic architecture of economic and political preferences. *Proceedings of the National Academy of Sciences*, *21*, 8026–8031. doi:10.1073/pnas.1120666109

Benjamin, D. K., & Dougan, W. R. (1997). Individuals' estimates of the risks of death: Part I–A reassessment of the previous evidence. *Journal of Risk and Uncertainty, 15*(2), 115–133-

Benjamin, D. K., Dougan, W. R., & Buschena, D. (2001). Individuals' estimates of the risks of death: Part II–New evidence. *Joural of Risk and Uncertainty, 22*(1), 35–57. doi

Bonem,, E. M.; Ellsworth, P. C., & Gonzalez, R. (2015). Age differences in risk: Perceptions, intentions, and domains. *Journal of Behavioral Decision Making*, 28(4), 317–330. doi: 10.1002/bdm.1848

Bonin, H., Dohmen, T., Falk, A., Huffman, D., & Sunde, U. (2007). Cross-sectional earnings risk and occupational sorting: The role of risk attitudes. *Labour Economics*, *14*, 926–937. doi:10.1016/j.labeco.2007.06.007

Botwinik, J. (1966). Cautiousness in advanced age. *Journal of Gerontology*, *21*(3), 347–353. doi:10.1093/geronj/21.3.347

Brandtstädter, J., Wentura, D., & Rothermund, K. (1999). Intentional self- development through adulthood and later life: Tenacious pursuit and flexible adjustment of goals. In J. Brandtstadter & R. M. Lerner (Eds.), *Action and self-development: Theory and research through the life span* (pp. 373–400). Thousand Oaks, CA: Sage.

Byrnes, J. P., Miller, D. C., & Schafer, W. D. (1999). Gender differences in risk taking: A meta-analysis. *Psychological Bulletin*, *125*(3), 367–383. doi:10.1037/0033-2909.125.3.367

Carstensen, L. L. (1995). Evidence for a life-span theory of socioemotional selectivity. *Current Directions in Psychological Science, 4*(5), 151–156. doi:10.1111/1467-8721.ep11512261

Carstensen, L. L., Isaacowitz, D. M., & Charles, S. T. (1999). Taking time seriously: A theory of socioemotional selectivity. *American Psychologist, 54*(3), 165–181. doi:10.1037/0003-066X.54.3.165

Calhoun, R. E., & Hutchinson, S. L. (1981). Decision-making in old age: Cautiousness and rigidity. *The International Journal of Aging and Human Development*, *13*(2), 89–98. doi:10.2190/LFUA-4KR0-B0QX-M584

Dohmen, T., Huffman, D., Schupp, J., Falk, A., Sunde, U., & Wagner, G. G. (2011). Individual risk attitudes: Measurement, determinants, and behavioral consequences. *Journal of the European Economic Association*, *9*(3), 522–550. doi:10.2307/25836078

Duke, J., Leventhal, H., Brownlee, S., & Leventhal, E. A. (2002). Giving up and replacing activities in response to illness. *The Journals of Gerontology, Series B: Psychological Sciences and Social Sciences, 57*(4), 367–376. doi:10.1093/geronb/57.4.P367

Figner, B., & Weber, E. U. (2011). Who takes risks when and why? Determinants of risk taking. *Current Directions in Psychological Science, 20*(4), 211–216. doi:10.1177/0963721411415790

Fredrickson, B. L., & Carstensen, L. L. (1990). Choosing social partners: How old age and anticipated endings make people more selective. *Psychology and Aging, 5*(3), 335–347. doi:10.1037/0882-7974.5.3.335

Gerrard*,* M., Gibbons E. X., & Bushman, B. J. (1996). Does perceived vulnerability to HIV motivate precautionarysexual behavior? A critical review of the literature. *Psychological Bulletin, 119*, 390-409.

Hanoch, Y., Johnson, J. G., & Wilke, A. (2006). Domain specificity in experimental measures and participant recruitment: An application to risk-taking behavior. *Psychological Science*, *17*(4), 300–304. doi:10.1111/j.1467-9280.2006.01702.x

Harris, C. R., Jenkins, M., & Glaser, D. (2006). Gender differences in risk assessment: Why do women take fewer risks than men. *Judgment and Decision Making, 1*(1), 48–63.

Heckhausen, J., Wrosch, C., & Schulz, R. (2010). A motivational theory of life-span development. *Psychological Review*, *117*(1), 32–60. doi:10.1037/a0017668

Hertwig, R., Pachur, T., & Kurzenhäuser, S. (2005). Judgments of risk frequencies: Tests of possible cognitive mechanisms. *Journal of Experimental Psychology: Learning, Memory, and Cognition. 31*(4), 621–642. doi: 10.1037/0278-7393.31.4.621

Johnson, E. J., McCaul, K. D., & Klein, W. M. P. (2002). Risk involvement and risk perception among adolescents and young adults. *Journal of Behavioral Medicine, 25*(1), 67–82. doi:10.1023/A:1013541802282

Johnson, J., Wilke, A., Weber, E. U. (2004). Beyond a trait view of risk taking: A domain-specific scale measuring perceptions, expected benefits, and perceived-risk attitudes in German-speaking populations. *Polish Psychological Bulletin*, *35*, 153-172. Available at SSRN: http://ssrn.com/abstract=1301128

Josef, A. K., Richter, D., Samanez-Larkin, G. R., Wagner, G. G., Hertwig, R., & Mata, R. (in press). Stability and change in risk-taking propensity across the adult lifespan. *Journal of Personality and Social Psychology.*

Konradt, A. E., & Rothermund, K. (2011). Contexts of aging: Assessing evaluative age stereotypes in different life domains. *The Journals of Gerontology, Series B: Psychological Sciences and Social Sciences, 66*(5), 547–556. doi:10.1093/geronb/gbr036

Krause, N. (2007). Age and decline in role-specific feelings of control. *Journals of Gerontology Series B-Psychological Sciences and Social Sciences*, *62*(1), 28–35. doi: 10.1093/geronb/62.1.S28

Lachman, M. E., & Weaver, S. L. (1998). Sociodemographic variations in the sense of control by domain: Findings from the MacArthur studies of midlife. *Psychology and Aging*, *13*(4), 553–562. doi:10.1037/0882-7974.13.4.553

Lichtenstein, S., Slovic, P., Baruch, F., Layman, M., & Combs, B. (1978). Judged frequency of lethal events. *Journal of Experimental Psychology: Human Learning and Memory, 4*(6), 551–578. doi: 10.1037/0278-7393.4.6.551

Lindenberger, U. (2014). Human cognitive aging: Corriger la fortune? *Science, 346*(6209), 572–578. doi:10.1126/science.1254403

Lönnqvist, J.-E., Verkasalo, M., Walkowitz, G., & Wichardt, P. C. (2011). Measuring individual risk attitudes in the lab: Task or ask? An empirical comparison. *CESifo Working Paper No. 4663.*

Lucas, E. L. & Donnellan, B. (2009). Age differences in personality: Evidence from a nationally representative Autralian sample. *Developmental Psychology, 45*(5), 1353–1363. doi:10.1037/a0013914

Mandal, B., & Roe, B. E. (2014). Risk tolerance among National Longitudinal Survey of Youth participants: The effects of age and cognitive skills. *Economica*, *81*(323), 522–543. doi:10.1111/ecca.12088

McAvay, G. J., Seeman, T. E., & Rodin, J. (1996). A longitudinal study of change in domain-specific self-efficacy among older adults. *Journals of Gerontology, Series B-Psychological Sciences and Social Sciences*, *51*(5), 243–253. doi: 0.1093/geronb/51B.5.P243

Mills, B., Reyna, V. F., & Estrada, S. (2008). Explanaining contradictory relations between risk perception and risk taking. *Psychological Science, 19*(5), 429–433. doi:10.1111/j.1467-9280.2008.02104.x

Moser, C., Spagnoli, J., & Santos-Eggimann (2011). Self-perception of aging vulnerability to adverse outcomes at the age of 65-70 years. *The Journals of Gerontology, Series B: Psychological Sciences and Social Sciences, 66*(6), 675–680. doi:10.1093/geronb/gbr052

Nordgren, L. F., van der Pligt, J., & van Harreveld, F. (2007). Unpacking perceived control in risk perception: the mediating role of anticipated regret. *Journal of Behavioral Decision Making*, *20*(5), 533–544. doi:10.1002/bdm.565

Okun, M. A. (1976). Adult age and cautiousness in decision. *Human Development, 19*(4), 220– 233. doi:10.1159/000271530

Okun, M. A. & Schultz, A. (2003). Age and motives for volunteering: Testing hypotheses derived from socioemotional selectivity theory. *Psychology and Aging, 18*(2), 231–239. doi:10.1037/0882-7974.18.2.231

Pleskac, T. J., & Hertwig, R. (2014). Ecological rational choice in a structured environment. *Journal of Experimental Psychology: General,143*(5), 2000–2019. doi:10.1037/xge0000013

Quetelet, A. (1969). *A treatise on man and the development of his faculties. A facsim. reproduction of the English translation of 1842, with an introd. by Solomon Diamond* (pp. xiii–x– 126 p.). Scholars' Facsimiles & Reprints Gainesville, Fla.

RCore Team (2015, March 30). R: A language and environment for statistical computing. Vienna, Austria: R Foundation for Statistical Compting. Retrieved from http://www.R-project.org/

Roalf, D. R., Mitchell, S. H., Harbaugh, W. T., & Janowsky, J. S. (2011). Risk, reward, and economic decision making in aging. *The Journals of Gerontology, Series B: Psychological Sciences and Social Sciences*, *67*(3), 289–298. doi:10.1093/geronb/gbr099

Rolison, J. J., Hanoch, Y., Wood, S., & Liu, P.-J. (2013). Risk-taking differences across the adult life span: a question of age and domain. *The Journals of Gerontology, Series B: Psychological Sciences and Social Sciences*, *69*(6), 870–880. doi:10.1093/geronb/gbt081

Rosman, A., Garcia, M., Lee, S., Butler, S., & Schwartz, A. (2013). DOSPERT+M: A survey of medical risk attitudes in the United States. *Judgment and Decision Making*, *8*(4), 470–481.

Ruthig, J. C., Chipperfield, J. G., Bailis, D. S., & Perry, R. P. (2008). Perceived control and risk characteristics as predictor of older adults' health risk estimates. *The Journal of Social Psychology, 148*(6), 667–688. doi:10.3200/SOCP.148.6.667-688

Salthouse, T. A (2010). Selective review of cognitive aging. *Journal of the International Neuropsychological Society, 16*(5), 754–760. doi:10.1017/S1355617710000706

Schwartz, A., Yamagishi, K., Hirahara, N., Onishi, H., Barnes, J., IV, Rosman, A., et al. (2013). Risk perception and risk attitudes in Tokyo: A report of the first administration of DOSPERT+M in Japan. *Judgment and Decision Making*, *8*(6), 691–699.

Seeman, T. E., Lusignolo, T. M., Marilyn, A., & Berkman, L. (2001). Social relationships, social support, and patterns of cognitive aging in healthy high-functioning older adults: MacArthur Studies of Successful Aging. *Health Psychology, 20*(4), 234–255. doi:10.1037/0278-6133.20.4.243

Skinner, E. A. (1996). A guide to construct of control. *Journal of Personality and Social Psychology, 71*(3), 549–570. doi:10.1037/002-3514.71.3.549

Slovic, P. (1987). Perception of risk. *Science*, *236*(4799), 280–285. doi: 10.1126/science.3563507

Szrek, H., Chao, L.-W., Ramlagen, S., & Peltzer, K. (2012). Predicting (un)healthy behavior: A comparison of risk-taking propensity measures. *Judgment and Decision Making*, *7*, 716–727.

Vaupel, J. W. (2014). Biodemography of human ageing. *Nature*, *464*(7288), 536–542. doi:10.1038/nature08984

Wagner, G. G., Frick, J. R., & Schupp, J. (2007). The German Socio- Economic Panel Study (SOEP): Scope, evolution and enhancements. *Journal of Applied Social Science Studies / Zeitschrift fur Wirtschafts- und Sozialwissenschaften, 127,* 139–169.

Weber, E. U., & Johnson, E. J. (2006). Constructing preferences from memory. In Lichtenstein, S. & Slovic, P. (Eds). *The Construction of Preference.* (p.397–410). New York, NY: Cambridge University Press

Weber, E. U., Blais, A.-R. E., & Betz, N. E. (2002). A domain-specific risk-attitude scale: measuring risk perceptions and risk behaviors. *Journal of Behavioral Decision Making*, *15*(4), 263–290. doi:10.1002/bdm.414

Weinstein, N. D. (1998). Accuracy of smokers' risk perceptions. *Annual Review of Behavioral Medicine, 20*, 135–140. doi:10.1007/BF02884459

Windsor, T. D., Anstey, K. J., & Walker, J. G. (2008). Ability perceptions, perceived control, and risk avoidance among male and female older drivers. *The Journals of Gerontology, Series B: Psychological Sciences and Social Sciences*, *63*(2), 75–83. doi: 10.1093/geronb/63.2.P75

Tables

Table 1.

Sample Characteristics

	%
Education	
Lower secondary education	35.6
Middle school	44.3
Highschool	10.2
University studies	9.8
Missing	0.1
Marital status	
Single	18.8
Married	65.8
Widowed/divorced	15.5
Occupational status	
Employed (full- & part-time)	62.4
Unemployed	5.2
Retired	23.8
Housewife/-husband	4.6
In apprenticeship	0.1
At school/university	2.9
Net monthly income	
<499€	8.1
500 – 749€	5.2
750 – 999€	14.2
1000 – 1249€	8.3
1250 – 1499€	15.2
1500 – 1999€	12.4
2000 – 2499€	9.6
2500 – 2999€	3.1
3000 – 3499€	2.1
3500 – 4999€	0.8
<4000	1.3
Missing	19.7

Table 2

Regression Models Describing the Effect of Chronological Age and Sex on Self-Reported Risk Propensity

	General (N = 1,786)			Driving (N = 1,786)			Financial (N = 1,786)			Recreational (N = 1,786)			Occupational (N = 1,786)			Health (N = 1,786)			Social (N = 1,786)		
Effect	Par.	*S.E.*	*p*	Par.	*S.E.*	*p*	Par.	*S.E.*	*p*	Par.	*S.E.*	*p*	Par.	*S.E.*	*p*	Par.	*S.E.*	*p*	Par.	*S.E.*	*p*
Intercept	5.031	.095	<.001	4.132	.101	<.001	3.016	.073	<.001	4.625	.086	<.001	4.781	.107	<.001	3.623	.083	<.001	4.526	083	<.001
Age	–.056	.003	<.001	–.039	.003	<.001	–.024	.003	<.001	–.061	.004	<.001	–.060	.004	<.001	–.027	.004	<.001	–.027	.004	<.001
Age^2	–.001	.0002	.008	–.001	.0002	.001							–.001	.0002	<.001						
Sex	–1.071	.106	<.001	–1.089	.113	<.001	–.565	.098	<.001	–.848	.114	<.001	–.651	.119	<.001	–.574	.111	<.001	–.354	.111	.001
AIC		7190			7405			6952			7474			7581			7376			7363	
BIC		7217			7432			6974			7496			7608			7397			7385	
R^2		.172			.110			.049			.157			.132			.045			.004	

Note. Age was mean-centered at the sample mean of 49.5 years; sex was dummy-coded (1 = female, 0 = male). Par. = Parameter; S.E. = standard errors. The sample included covers an age range of 20-75 years**.** More complicated models involving age polynomials and its interaction with gender were selected only when the inclusion of the higher order term improved overall model fit. Coefficients for age are reported from the final selected model. N =134 observations were deleted due to missingness.

Table 3

Intercorrelations of Self-Reported Domain-Specific Risk Propensity

	General	Driving	Financial	Recreational	Occupational	Health
Driving	.52					
Financial	.45	.48				
Recreational	.61	.51	.44			
Occupational	.61	.46	.48	.57		
Health	.43	.54	.43	.47	.40	
Social	.47	.41	.42	.45	.46	.35

Note. All correlations were significant at $p < .05$.

Table 4

Regression Models Describing the Effect of Chronological Age, Sex, Risk Perception, Expected Benefit and Control Belief on Self-Reported Risk Propensity

	Driving (N = 1,786)			Financial (N = 1,786)			Recreational (N = 1,786)			Occupational (N = 1,786)			Health (N = 1,786)			Social (N = 1,786)		
Effect	Par.	*S.E.*	*p*	Par.	*S.E.*	*p*	Par.	*S.E.*	*p*	Par.	*S.E.*	*p*	Par.	*S.E.*	*p*	Par.	*S.E.*	*p*
Intercept	1.210	.202	<.001	1.223	141	<.001	1.159	174	<.001	.745	.205	<.001	1.340	.177	<.001	1.065	212	<.001
Age	.027	.009	.004	.020	.009	.02	.004	.011	.68	–.0004	.009	.99	.014	.011	.20	.024	.011	.03
Age^2	–.0001	.0006	.86							–.0005	.0006	.37				.0002	.0007	.69
Sex	–.678	.093	<.001	–.353	.088	<.001	–.466	.089	<.001	–.237	.087	.007	–.350	.094	<.001	–.167	.088	.06
Perception	.322	.024	<.001	.157	.016	<.001	.421	.021	<.001	.473	.031	<.001	.385	.020	<.001	.361	.029	<.001
Age x Perception	–.004	.001	<.001	–.004	.001	<.001	–.003	.001	.02	.0009	.001	.12	–.007	.001	<.001	–.004	.001	.005
Age^2 x Perception	–.00006	.00008	.40							.0002	.00009	.547				–.00003	.00009	.73
Benefit	.399	.026	<.001	.251	.018	<.001	.314	.020	<.001	.309	.028	<.001	.241	.018	<.001	.391	.027	<.001
Age x Benefit	–.004	.001	.001	–.002	.001	.15	–.002	.001	.04	–.005	.001	<.001	.002	.001	.06	–.002	.001	.13
Age^2 x Benefit	–.0002	.00009	.01							–.0001	.00009	.23				–.000006	.00001	.50
Control Belief	.011	.026	.66	–.001	.014	.95	.026	.020	.18	.039	.025	.12	–.026	.019	.19	–.0005	.026	.85
Age x Control Belief	–.003	.001	.02	–.002	.0009	.05	–.002	.001	.18	.0000006	.002	.99	–.0001	.001	.28	–.002	.001	.15
Age^2 x Control Belief	.00003	.00008	.73							–.00003	.00007	.66				–.000008	.0001	.92
AIC		6713			6584			6606			6546			6795			6595	
BIC		6789			6639			6660			6621			6849			6670	
R^2		.418			.245			.505			.542			.330			.400	

Note. Age was mean-centered at the sample mean of 49.5 years; sex was dummy-coded (1 = female, 0 = male). Par. = Parameter; S.E. = standard errors. The sample included covers an age range of 20-75 years**.** More complicated models involving age polynomials and its interaction with gender were selected only when the inclusion of the higher order term improved overall model fit. Coefficients for age are reported from the final selected model. N = 134 observations were deleted due to missingness.

Figures

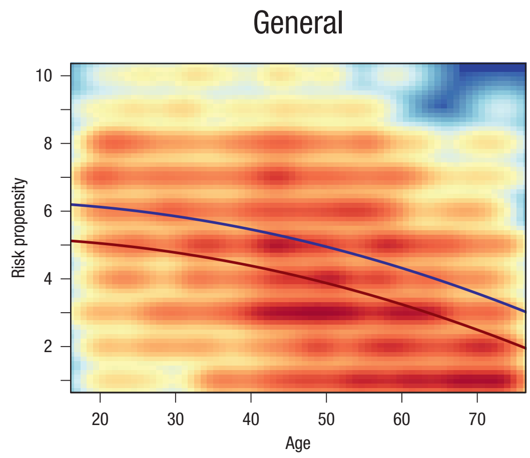

Figure 1. Lifespan trajectory of domain-general risk-taking propensity. Blue line = male, red line = female. Curves are plotted on a kernel density plot of the raw data (kernel width used for density estimation on x and y axis is 75).

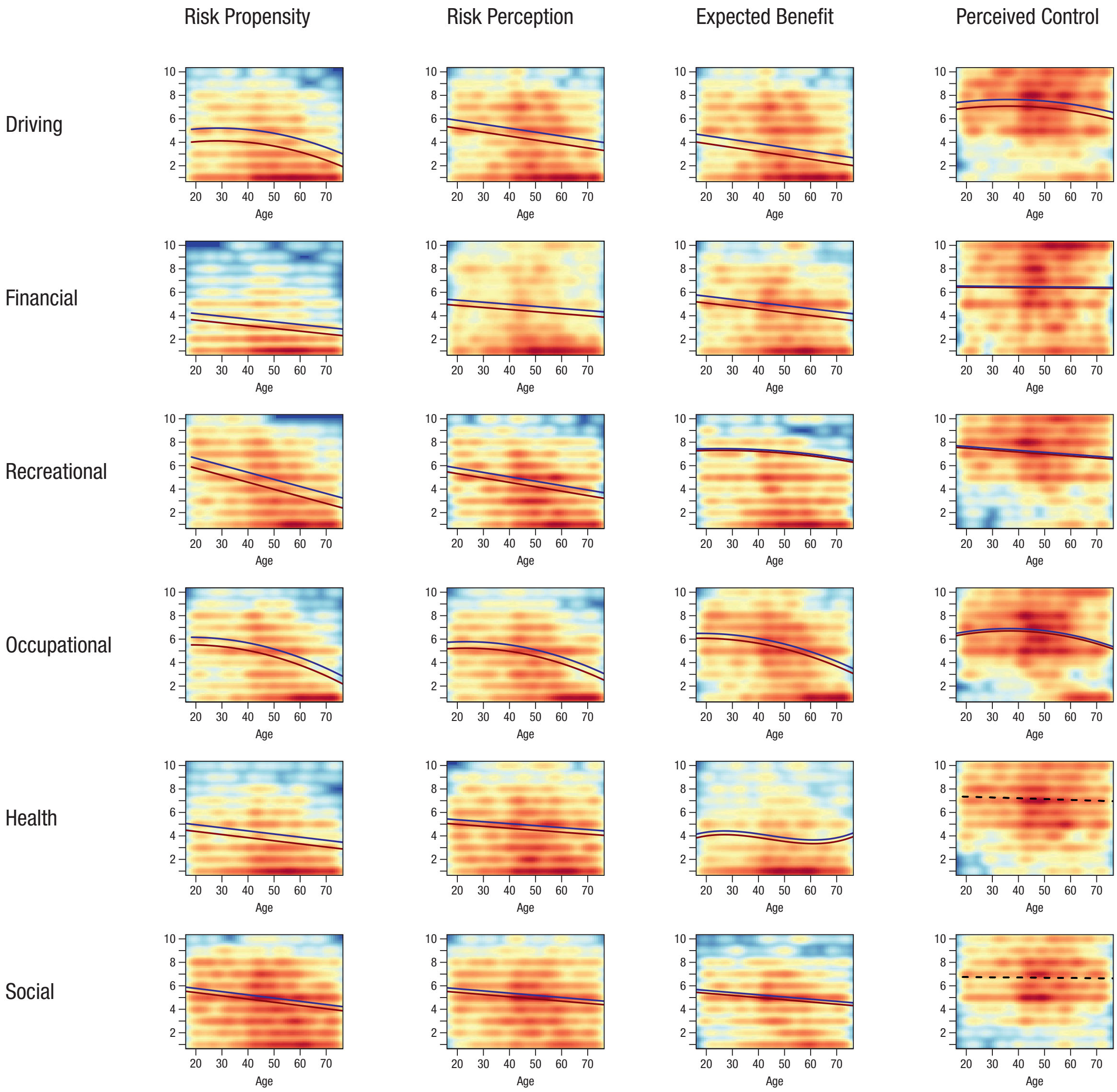

Figure 2. Lifespan trajectories of risk-taking propensity, risk perception, expected benefit, and perceived control in disparate domains of life obtained from regression models. Blue line = male, red line = female. Dashed line indicates no sex differences. Curves are plotted on a kernel density plot of the raw data (kernel width used for density estimation on x and y axis is 75).

Appendix

Table A1. *Distribution of Sample Age*

Age	N	%
20	17	1.0
21	21	1.2
22	26	1.5
23	33	1.8
24	16	0.9
25	20	1.1
26	22	1.2
27	22	1.2
28	23	1.3
29	20	1.1
30	23	1.3
31	23	1.3
32	17	1.0
33	29	1.6
34	30	1.7
35	22	1.2
36	27	1.5
37	29	1.6
38	26	1.5
39	22	1.2
40	24	1.3
41	24	1.3
42	40	2.2
43	40	2.2
44	39	2.2
45	64	3.6
46	48	2.7
47	34	1.9
48	39	2.2
49	47	2.6
50	46	2.6
51	42	2.4
52	51	2.9
53	43	2.4
54	29	1.6
55	45	2.5
56	35	2.0
57	43	2.4
58	44	2.5
59	47	2.6
60	33	1.8
61	38	2.1
62	40	2.2
63	24	1.3
64	35	2.0
65	32	1.8
66	28	1.6
67	24	1.3
68	22	1.2
69	27	1.5
70	33	1.8
71	25	1.4
72	32	1.8
73	35	2.0
74	29	1.6
75	37	2.1
Total	1786	100

Figures

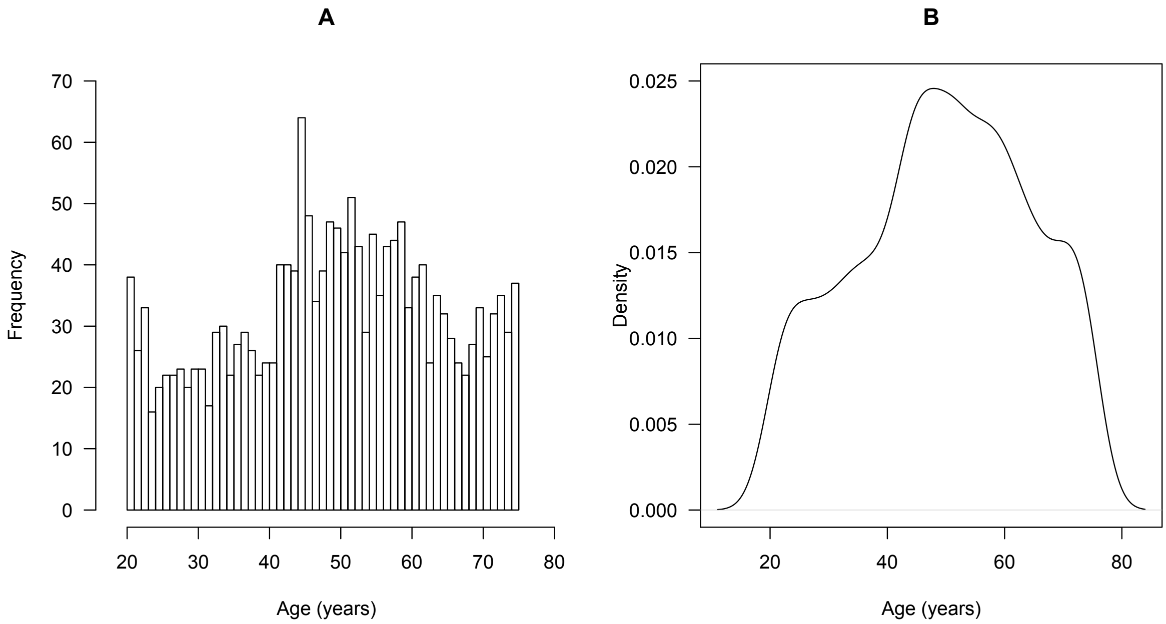

Figure A1**. A.** Histogram of sample age. **B** Density plot of sample age.

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Research Article

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Propensity for Risk Taking Across the Life Span and Around the Globe

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Abstract
Past empirical work suggests that aging is associated with decreases in risk taking. But are such effects universal? Life-history theory suggests that the link between age and risk taking is a function of specific reproductive strategies that can be more or less risky depending on the ecology. We assessed variation in the age-risk curve using World Values Survey data from 77 countries (N = 147,118). The results suggest that propensity for risk taking tends to decline across the life span in the vast majority of countries. In addition, there is systematic variation among countries: Countries in which hardship (e.g., high infant mortality) is higher are characterized by higher levels of risk taking and flatter age-risk curves. These findings suggest that hardship may function as a cue to guide life-history strategies. Age-risk relations thus cannot be understood without reference to the demands and affordances of the environment.

Keywords
risk taking, adult development, gender differences, cross-cultural differences, open materials

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How does propensity for risk taking change across the life span and around the world? Several lines of evidence suggest that propensity for risky behavior increases in adolescence, peaks in young adulthood, and declines with aging (Dohmen et al., 2011; Mandal & Roe, 2014; Quetelet, 1842/2013). One paradigmatic example of this progression is the link between age and criminal behavior—one possible manifestation of risk taking that has been well documented since the 19th century (Quetelet, 1842/2013). The relation between age and crime has been replicated in different cohorts and cultures, albeit with significant variation (Steinberg, 2013; Ulmer & Steffensmeier, 2014), but to what extent do cultures vary systematically in age-risk progression?

One influential conception of risk taking is that it serves a functional role (i.e., an adaptation) that may be biologically determined (Mishra, 2014; Sih & Del Giudice, 2012; Wilson & Daly, 1985). In line with this view, propensity for risk taking and associated constructs, such as impulsivity and sensation seeking, have been conceptualized as traits with strong biological underpinnings (Steinberg, 2008; Zuckerman, 2007) that show moderate to high heritability (Anokhin, Golosheykin, Grant, & Heath, 2012; Benjamin et al., 2012; Bezdjian, Baker, & Tuvblad, 2011) and reliable gender differences (Cross, Copping, & Campbell, 2011; Cross, Cyrenne, & Brown, 2013).

The view that risk taking serves a functional role is best discussed in the context of life-history theory, a framework that addresses how organisms allocate time and energy to tasks and traits so as to maximize their fitness. This framework focuses particularly on how evolutionary forces shape the timing of life events involved in development, growth, and reproduction as a result of ecological characteristics (Kaplan & Gangestad, 2005). According to life-history theory, even universal adaptations "may be limited by sex, life history stage, or circumstance" (Tooby & Cosmides, 1990, p. 393). In other words, life-history strategies, such as reproductive strategies, can be expected to change as a function of ecological circumstances.

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Current views suggest that one can frame human reproductive strategies along a continuum (Ellis et al., 2012): Toward one end, individuals may adopt a slower life-history strategy that focuses on avoiding risks and producing a few high-quality offspring that are likely to survive and reproduce; toward the other end, individuals may adopt faster life strategies that consist of taking risks in the service of promoting mating opportunities, early reproduction, and a greater number of offspring with more variable outcomes. These risky strategies may be particularly adaptive in harsh environments, in which morbidity and mortality are high and individuals have to compete fiercely for resources. In contrast, in rich, predictable environments, a slower reproductive strategy could be more appropriate. In other words, the rationale is that harsh, unpredictable environments may lead individuals to gamble on shorter life spans and earlier reproduction, given that fitness is likely enhanced by breeding early and abundantly rather than wasting resources on promoting one's own (unlikely) survival in such conditions (Ellis et al., 2012; Frankenhuis & de Weerth, 2013). There is indeed empirical evidence of the dependency between reproductive strategies and the harshness or unpredictability of local environments (Belsky, Schlomer, & Ellis, 2012; Simpson, Griskevicius, Kuo, Sung, & Collins, 2012; Wilson & Daly, 1997). Life-history theory also suggests that risky behaviors can be expected to be more prevalent among males, who are more likely than females to face reproductive competition (Ellis et al., 2012).

In sum, local conditions, such as the availability of resources and associated competition, are likely to affect individuals' propensity for risk taking. Ultimately, such factors may play a role in determining the shape of the age-risk relation, and resource scarcity and hardship may lead to longer periods of risk taking across the adult life span. In the present study, we tested whether local conditions of hardship could be used to predict cross-cultural variation in risk taking across the life span.

The Present Study

There has been considerable interest in accounting for similarities and differences in risk taking between cultures and countries (Becker, Dohmen, Enke, & Falk, 2014; Hsee & Weber, 1999; Rieger, Wang, & Hens, 2015; Vieider et al., 2015). However, this past work has not considered the extent to which the propensity to take risks is associated with age across cultures. We aimed to contribute to this effort by investigating the following research questions: Is a universal progression of risk propensity associated with age, such that risk propensity declines from adulthood to old age? Do local characteristics (e.g., exposure to hardship), as well as age and gender differences, account for potential differences in risk taking across cultures?

To answer these questions, we analyzed data from the World Values Survey (http://www.worldvaluessurvey.org), which aims to explore people's values and beliefs around the globe. It consists of a series of nationally representative surveys of various countries in which similar questionnaires are used, mostly in face-to-face interviews. We analyzed data collected in the last two independent waves of the survey (World Values Survey Association, 2008, 2014), which included one item we take to measure propensity for risk taking. Data for this item were available for 77 countries (see Fig. 1). In particular, participants were asked to report their similarity to a hypothetical individual: "Adventure and taking risks are important to this person; to have an exciting life" (for details, see Method). This item stems from Schwartz's (2012) Value Survey, which was designed to tap into a set of 10 independent universal values. According to Schwartz, this item captures individuals' need for variety and stimulation to maintain an optimal level of activation, and relates to feelings of excitement, variety seeking, and daringness. We take this item to measure the closely linked constructs of propensity for risk taking and sensation seeking that are empirically and theoretically related. For example, sensation seeking has been characterized as "a trait defined by the *seeking* of varied, novel, complex, and *intense* sensations and experiences, and the willingness to take physical, social, *legal*, and *financial* risks for the sake of such experience" (Zuckerman, 2007, p. 27).

Our analytic strategy proceeded in two steps. First, we analyzed the link between age and propensity for risk taking across the 77 countries. Second, we examined the extent to which a measure of exposure to hardship (i.e., a composite index capturing economic and social hardship through measures of gross domestic product per capita, homicide rate, and income inequality, among others) could account for cross-country variation in the pattern of the propensity for risk taking across the life span. The rationale for the latter analysis was to test the expectation that countries in which individuals are most exposed to hardship are likely to show higher levels of risk taking and longer periods of risk taking across the adult life span.

Method

Participants and procedure

We used data from the last two independent waves, Waves 5 and 6, of the World Values Survey (World Values Survey Association, 2008, 2014). We based our analysis on a balanced sample that consisted of respondents with valid answers on the risk item as well as all covariates of interest. Our final sample comprised 147,118 individuals

Fig. 1. World map showing countries for which data on the measure of propensity for risk taking were available from the World Values Survey.

(76,617 females, 52%; age range = 15–99 years). The countries included in the analysis cover the full range of global variation, from very poor to very rich countries, in all of the world's major cultural zones.

Measures

Propensity for risk taking and demographic covariates. Each respondent in the World Values Survey (World Values Survey Association, 2008, 2014) heard the following information:

> Now I will briefly describe some people. Using this card, would you please indicate for each description whether that person is very much like you, like you, somewhat like you, a little like you, not like you, or not at all like you?

Respondents were then asked to rate a number of statements, including the following statement about adventure, excitement, and risk taking: "Adventure and taking risks are important to this person; to have an exciting life." Respondents rated the statements using a 6-point scale (1 = *very much like me*, 6 = *not at all like me*).

In our analyses, we reversed the scale of the item such that the highest value (6) represented the highest propensity for risk taking and the lowest value (1) represented the lowest propensity for risk taking. We also considered a number of demographic variables from the survey, including age and gender, education, marital status, parental status, and current occupational status. These variables represent (a) important indicators of human capital and (b) life-cycle phases that have been hypothesized to influence risk taking (Dohmen et al., 2011; Wilson & Daly, 1985).

Hardship index. To capture exposure to hardship in each country, we considered a number of indicators that could plausibly capture adversity and economic and social strife: homicide rate, gross domestic product, income inequality, infant mortality, life expectancy at birth, and gender equality (as indexed by the ratio of males to females receiving primary education). We manually compiled data concerning these indicators from the World Health Organization (homicide rate; World Health Organization, 2015), the World Bank (gender equality; World Bank, 2015), and the U.S. Central Intelligence Agency (gross domestic product, income inequality, infant mortality, life expectancy at birth; U.S. Central Intelligence Agency, 2015). By and large, the single indicators were significantly correlated. To obtain a single index representing exposure to hardship in each country, we *z*-standardized all of the indicators and used appropriate transformations (i.e., log transform); some of the indicators required reverse coding. Each indicator had missing data; the number of countries with missing data ranged from one (1% of the sample) to nine (12% of the sample). We imputed the missing values with the median of each indicator so that we could use all countries and indicators in our analyses. Overall, the standardized and transformed hardship indicators were reasonably consistent, Cronbach's $\alpha = .86$. Consequently, we obtained a single hardship index by averaging all six *z*-standardized and transformed indicators. The specific data sources, as well as our procedure and the intercorrelations among indicators, are described in detail in the Supplemental Tables and Figures in the Supplemental Material available online.

Statistical analysis

We opted to use a linear regression approach to model the dependent variable, propensity for risk taking. First, however, we normalized it to have a mean of 50 and a standard deviation of 10 (i.e., *T* score), which is a common approach when using single, ordinal variables in linear regression models (Stevenson & Wolfers, 2008). Note, however, that the results were identical for the linear regression and the ordinal logistic regression, but the latter are less straightforward to depict and interpret (see Supplemental Tables and Figures).

We estimated the effects of different independent variables on the risk measure using mixed-effects linear regression in R (R Development Core Team, 2013). Specifically, we used the function lmer in the *lme4* package (Bates, Maechler, Bolker, & Walker, 2014), and we obtained *p* values for each effect on the basis of Satterthwaite's approximation using the package *lmerTest* (Kuznetsova, Brockhoff, & Christensen, 2015). Note that our modeling approach was particularly suited to our research question because it considered fixed effects (i.e., across country, average) of age and gender but also random effects (i.e., country specific) of these factors. This approach permitted us to assess the effect of ecological (i.e., country) characteristics on age and gender differences in propensity for risk taking and to control for other potentially relevant demographic covariates, such as marital status and education.

We report models estimating linear effects of age and gender but no age-by-gender interactions because models including covariates as well as quadratic effects of age or interactions with gender (or both) failed to converge. This finding suggests that the models that included interactions do not provide an appropriate description of the data. In all our analyses, we used age as a continuous variable and binary or dichotomized predictors to simplify coefficient estimation and interpretation, leading to the following additional predictors: gender (0 = female, 1 = male), marital status (0 = not married, 1 = married), parental status (0 = no children, 1 = children), education (0 = no or incomplete primary education, 1 = primary education or higher), and occupational status (0 = not currently employed, 1 = currently employed). We compared different regression models using log-likelihood tests.

Results

We conducted a number of mixed-effects regression models with propensity for risk taking as the dependent variable. Table 1 presents the fixed-effects coefficients of all relevant models. We first compared a baseline model that did not consider any predictors (intercept-only model; not shown) with Model 1, which included age and gender as predictors. The significantly better fit of Model 1 relative to baseline suggests that age and gender are important predictors that contribute to explaining a

Table 1. Estimated Fixed-Effects Coefficients From the Mixed-Effects Regression Models of Propensity for Risk Taking Across the 77 Countries

Model and predictor	*b*	*SE*	*T* score	*p* value
Model 1: Age + gender				
Intercept	51.46	0.29	174.99	< .001
Age	−1.98	0.11	−18.15	< .001
Gender	−2.33	0.12	−20.10	< .001
Model 2: Age + gender + demographic covariates				
Intercept	52.09	0.27	192.40	< .001
Age	−1.43	0.09	−16.19	< .001
Gender	−2.17	0.12	−17.82	< .001
Parental status	−1.32	0.13	−10.27	< .001
Marital status	−0.85	0.10	−8.59	< .001
Occupational status	0.16	0.08	2.06	.04
Education	0.79	0.12	6.66	< .001
Model 3: Age + gender + demographic covariates + hardship				
Intercept	52.10	0.26	198.17	< .001
Age	−1.42	0.07	−19.22	< .001
Gender	−2.16	0.11	−18.83	< .001
Parental status	−1.32	0.13	−10.29	< .001
Marital status	−0.85	0.10	−8.70	< .001
Occupational status	0.16	0.08	2.02	.05
Education	0.79	0.12	6.83	< .001
Hardship	0.67	0.33	2.04	.04
Hardship × Age	0.48	0.10	4.97	< .001
Hardship × Gender	0.29	0.14	2.03	.05

Note: Variables were coded as follows—gender: 0 = male, 1 = female; parental status: 0 = no children, 1 = children; marital status: 0 = unmarried, 1 = married; occupational status: 0 = unemployed, 1 = employed; and education: 0 = no or incomplete primary education, 1 = primary education or higher.

significant amount of variance in propensity for risk taking, $\chi^2(7, N = 147{,}118) = 9{,}293$, $p < .001$. Table 1 shows that propensity for risk taking tended to decrease as a function of age and was lower for females than for males. We also ran Model 2, which included additional covariates of interest (i.e., education, parental status, marital status, and occupational status). Model 2 provided a significant improvement in fit relative to Model 1, $\chi^2(26, N = 147{,}118) = 1{,}524$, $p < .001$, but the results in Table 2 show that the main effects of age and gender remained after the inclusion of the additional demographic predictors.

But to what extent are life-span reductions in propensity for risk taking universal? Figure 2 plots the aggregate results as well as the country-specific effects of age and gender as estimated from Model 2. The pattern of reduction in propensity for risk taking across the life span, as well as the increased propensity for risk taking of males relative to females, was replicated in the vast majority of countries.

Despite the commonalities across countries, Figure 2 also highlights considerable variance in propensity for risk taking; it steeply declined with age in most countries but there are exceptions, such as Nigeria or Mali. As expected from the predictions of life-history theory, variation between countries in propensity for risk taking was associated with local characteristics as captured by our hardship index. Model 3, which included the hardship index as a covariate as well as interactions of hardship with age and gender, provided an additional improvement in fit relative to Model 2, $\chi^2(3, N = 147{,}118) = 124{,}283$, $p < .001$. Moreover, the results suggest that hardship was related to intercept differences in propensity for risk taking, as well as the age and gender effects identified in the previous models.

The substantive interpretation of the hardship effects is better captured in Figure 3, which depicts the relation between the random coefficients for each country (i.e., intercepts, age, gender) from the model without hardship as a predictor (Model 2). Figure 3 presents the zero-order correlations between the model coefficients for each country and the hardship index. The hardship index was significantly correlated to the intercept of propensity for risk taking in each country, $r = .24$, $p < .03$, as well as with the age coefficients, $r = .56$, $p < .001$, and gender coefficients, $r = .40$, $p < .001$. For example, Figure 3 shows that the higher the hardship experienced in each country, the closer the age coefficient was to 0, which represents a flat propensity-for-risk-taking curve across the adult life span.

In summary, we found that harsher environments were associated with increased propensity for risk taking in young adults, smaller gender differences, and smaller differences in propensity for risk taking between younger and older individuals (i.e., a flattening of the age-risk curve). Overall, this finding suggests that ecologically dire circumstances may reduce differences in propensity for risk taking between younger and older individuals.

Discussion

We analyzed data from a large-scale survey of 77 countries to test whether the typical age-risk progression, which peaks in young adulthood and declines with increased age, represents a pancultural regularity. We found that the overwhelming majority of countries show the typical age-risk pattern, but there is significant variation in the relation between age and propensity for risk taking. Crucially, we found that an index of hardship in each country is significantly associated with the shape of the age-risk function: Hardship is associated with flatter age-risk curves and thus with smaller differences between younger and older age groups and between males and females. In other words, ecologies with scarce resources and therefore heightened competition may lead to increased propensity for risk taking regardless of age and gender. Our work matches expectations from life-history theory that associate ecological characteristics with life-span development of traits and reproductive strategies (Ellis et al., 2012; Mishra, 2014; Wilson & Daly, 1985).

Our work has connections to the broader debate about universals in life-span personality development; exploration and risk taking may represent important facets of such development. Whereas some researchers emphasize universals (McCrae et al., 2000), others emphasize the importance of normative as well as idiosyncratic life events in shaping personality; these events are likely to vary across cultures and individuals (Roberts, Wood, & Smith, 2005). Previous research indicates that there are indeed reliable age differences in personality development, such as decreases in openness to new experiences or increases in conscientiousness with increasing age, that have been replicated across samples and cultures (Roberts, Walton, & Viechtbauer, 2006). Nevertheless, considerable variation in personality development across cultures is explained by differences in timing of normative life events (Bleidorn et al., 2013). For example, Bleidorn et al. showed that cultures with an earlier onset of adult-role responsibilities, such as starting employment and parenting, were marked by relatively early personality maturation. Our results, which demonstrate a default progression of propensity for risk taking modified by ecological circumstances, are in line with the findings of Bleidorn et al. and with associated theories positing that personality development is a product, at least in part, of experience with the characteristics of local ecologies. Viewed more generally, our work contributes to understanding the causes underlying cultural variation (Weber & Hsee, 1999) and resonates with calls

Table 2. Demographics and Results From Model 2 by Country

								b					
Country	ISO Country Code	n	Female (%)	Mean age	Age range	Hardship index	Intercept	Age	Gender	Parental status	Marital status	Occupational status	Education
Algeria	DA	1,101	50	37.14	18–81	0.24	53.41	−2.20	−1.21	−3.73	−1.17	0.20	1.67
Andorra	AD	1,001	50	40.63	18–88	−0.81	53.54	−1.47	−2.70	−1.79	−1.49	0.31	0.98
Argentina	AR	978	53	42.26	18–88	0.03	49.43	−1.29	−2.35	−2.36	−1.30	0.07	2.05
Armenia	AM	1,087	66	46.47	18–85	−0.73	52.91	−1.97	−3.05	−2.06	−1.08	0.18	0.88
Australia	AU	2,367	55	50.29	18–95	−0.90	51.89	−1.98	−3.25	−1.34	−1.23	0.40	0.72
Azerbaijan	AZ	1,002	50	41.13	18–85	0.05	52.46	−1.58	−4.58	−1.09	−1.18	−0.16	0.55
Bahrain	BH	1,190	45	39.23	18–72	−0.79	54.97	0.05	−1.01	0.37	0.08	0.59	0.27
Belarus	BY	1,518	56	44.33	18–86	−0.43	51.83	−2.45	−3.33	−1.92	−0.82	−0.50	0.92
Brazil	BR	2,922	60	41.32	18–93	0.84	49.19	−1.23	−2.52	−1.52	−1.46	−0.15	0.60
Bulgaria	BG	935	54	46.88	18–84	0.00	50.19	−1.45	−1.79	−1.19	−1.07	0.74	2.01
Burkina Faso	BF	1,250	47	34.12	16–94	1.29	53.50	−0.40	−2.28	−0.71	−0.37	−0.08	0.61
Canada	CA	2,094	58	48.19	16–94	−0.82	53.07	−1.97	−3.19	−1.31	−1.65	0.88	−0.03
Chile	CL	1,874	53	43.26	18–85	0.10	52.69	−2.07	−2.14	−2.46	−0.69	0.27	1.26
China	CN	3,872	53	44.20	18–75	−0.03	49.64	−1.79	−1.62	−2.09	−1.01	−0.22	1.17
Colombia	CO	1,487	50	40.34	18–82	0.69	52.42	−1.19	−3.07	−2.03	−0.84	0.07	0.36
Cyprus	CY	2,020	52	41.87	17–91	−0.51	53.75	−2.17	−2.90	−1.25	−1.82	0.35	1.29
Ecuador	EC	1,201	52	39.78	18–97	0.35	54.21	−1.44	−1.45	−0.31	−0.27	0.04	0.88
Egypt	EG	4,549	64	40.86	18–99	0.20	47.82	−0.53	−0.67	−2.21	−0.39	0.72	1.18
Estonia	EE	1,507	56	48.25	18–93	−0.37	50.81	−2.26	−2.43	−1.99	−1.14	0.14	0.98
Ethiopia	ET	1,479	48	29.94	16–76	1.37	52.78	−0.63	−0.22	−1.54	−0.67	1.29	0.02
Finland	FI	1,004	52	47.52	17–87	−0.90	50.11	−1.69	−2.13	−1.27	−1.34	0.15	0.19
France	FR	993	52	47.05	18–92	−0.93	52.17	−1.88	−3.12	−2.04	−1.52	−0.07	0.45
Georgia	GE	2,637	54	45.06	18–91	0.20	51.27	−1.18	−3.76	−0.44	−1.15	0.36	1.06
Germany	DE	3,968	53	49.85	17–95	−1.01	48.95	−2.28	−2.78	−1.43	−1.41	0.18	1.16
Ghana	GH	3,065	50	32.38	16–90	0.66	56.57	−0.70	−1.24	−0.01	0.01	0.19	0.16
Gibraltar	GI	1,181	47	36.58	18–83	−0.43	50.70	−1.34	−1.75	−1.32	−0.10	−0.23	1.30
Great Britain	GB	1,006	51	45.67	15–94	−0.74	54.11	−1.61	−3.68	−1.56	−1.57	0.16	−0.45
Hungary	HU	999	53	45.54	18–91	−0.67	49.69	−2.37	−2.44	−1.66	−1.08	0.14	1.41
India	IN	2,759	39	40.38	18–90	0.34	54.56	−0.30	−0.77	0.59	−0.19	0.38	0.28
Indonesia	ID	1,922	47	35.75	15–84	0.22	54.96	−0.90	−2.52	−1.00	−0.55	0.64	0.51
Iran	IR	2,545	50	32.72	16–90	0.27	52.40	−1.76	−1.33	−1.98	−1.15	0.68	0.60
Japan	JP	3,019	52	49.32	18–80	−1.07	46.60	−0.55	−2.30	−0.81	−0.95	−0.23	−0.33
Jordan	JO	1,193	50	39.71	18–84	0.13	53.93	−1.75	−2.24	−1.52	−0.81	0.21	0.57
Kazakhstan	KZ	1,500	60	40.02	18–88	−0.02	49.62	−1.37	−1.83	−1.71	−0.84	0.45	0.59
Kuwait	KW	1,165	36	36.56	16–79	−0.40	55.03	−2.89	−2.21	−1.31	−1.26	−0.41	−0.15
Kyrgyzstan	KG	1,487	51	38.70	18–89	0.51	51.67	−0.35	−1.08	−0.73	0.14	−0.13	1.76
Lebanon	LB	1,155	51	38.09	18–82	0.11	55.51	−1.56	−2.15	−0.68	−0.40	0.07	−0.06
Libya	LY	1,963	48	38.13	18–78	−0.02	52.94	−1.99	−2.78	−1.22	−1.16	0.36	0.57

(continued)

Table 2. *(continued)*

Country	ISO Country Code	*n*	Female (%)	Mean age	Age range	Hardship index	Intercept	*b* Age	*b* Gender	*b* Parental status	*b* Marital status	*b* Occupational status	*b* Education
Malaysia	MY	2,497	49	36.09	15–80	0.30	49.79	–0.73	–1.50	–1.13	–0.17	0.00	1.04
Mali	ML	1,187	52	36.91	16–95	1.74	55.03	–0.44	–0.87	–1.05	0.38	–0.15	0.20
Mexico	MX	3,490	50	38.14	18–93	0.32	52.16	–1.14	–2.75	–2.40	–1.35	0.16	–0.18
Moldova	MD	1,028	53	42.62	18–86	0.19	50.48	–1.80	–1.18	–2.27	–0.86	0.20	0.43
Morocco	MA	1,978	49	37.48	18–87	0.30	52.41	–1.22	–2.55	–1.55	–0.96	0.15	1.18
Netherlands	NL	2,757	52	50.98	15–90	–1.02	49.97	–1.69	–3.09	–0.92	–1.46	0.01	0.66
New Zealand	NZ	739	58	50.53	18–90	–0.73	53.04	–2.21	–2.20	–1.58	–1.18	0.06	0.39
Nigeria	NG	1,759	50	31.22	18–98	1.53	56.60	–0.11	–0.38	–0.70	0.57	0.46	1.85
Norway	NO	1,015	50	45.64	18–79	–1.25	52.78	–2.12	–1.33	–1.62	–0.90	–0.08	1.12
Pakistan	PK	1,176	48	34.40	18–85	1.02	56.03	–0.23	–1.49	–0.46	–0.01	–0.60	0.66
Palestine	PS	968	51	36.32	18–86	–0.08	51.65	–1.84	–2.34	–1.00	–0.93	0.59	1.35
Peru	PE	2,575	50	38.08	18–89	0.38	50.66	–0.94	–2.87	–2.02	–0.96	–0.28	0.34
Philippines	PH	1,198	50	42.69	18–87	0.56	55.63	–0.57	–0.95	–0.49	–0.50	0.18	0.63
Poland	PL	1,926	52	46.77	18–92	–0.60	53.56	–1.43	–2.59	–2.12	–0.60	0.19	1.52
Qatar	QA	1,051	54	37.75	18–93	–0.13	52.90	–1.10	–3.08	–0.85	–0.96	0.52	0.49
Romania	RO	2,943	55	47.96	18–97	–0.38	48.91	–1.57	–2.39	–1.49	–0.93	0.58	1.47
Russia	RU	3,640	53	42.12	16–91	0.08	51.12	–1.27	–2.20	–0.94	–1.24	0.67	1.59
Rwanda	RW	2,573	49	34.31	16–90	0.97	53.30	–0.43	–1.02	0.30	–0.60	0.03	–0.24
Serbia	RS	1,099	49	42.68	18–87	–0.33	51.62	–1.92	–1.79	–2.96	–1.47	0.49	1.27
Singapore	SG	1,924	55	41.83	18–89	–0.86	54.41	–0.97	–1.78	–1.23	–0.49	0.07	0.39
Slovenia	SI	2,032	55	47.56	18–94	–0.99	52.01	–2.69	–2.79	–1.96	–1.88	0.39	1.01
South Africa	ZA	6,370	50	37.59	16–94	1.74	53.26	–0.96	–0.90	–0.18	–0.18	0.72	2.19
South Korea	KR	2,357	50	42.28	19–91	–0.71	53.69	–1.85	–1.42	–1.01	–0.57	0.11	0.48
Spain	ES	2,319	51	46.24	18–99	–0.85	52.79	–1.92	–1.54	–1.63	–1.24	0.26	0.81
Sweden	SE	2,133	51	48.05	18–85	–1.17	52.10	–1.80	–2.65	–1.70	–1.24	–0.25	0.72
Switzerland	CH	1,219	55	52.30	18–86	–1.11	50.43	–1.41	–3.63	–0.64	–1.71	0.32	0.63
Taiwan	TW	2,415	50	44.31	18–85	–0.54	47.70	–1.95	–2.33	–1.54	–1.03	–0.21	0.80
Thailand	TH	2,597	50	45.50	17–88	0.19	51.85	–0.59	–0.90	–1.13	0.25	–0.35	0.82
Trinidad	TT	1,976	55	44.18	18–94	0.46	52.05	–1.74	–2.57	–0.20	–0.81	0.30	1.03
Tunisia	TN	1,096	45	37.33	18–87	0.07	51.64	–2.73	–2.79	–2.11	–1.06	–0.20	0.88
Turkey	TR	2,875	50	37.33	18–86	0.05	52.25	–1.23	–1.67	–1.53	–0.73	0.32	1.66
Ukraine	UA	2,439	62	45.43	18–90	–0.18	50.54	–2.15	–2.59	–1.82	–0.88	0.31	0.71
Uruguay	UY	1,938	54	45.66	18–97	0.15	49.10	–1.61	–1.87	–1.87	–1.03	–0.14	0.37
United States	US	2,163	52	49.16	18–93	–0.26	51.98	–2.21	–2.64	–0.88	–1.17	0.37	0.11
Uzbekistan	UZ	1,424	61	39.09	18–89	0.27	52.73	–0.82	–2.42	–0.46	–0.70	0.36	0.90
Vietnam	VN	1,406	48	40.36	18–86	0.28	49.42	–0.96	–2.71	–0.78	–0.49	–0.40	–0.25
Yemen	YE	922	50	35.09	18–90	1.27	48.08	–1.37	–2.29	–2.06	–1.03	0.01	0.90
Zambia	ZM	1,419	49	29.72	16–80	1.57	53.37	–0.95	–1.82	–0.34	0.48	–0.42	0.96

Note: For each country, the coefficient estimate for the intercept was obtained by summing the average coefficient and that country's deviation from the average coefficient. ISO = International Organization for Standardization.

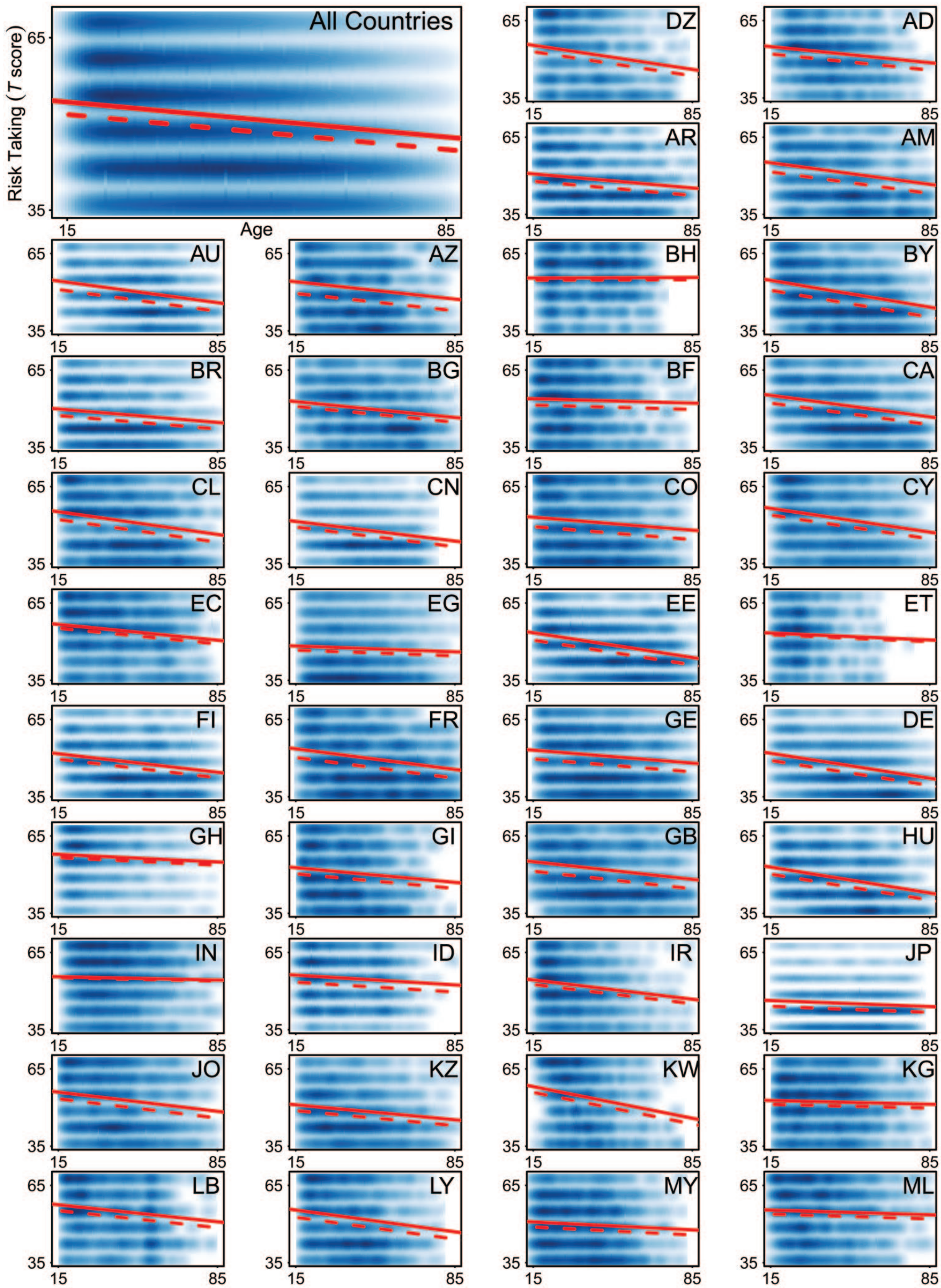

Fig. 2. *(continued on next page)*

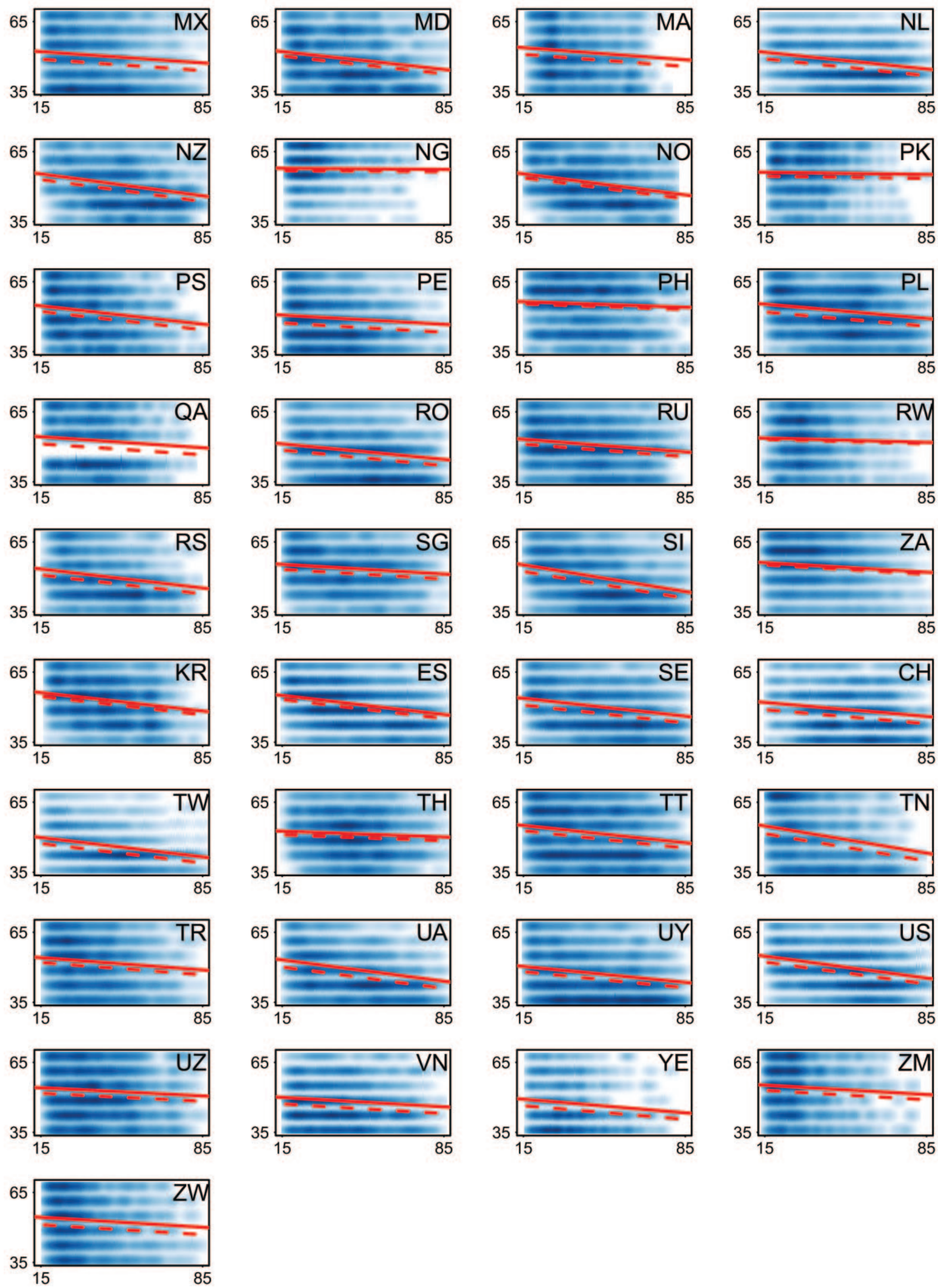

Fig. 2. Density plots of propensity for risk taking as a function of age for all countries combined and for each country separately. The blue background represents the response density; darker colors represent higher densities. Solid lines and dashed lines represent the estimated patterns of propensity for risk taking among males and females, respectively.

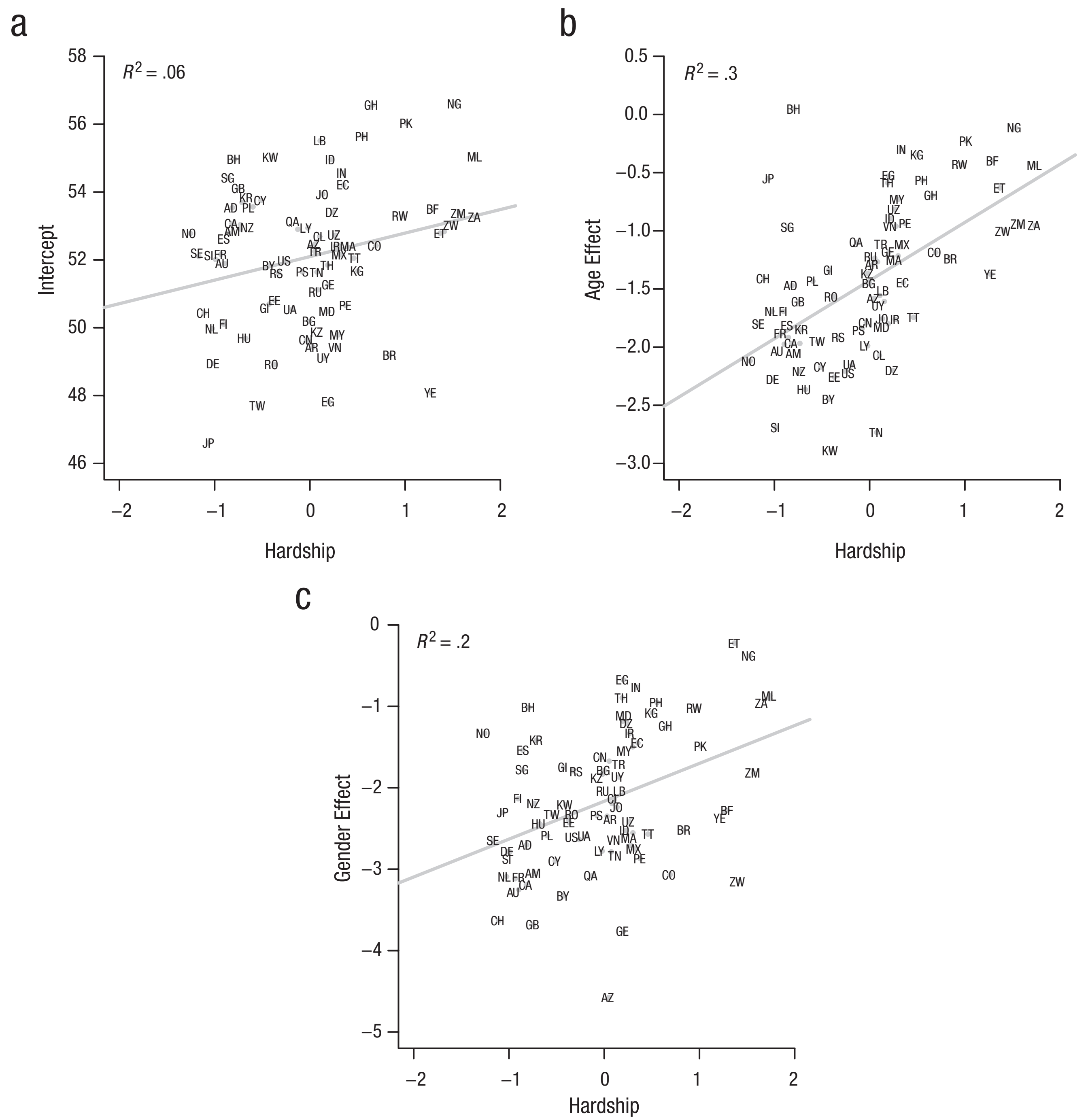

Fig. 3. Scatterplots (with best-fitting regression lines) of the relations between the hardship index and the country-specific (a) intercepts, (b) age-effect estimates, and (c) gender-effect estimates obtained from the mixed-effects regression model in which age and gender (but not hardship) were used to predict risk taking (Model 2). Values on the *y*-axes in (b) and (c) represent deviations from the mean estimate of the effects of age and gender, respectively. See Table 2 for explanations of the country codes.

for the use of diverse samples and cohorts (Henrich, Heine, & Norenzayan, 2010).

There are a number of limitations associated with the data we report. First, the item "adventure and taking risks are important to this person; to have an exciting life" likely reflects a number of constructs, including propensity for risk taking, sensation seeking, and impulsivity, which are related but not necessarily identical (Zuckerman, 2007). Research on such constructs suggests that each involves distinct components that may merit individual investigation (Cross et al., 2013; Mata, Josef, Samanez-Larkin, & Hertwig, 2011; Sharma, Markon, & Clark, 2014). Future work may consider other, more specific measures than these that disentangle potential subcomponents of these traits to examine any differential life-span courses between them.

Second, we relied solely on a self-report measure, which may capture current as well as retrospective reports of risk taking and thus cannot assess whether similar patterns would be observed for behavioral measures of risk taking. Past work suggests that there is a correlation, albeit small, between self-reported propensity for risk taking and behavior in economic tasks (Dohmen et al., 2011; Lauriola, Panno, Levin, & Lejuez, 2013; Mishra & Lalumière, 2011). However, the pattern of age differences in behavioral measures of risk is considerably heterogeneous; only a few tasks suggest a decline in propensity for risk taking with increased age (Mata et al., 2011). In future work, researchers will need to systematically assess the link between self-report and behavioral measures of propensity for risk taking and do so across cultures (Rieger & Mata, 2013). Finally, a third limitation of the data is that the meaning of adventure, risk, and excitement is likely to differ between cultures, rendering direct comparisons between countries challenging. Future research may want to relate cultural differences in the perceptions of risk behavior to age differences in propensity for risk taking.

Our work also raises some questions. The monotonic age-related decline in risk taking that we found may not immediately follow from a life-history framework: If risk taking reflects the expected future trajectory of fitness prospects, life-history theory leads to the prediction that very old individuals with increased risk of morbidity and mortality could be more willing to take risks in the hope of immediate successful reproductive efforts, which would lead to a peak in propensity for risk taking in old age (Daly & Wilson, 2005). Some researchers have suggested that the monotonic reduction in risk taking across the adult life span could be explained by the possibility of resource transfers from older adults (i.e., individuals with lower reproductive value) to their offspring with higher reproductive value (Rogers, 1994). Future work that tracks the risk patterns of older individuals in combination with resource transfer behavior and goals could perhaps test this possibility.

In conclusion, age is associated with reduced propensity for risk taking in a quasi-universal fashion. Nevertheless, the considerable variation in the link between age and propensity for risk taking is systematically associated with local hardship. Specifically, high-risk ecologies favor reproductive strategies associated with increased risk taking across the life span and a flattening of the age-risk curve. Age-risk relations appear to reflect, among other factors, individuals' adjustment to the characteristics of local ecologies and cannot be understood without reference to the demands and affordances of the environment.

Author Contributions

R. Mata developed the study concept, conducted the analyses, and drafted the manuscript. A. K. Josef and R. Hertwig provided critical revisions. All authors approved the final version of the manuscript for submission.

Declaration of Conflicting Interests

The authors declared that they had no conflicts of interest with respect to their authorship or the publication of this article.

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References

Anokhin, A. P., Golosheykin, S., Grant, J., & Heath, A. C. (2012). Heritability of risk-taking in adolescence: A longitudinal twin study. *Twin Research and Human Genetics*, *12*, 366–371. doi:10.1375/twin.12.4.366

Bates, D., Maechler, M., Bolker, B., & Walker, S. (2014). lme4: Linear mixed-effects models using Eigen and S4 (Version 1.1-7) [Software]. Retrieved from http://cran.r-project.org/package=lme4

Becker, A., Dohmen, T., Enke, B., & Falk, A. (2014). *The ancient origins of the cross-country heterogeneity in risk preferences*. Retrieved from https://site.stanford.edu/sites/default/files/site_enke.pdf

Belsky, J., Schlomer, G. L., & Ellis, B. J. (2012). Beyond cumulative risk: Distinguishing harshness and unpredictability as determinants of parenting and early life history strategy. *Developmental Psychology*, *48*, 662–673. doi:10.1037/a0024454

Benjamin, D. J., Cesarini, D., van der Loos, M. J. H. M., Dawes, C. T., Koellinger, P. D., Magnusson, P. K. E., . . . Visscher,

P. M. (2012). The genetic architecture of economic and political preferences. *Proceedings of the National Academy of Sciences, USA*, *109*, 8026–8031. doi:10.1073/pnas.1120666109

Bezdjian, S., Baker, L. A., & Tuvblad, C. (2011). Genetic and environmental influences on impulsivity: A meta-analysis of twin, family and adoption studies. *Clinical Psychology Review*, *31*, 1209–1223. doi:10.1016/j.cpr.2011.07.005

Bleidorn, W., Klimstra, T. A., Denissen, J. J. A., Rentfrow, P. J., Potter, J., & Gosling, S. D. (2013). Personality maturation around the world: A cross-cultural examination of social-investment theory. *Psychological Science*, *24*, 2530–2540. doi:10.1177/0956797613498396

Cross, C. P., Copping, L. T., & Campbell, A. (2011). Sex differences in impulsivity: A meta-analysis. *Psychological Bulletin*, *137*, 97–130. doi:10.1037/a0021591

Cross, C. P., Cyrenne, D.-L. M., & Brown, G. R. (2013). Sex differences in sensation-seeking: A meta-analysis. *Scientific Reports*, *3*, Article 2486. doi:10.1038/srep02486

Daly, M., & Wilson, M. (2005). Carpe diem: Adaptation and devaluing the future. *The Quarterly Review of Biology*, *80*, 55–60. doi:10.1086/431025

Dohmen, T., Huffman, D., Schupp, J., Falk, A., Sunde, U., & Wagner, G. G. (2011). Individual risk attitudes: Measurement, determinants, and behavioral consequences. *Journal of the European Economic Association*, *9*, 522–550. doi:10.1111/j.1542-4774.2011.01015.x

Ellis, B. J., Del Giudice, M., Dishion, T. J., Figueredo, A. J., Gray, P., Griskevicius, V., . . . Wilson, D. S. (2012). The evolutionary basis of risky adolescent behavior: Implications for science, policy, and practice. *Developmental Psychology*, *48*, 598–623. doi:10.1037/a0026220

Frankenhuis, W. E., & de Weerth, C. (2013). Does early-life exposure to stress shape or impair cognition? *Current Directions in Psychological Science*, *22*, 407–412. doi:10.1177/0963721413484324

Henrich, J., Heine, S. J., & Norenzayan, A. (2010). The weirdest people in the world? *Behavioral & Brain Sciences*, *33*, 61–83. doi:10.1017/S0140525X0999152X

Hsee, C. K., & Weber, E. U. (1999). Cross-national differences in risk preference and lay predictions. *Journal of Behavioral Decision Making*, *12*, 165–179. doi:10.1002/(SICI)1099-0771(199906)12:2<165::AID-BDM316>3.0.CO;2-N

Kaplan, H. S., & Gangestad, S. W. (2005). Life history theory and evolutionary psychology. In D. M. Buss (Ed.), *The handbook of evolutionary psychology* (pp. 68–96). New York, NY: Wiley.

Kuznetsova, A., Brockhoff, P. B., & Christensen, R. H. B. (2015). lmerTest: Tests in linear mixed effects models (Version 2.0-25) [Software]. Retrieved from http://cran.r-project.org/web/packages/lmerTest/

Lauriola, M., Panno, A., Levin, I. P., & Lejuez, C. W. (2013). Individual differences in risky decision making: A meta-analysis of sensation seeking and impulsivity with the balloon analogue risk task. *Journal of Behavioral Decision Making*, *27*, 20–36. doi:10.1002/bdm.1784

Mandal, B., & Roe, B. E. (2014). Risk tolerance among National Longitudinal Survey of Youth participants: The effects of age and cognitive skills. *Economica*, *81*, 522–543. doi:10.1111/ecca.12088

Mata, R., Josef, A. K., Samanez-Larkin, G. R., & Hertwig, R. (2011). Age differences in risky choice: A meta-analysis. *Annals of the New York Academy of Sciences*, *1235*, 18–29. doi:10.1111/j.1749-6632.2011.06200.x

McCrae, R. R., Costa, P. T., Ostendorf, F., Angleitner, A., Hrebícková, M., Avia, M. D., . . . Smith, P. B. (2000). Nature over nurture: Temperament, personality, and life span development. *Journal of Personality and Social Psychology*, *78*, 173–186. doi:10.1037//0022-3514.7S.1.173

Mishra, S. (2014). Decision-making under risk: Integrating perspectives from biology, economics, and psychology. *Personality and Social Psychology Review*, *18*, 280–307. doi:10.1177/1088868314530517

Mishra, S., & Lalumière, M. L. (2011). Individual differences in risk-propensity: Associations between personality and behavioral measures of risk. *Personality and Individual Differences*, *50*, 869–873. doi:10.1016/j.paid.2010.11.037

Quetelet, A. (2013). *A treatise on man and the development of his faculties* (R. Knox, Ed.). New York, NY: Cambridge University Press. (Original work published 1842)

R Development Core Team. (2013). R: A language and environment for statistical computing (Version 3.1.2) [Computer software]. Retrieved from https://www.r-project.org/index.html

Rieger, M., & Mata, R. (2013). On the generality of age differences in social and nonsocial decision making. *The Journals of Gerontology, Series B: Psychological Sciences & Social Sciences*, *70*, 202–214. doi:10.1093/geronb/gbt088

Rieger, M. O., Wang, M., & Hens, T. (2015). Risk preferences around the world. *Management Science*, *61*, 637–648. doi:10.1287/mnsc.2013.1869

Roberts, B. W., Walton, K. E., & Viechtbauer, W. (2006). Patterns of mean-level change in personality traits across the life course: A meta-analysis of longitudinal studies. *Psychological Bulletin*, *132*, 1–25. doi:10.1037/0033-2909.132.1.1

Roberts, B. W., Wood, D., & Smith, J. L. (2005). Evaluating Five Factor Theory and social investment perspectives on personality trait development. *Journal of Research in Personality*, *39*, 166–184. doi:10.1016/j.jrp.2004.08.002

Rogers, A. R. (1994). Evolution of time preference by natural selection. *The American Economic Review*, *84*, 460–481. Retrieved from http://www.jstor.org/stable/2118062

Schwartz, S. H. (2012). An overview of the Schwartz theory of basic values. *Online Readings in Psychology and Culture*, *2*(1), 1–20. doi:10.9707/2307-0919.1116

Sharma, L., Markon, K. E., & Clark, L. A. (2014). Toward a theory of distinct types of "impulsive" behaviors: A meta-analysis of self-report and behavioral measures. *Psychological Bulletin*, *140*, 374–408. doi:10.1037/a0034418

Sih, A., & Del Giudice, M. (2012). Linking behavioural syndromes and cognition: A behavioural ecology perspective. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *367*, 2762–2772. doi:10.1098/rstb.2012.0216

Simpson, J. A., Griskevicius, V., Kuo, S. I.-C., Sung, S., & Collins, W. A. (2012). Evolution, stress, and sensitive periods: The influence of unpredictability in early versus late childhood on sex and risky behavior. *Developmental Psychology*, *48*, 674–686. doi:10.1037/a0027293

Steinberg, L. (2008). A social neuroscience perspective on adolescent risk-taking. *Developmental Review*, *28*, 78–106. doi:10.1016/j.dr.2007.08.002

Steinberg, L. (2013). The influence of neuroscience on US Supreme Court decisions about adolescents' criminal culpability. *Nature Reviews Neuroscience*, *14*, 513–518. doi:10.1038/nrn3509

Stevenson, B., & Wolfers, J. (2008). *Economic growth and subjective well-being: Reassessing the Easterlin paradox* (NBER Working Paper No. 14282). Retrieved from the National Bureau of Economic Research Web site: http://www.nber.org/papers/w14282

Tooby, J., & Cosmides, L. (1990). The past explains the present: Emotional adaptations and the structure of ancestral environments. *Ethology and Sociobiology*, *11*, 375–424. doi:10.1016/0162-3095(90)90017-Z

Ulmer, J. T., & Steffensmeier, D. (2014). The age and crime relationship: Social variation, social explanations. In K. Beaver, B. Boutwell, & J. C. Barnes (Eds.), *The nurture versus biosocial debate in criminology: On the origins of criminal behavior and criminality* (pp. 377–396). London, England: Sage. doi:10.4135/9781483349114.n24

U.S. Central Intelligence Agency (2015). The world factbook. Retrieved from https://www.cia.gov/library/publications/the-world-factbook

Vieider, F. M., Chmura, T., Fisher, T., Kusakawa, T., Martinsson, P., Mattison Thompson, F., . . . Sunday, A. (2015). Within- versus between-country differences in risk attitudes: Implications for cultural comparisons. *Theory and Decision*, *78*, 209–218. doi:10.1007/s11238-014-9418-3

Weber, E. U., & Hsee, C. K. (1999). Models and mosaics: Investigating cross-cultural differences in risk perception and risk preference. *Psychonomic Bulletin & Review*, *6*, 611–617. doi:10.3758/BF03212969

Wilson, M., & Daly, M. (1985). Competitiveness, risk taking, and violence: The young male syndrome. *Ethology and Sociobiology*, *6*, 59–73. doi:10.1016/0162-3095(85)90041-X

Wilson, M., & Daly, M. (1997). Life expectancy, economic inequality, homicide, and reproductive timing in Chicago neighbourhoods. *British Medical Journal*, *314*, 1271–1274. doi:10.1136/bmj.314.7089.1271

World Bank. (2015). World databank. Retrieved from http://databank.worldbank.org/data/

World Health Organization. (2015). Global health observatory data repository. Retrieved from http://apps.who.int/gho/data

World Values Survey Association. (2008). *Wave 5 2005–2008 official aggregate v.20140429*. Retrieved from http://www.worldvaluessurvey.org/WVSDocumentationWV5.jsp

World Values Survey Association. (2014). *Wave 6 2010–2014 official aggregate v.20140429*. Retrieved from http://www.worldvaluessurvey.org/WVSDocumentationWV6.jsp

Zuckerman, M. (2007). *Sensation seeking and risky behavior*. Washington, DC: American Psychological Association. doi:10.1037/11555-000

Manuscript 4

How Cognitive Aging Affects Decision Making When Memory Demands Rise

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Abstract

Sometimes, cognitive aging coincides with decrements in decision performance. The determinants of the existence and magnitude of such age differences, however, are little understood. Based on effects of task complexity, we hypothesized that decrements in older adults' performance may depend on the degree to which decisions tax memory capacities. In two studies, younger (18–30 years of age) and older adults (>65 years) made decisions with high or low demands on memory. In a personnel-selection scenario, participants decided which candidate would be best suited for a job. To this end, they had to retrieve from memory either all (high demand) or a subset (low demand) of information. Older adults' decisions, relative to those of younger adults, were most compromised when demands on memory were high. Individual differences in memory ability mediated the relationship between age, memory demand, and decision performance. Modeling of the strategies underlying decisions suggests that younger adults balance the high demand on memory by switching to a simpler noncompensatory strategy. Older adults do not seem to compensate but instead their use of idiosyncratic strategies rises. The findings suggests that one of the pathways through which memory demands produce age-dependent effects on decision performance is through the triggering of different decision making strategies. Younger adults appear more able to balance increasing memory demands by simpler strategies, an adaptive response less available to older adults.

Max: 250; Actual: 226

Keywords: aging, decision making, memory demand, strategy selection

How Cognitive Aging Affects Decision Making When Memory Demands Rise

Aging is associated with reductions in fluid cognitive abilities. This can have implications for many everyday behaviors, including making decisions (Tymula, Rosenberg Belmaker, Ruderman, Glimcher, & Levy, 2013). Specifically, studies have observed lower decision performance of older relative to younger adults (e.g. Bruine de Bruin, Parker, & Fischhoff, 2010; Finucane, Mertz, Slovic, & Schmidt, 2005; Henninger, Madden, & Huettel, 2010; Mata & Nunes, 2010; Yoon, Cole, & Lee, 2009). Yet, such age differences are not observed across the board. In some studies older adults' decisions match those of younger adults (e.g., Frey, Mata, & Hertwig, 2015; Hosseini et al., 2010; Li, Gao, Enkavi, Zaval, Weber, & Johnson, 2015). We propose that the diversity in results are a function of a studies' different task demands, and in particular the demands on memory abilities (Bruine de Bruin et al., 2010; Del Missier et al., 2013). The missing link, however, is how memory demands translate into decision performance. To shed light on this link, we investigate and model how a task captivates memory abilities and steers the selection of decision strategies. Accounting for this process offers a window onto the effects of aging on decision making and, more generally, a window on the selection and use of specific decision strategies in younger and older adults in general.

The aging literature has since long found support for *task complexity effects* that is, the notion that characteristics of the task in question moderate the effects of aging (e.g. Cerella, Poon, & Williams, 1980; Clay, 1954). However, task complexity per se does not suffice to predict effects of cognitive aging on decision performance. In addition, one needs to theorize *how* the properties of a task environment lead older adults to perform as well, better or worse than younger adults. There are, of course, a number of candidate pathways. First, the requirements implied by the task at hand can be more or less taxing on older adults' declining fluid abilities, such as when options' values have to be extracted and learned from probabilistic feedback (Henninger et al., 2010) or when many pieces of information are presented (Finucane et al., 2005; Mata & Nunes, 2010). Second, the decision maker can offset these high demands on processing resources (e.g., memory, processing speed) by enlisting simpler strategies that put less strain on already taxed resources than more complex strategies. Third, older adults with declining processing resources (but also those younger adults endowed with fewer resources) will more likely adjust their employed strategy when task demand is high. Fourth, this age- and resources-dependent compensatory use of simpler strategies can exact age differences in the quality of decisions (Henninger et al., 2010; Mata, Schooler, & Rieskamp, 2007).

To date, no study has directly tested the effects of memory demand, or, retrieval effort, on strategy selection and adult age differences in decision making. We here aim to fill this gap. We examine to what extent varying task demands in terms of the mnemonic retrieval of information can result in the selection of different strategies, and, eventually, in adult age differences in decision making. Next, we first briefly review the literature on memory and aging. Then, we provide a summary of past work on decision making and aging. Finally, we give an overview of our two studies that link these two largely unconnected lines of research.

Memory and Aging

Aging is associated with sizeable decline in declarative components of long-term and working memory (Bäckman, Small, & Wahlin, 2001; Fleischmann, Wilson, Garbrieli, Bienieas, & Bennett, 2004; Hedden & Gabrieli, 2004; Old & Naveh-Benjamin, 2008). Age differences in memory performance are likely to be moderated by the degree of self-initiated processing, that is, the retrieval depending on self-generated cues and control processes in memory (Craik, Routh, & Broadbent, 1983; La Voie & Light, 1994; Old & Naveh-Benjamin, 2008). This maps onto a view about the aging of memory that attributes age-related recall and learning deficits to at least two components: aging impacts, first, the strategic manipulation of information (Bouazzaoui et al., 2010; Insingrini, Angel, Fay, Taconnat, Lemaire, & Bouazzaoui, 2015; Sander, Lindenberger, & Werkle-Bergner, 2012), and, second, the basic encoding and storage of information in terms of a bound representation (i.e., a memory representation composed of the qualities of several pieces of information; Naveh-Benjamin, 2000; Shing, Werkle-Bergner, Li, & Lindenberger, 2008). Whereas strategic processes are localized in frontal brain areas, the associative binding components are more posterior (i.e., parietal, temporal). During memory retrieval posterior activations are controlled by the prefrontal cortex (e.g., Badre & Wagner, 2007; Buckner, 2004). This dovetails nicely with research showing that older adults engage in memory-demanding strategic processes (e.g. retrieval-strategies) less often and less efficiently than younger adults (Touron, 2015). This effect seems to be moderated by the relative effort of retrieval strategies: Older adults use retrieval strategies less often when the amount of information to be recalled is large relative to when it is smaller (Touron & Hertzog, 2004a; Touron & Hertzog, 2004b). Yet, there is still debate on the extent to which failures in strategic processes evidence in, for instance, higher error rates during the execution of memory strategies, can account for age differences in several aspects of memory functioning (Dunlosky & Hertzog, 1998; Hertzog & Dunlosky, 2004). For example, older and younger adults can show the same memory performance, but older adults are still less likely to use memory strategies throughout a task (Touron & Hertzog, 2004b). When memory demand is lower because a task provides retrieval cues, age-related deficits in memory performance decrease or disappear altogether (Lindenberger & Mayr, 2014).

Decision Making and Cognitive Aging

Decision strategies differ in their informational and computational demands, and, by extension, their cognitive demands (Marewski & Schooler, 2011; Shah & Oppenheimer, 2008). Consider, for instance, the decision of which of two job candidates is better qualified for a job (the criterion). Lacking direct knowledge of candidates' criterion value, one must employ predictive information (*cues*, that is, variables that correlate, albeit imperfectly, with the criterion variable in a decision problem). For example, cues associated with a candidates' qualities could be experience on the job or how socially competent he or she is.

Models of decision strategies differ in how they process cues. Compensatory decision strategies use all available cues and typically process them in sophisticated ways. For instance, the *weighted additive strategy* (WADD; Payne, Bettman, & Johnson, 1993) weighs each cue according to a measure of cue goodness called validity, adds up the thus weighted cues and chooses the option with the higher weighted sum of cue values. Tallying, albeit a compensatory strategy dispenses with weighting and simply adds binary (or dichotomized positive and negative) cue values and chooses the option with the higher sum of cue values (Dawes, 1979). Noncompensatory strategies simplify processing of cues in various ways. *Take-the-best* (TTB; Gigerenzer & Goldstein, 1996), for instance, orders cues by their validity and looks them up one at a time. As soon as a discriminating cue is found, search is stopped and a decision is made on the basis of that cue alone. Other strategies simplify the processing even further, for instance, by dispensing with any ordering of cues.

What determines which strategy people select in a given decision situation? The concept of ecological rationality suggests that decision strategies are adapted to particular environments. Competent decision makers adaptively select the decision strategy that matches the given decision situation and their cognitive resources (Gigerenzer & Goldstein, 1996). As stated earlier, decision strategies differ in their level of effort needed to use them. Compensatory decision strategies are more effortful than noncompensatory ones because they require more exhaustive information search, time spent on the problem, and more complex computations. This is particularly the case when the information, entered into the decision strategies, has to be retrieved from memory (Bröder & Schiffer, 2003b; 2006). Past work has shown that when cognitive capacities are limited or when costs of information search are high (young) adults have been shown to be more likely to enlist simpler strategies. Such a shift is generally explained by an effort-accuracy tradeoff (Beach &

Mitchell, 1978). Individuals weigh the costs of using a strategy (i.e. the cognitive effort) against its benefits (i.e. decision accuracy) when choosing among strategies. Increased reliance on simple decision strategies, in turn, has been related to individual differences in fluid abilities, such as working memory (Horn, Pachur, & Mata, 2015; Mata et al. 2007; Pachur, Mata, & Schooler, 2009).

As highlight above, memory and the waning of its power with age is one key to understand older people's cognition. Past research has shown that performance decreases in older adults are associated with the selection of simpler decision strategies that may not be appropriate to the decision situation at hand (Mata, Pachur, von Helversen, Hertwig, Rieskamp, & Schooler, 2012; Mata et al., 2007). Therefore, one may suspect that older people—akin to younger people whose cognitive resources are taxed—transition to the use of simpler, cognitively less demanding strategies. This strategy shift, in turn, may explain age differences in accuracy when decision making requires extensive information search in memory.

Overview of the Studies

In two experiments, we investigated the role of memory demands on the emergence of age differences in decision performance and strategy selection. Participants memorized cue information about several options in question. They then made decisions in a context in which retrieval or consideration of all information was necessary for high decision accuracy. To vary memory demands, decisions were based on information retrieval from memory (high memory demand, HD) or on information displayed in front of the decision maker (low memory demand, LD). We tested the following hypotheses:

(1) Older adults' decisions reach a lower level of accuracy than younger adults and the former relied more on simpler strategies than the latter. Both effects occur most strongly when demands on memory are high and when decision making demands a high degree of self-initiated processing.

(2) Individuals' differential memory is key in the occurrence of individual and age differences in performance when tasks strongly call upon memory.

Both experiments simulated a personnel selection task, involving a set of job candidates. Participants initially learnt pertinent information about the candidates, and then aimed to decide, facing pairs of candidates, which one was best qualified for a given job (for a similar design, see Bröder & Schiffer, 2003b). Since both experiments adopted the same design, except in the initial learning criterion (explained shortly), we describe their methods and results side by side.

Methods

Experimental Design and Procedure

Both experiments began with a learning phase. Participants memorized relevant information about the job candidates and the quality of the information. Then, each participant faced two decision tasks varying in memory demand. Between the two tasks, participants were asked to recall the information they had learned. Finally, participants received feedback regarding their recall and decision performances. Finally, each individual completed a battery of cognitive tasks (see Table 1) including, in this order, a vocabulary test (MWT-B; Lehrl, 1999), a processing-speed measure (Digit-Symbol-Substitution Test; Wechsler, 1981), a paired-recall task (long term memory; Shing et al., 2008), and a working memory task (automated operation span; Unsworth, Heitz, Schrock, & Engle, 2005).

Overall, the experiment used a mixed factorial design, with age group (younger adults vs. older adults) as a between-subjects factor and memory demand in the decision task (high vs. low) as a within-subjects factor (see Figures 1 and 2).

Learning phase. After being introduced to the simulated personnel-selection scenario, participants learnt information about five female job candidates. Specifically, they were trained on information about cue values, the cue ordering and the direction of cues (see Figure 1).

First, participants memorized candidates' values (binary values) on five different cues: social competence, work experience, knowledge of foreign languages, foreign experience, and specialty. In total, 25 cue values were presented. Learning proceeded as follows: Participants studied a table of all 25 cue values for three minutes (presented along side of portraits of the candidates and their first names; Figure 1A). Subsequently, the portrait of a candidate was presented and participants reproduced his or her cue values (in any order; Figure 1B). Immediate feedback was given after each response. Then the next portrait was presented. To make sure that older and younger adults' knowledge about the cue values was similarly extensive, participants could only move forward once they reached a learning criterion, namely, the correct recall of 21 (84%; Experiment 1) and 23 (92%; Experiment 2) of the 25 cue values. The learning procedure was repeated (with a shortened 1-minute presentation of the cue value table) until these criteria were reached.

The next step consisted in learning the ranking of the cues (i.e., how important is the cue in selecting a person for the job). Learning began with all cues being presented (Figure 1C), and participants indicated their ranking (in the first round by guessing). The correct ranking was then presented on the right side of the screen after each trial. The learning criterion was the ability to correctly reproduce the cue ranking two times (Experiment 1) or four times (Experiment 2) consecutively.

Finally, participants learnt the directions of the cues, that is, the direction of the association between cues and criterion (i.e., which of the cue values are associated with the higher values on the criterion). For each trial, the cue name (e.g., knowledge of foreign language), and its two possible values (e.g., Dutch or Polish) were presented and participants indicate which value indicates higher quality (initially by guessing) (Figure 1D). The learning criterion was the ability to correctly reproduce all cue directions two (Experiment 1) or four times (Experiment 2) consecutively.

Decision tasks. In two different response scenarios, participants decided which of two job candidates is better qualified for the job (Figure 2). First, only the portraits and names of two candidates were presented on the screen and all cue information had to be retrieved from memory. This represented a high-memory-demand (HD) decision (Figure 2A). Second, the two candidates' cue values were presented, with cues ordered according to their ranking. Here the decision maker had to merely retrieve the direction of each cue from memory. This represented the low-memory-demand (LD) decision (Figure 2B). In both decisions, the candidates' cue value information was identical but different portraits and names of the candidates were used. Thus, the performance in both decisions could be compared.

Participants were instructed that out of the two candidates per decision the one with the higher number of cue values positively associated with the criterion is the one with better qualification. With this instruction, we determined tallying as the strategy to reach a correct decision (see Appendix Table A1 and A2 for object descriptions and choice predictions). In order to enable participants to employ tallying, they were instructed and incentivized to remember as much information as possible. With five job candidates, a total of ten ($n_{objects}$*($n_{objects}$-1)/2) distinct paired comparisons were possible. Because each pair was presented twice, we arrived at 20 HD and 20 LD decisions.

Recall Test. After the HD decision, participants completed a recall test in which they were asked to retrieve their knowledge of all cue values of each candidate, the cue ordering and directions). No feedback was given.

Participants

A total of 80 and 103 participants took part in Experiment 1 and 2: forty younger (ages 18–30 years, *M* = 22.0, *SD* = 3.5, 57.5% female) and forty older participants (64–79 years, *M* = 69.9, *SD* = 3.8, 57.5% female) in Experiment 1, and fifty-three younger (ages 18–30 years, *M* = 22.5, *SD* = 3.4, 50% female) and fifty older adults (64–80 years, *M* = 68.7, *SD* = 3.2, 50% female) in Experiment 2. Younger and older participants were matched in terms of the number of years of formal education and gender (for a detailed description of participant characteristics, see Table 1). In Experiment 1, the majority of young adults were students from the University of Basel. Older adults came from the Basel community, recruited via newspaper ads and flyers. In Experiment 2, young and older adults were residents from Berlin, recruited via local newspaper ads. In Experiment 1, young and older participants took about 1–1.5h and 2.5–3.0h, respectively, to complete all tasks. In Experiment 2, the learning criteria were stricter (see learning phase). As a consequence, 60% of the older adults needed a second learning session to meet the criterion. This additional session always took place one day after the first session. In total, younger adults needed on average 2.3 and 8.9 learning trials (i.e. where one trial equals recall of the cue information of all five candidates) to reach the learning criterion in Experiments 1 and 2, respectively. Older adults, by contrast, needed on average 13.3 and 34.7 learning trials in Experiments 1 and 2, respectively. Experiment 2's stricter criteria made the learning phase became more challenging. In Experiments 1 and 2, ten (20%) and eight (14%) older participants did not reach the learning criterion and were omitted from the study. All participants received a show-up fee (Experiment 1: 10 CHF per hour; Experiment 2: 7.50 EUR per hour) plus a performance-contingent bonus for each correct decision in the HMD and LMD decisions (Experiment 1: 0.20 CHF; Experiment 2: 0.50 EUR).

Results

The effects of age and memory demand on decision performance were analyzed using a mixed-effects ANOVA model. Furthermore, to test for the effect of memory and recall ability on performance, we combined these variables in a mediation model. The ANOVA was implemented using the afex (Singmann et al, 2015), the mediation model was conducted using the lavaan (Rosseel et al., 2014) package for R (R Core Team, 2013). Finally, we classified participants as users of either a compensatory or noncompensatory decision strategy (e.g., TALLY/WADD vs. TTB) in the HD and LD decisions. The strategy classification was based on a multinomial processing tree (MPT) approach, implemented within a Bayesian framework (Hilbig & Moshagen, 2014; Riefer & Batchfelder, 1988; see also Lee, 2015). The Bayesian estimation of the MPT models was implemented using JAGS (Denwood & Plummer, 2015) and the R package R2jags (Su & Yajima, 2015).

What is the Effect of Memory Demand on Decision Performance?

Decision performance was defined as the percentage of correct decisions across all trials. Figure 3 shows older and younger adults' percentages of correct HD and LD decisions in both experiments (see Table 2). An ANOVA revealed main effects for age group and memory demand on performance. Young adults performed better than older adults (Experiment 1: $F(1, 78) = 16.44$, $p < .001$, $\eta^2_p = .17$; Experiment 2: $F(1, 101) = 7.44$, $p = .008$, $\eta^2_p = .069$). Performance was lower in HD decisions relative to LD decisions (Experiment 1: $F(1, 78) = 71.12$, $p < .001$, $\eta^2_p = .48$; Experiment 2: $F(1, 101) = 123.37$, $p < .001$, $\eta^2_p = .55$).

Importantly, high memory demand in the HD decisions had a differential effect on performance for the two age groups; specifically, the age difference was larger in HD than in LD decisions. This was indicated by an interaction between kinds of decisions and age group, Experiment 1: $F(1, 78) = 4.99$, $p = .03$, $\eta^2_p = .06$; Experiment 2: $F(1, 101) = 4.83$, $p = .03$, $\eta^2_p = .05$. The inclusion of individual learning performance, defined as each participant's proportion of correctly recalled cue values in the last learning trial of the cue-learning phase, did not change these results. This suggests that individual differences in knowledge about the cues per se did not drive the age differences in both experiments. But what then is behind these differences?

Is Decision Performance Related to Memory Performance?

To answer this question, we next analyzed the relationships between decision performance and memory performance. The latter was composed of the ability to correctly recall the learned cue information, and in addition, an individual's general (independent of his or her cue-based recall) memory ability. Recall ability was measured both in terms of participants' ability to correctly recall the information acquired in the learning phase (i.e., cue values, cue direction, cue ranking); general memory ability was measured through the performance in the associative and working memory tasks of the cognitive battery.

We first computed pairwise correlations between all these variables. Performance in the LD decisions correlated with recall of the direction of cues (see Supplemental Materials). Relative to older adults, young adults showed perfect recall of cue directions (see Table 2). Age differences in the accuracy of LD decisions are thus due to older individuals' less accurate recall of cue directions. Performance in the HD decision task, in contrast, correlated with recall of all three types of cue information. Cue recall, in turn, was significantly related to general memory ability, with a stronger link between cue recall and associative memory relative to working memory.

Next, we constructed a mediation model and tested whether the effect of age on decision performance in the HD decisions was mediated by individual differences in memory ability via cue recall. Memory ability was indexed by a composite measure, summarizing performance in the operation span and associative recall task. Cue recall was indexed by a composite measure, summarizing recall of cue profiles, directions, and ranking. Figure 4 depicts the model and the standardized regression coefficients for Experiment 1 and 2. The effect of age on decision performance proved to be mediated by memory ability via cue recall. The effect of age on memory was significantly negative (Experiment 1: $b = –0.59$, SE = 0.09, $p <.001$; Experiment 2: $b = –0.64$, SE = 0.08, $p <.001$); the effect of memory on recall (Experiment 1: $b = 0.42$, SE = 0.09, $p = .001$; Experiment 2: $b = 0.48$, SE = .12, $p < .001$) and recall on decision performance was significantly positive (Experiment 1: $b = 0.58$, SE = 0.17, $p <.001$; Experiment 2: $b = 0.41$, SE = 0.09, $p <.001$). The effect of age on recall was negative (Experiment 1: $b = –0.32$, SE = 0.11, $p = .003$;

Experiment 2: $b = -0.20$, SE = 0.10, $p < .001$). Age no longer affected recall performance when memory ability was controlled for (Experiment 1: $b = -0.04$, SE = 0.13, $p = .73$; Experiment 2: $b = 0.10$, SE = 0.12, $p = .38$).

Overall, these results suggest that individuals with better general memory ability were better able to recall cue information and therefore performed better in the HD decisions. We also ran a model with a direct path from age to accuracy of decisions to test for direct effects of age. This model did not yield a significantly better model fit.

Let us conclude by emphasizing that we do not make any causal inferences about age-related mechanisms unfolding over time from the results described above as age differences in a cross-sectional sample need not be identical to longitudinal mediations (see Lindenberger, von Oertzen, Ghisletta, & Hertzog, 2011).

How does Memory Demand Affect Strategy Selection?

Does older adults' decreased memory performance also impact the decision strategy they select and employ? Previous research has shown that also young adults respond to increasing cognitive demands by switching to a simpler, noncompensatory strategy such as take-the-best (Bröder & Schiffer, 2003b). This heuristic inspects cues by their ranking and looks them up one at a time. As soon as a discriminating cue is found, search is stopped and a decision is made on the basis of that cue alone (e.g., Gigerenzer & Goldstein, 1996; for an overview, see Pachur & Bröder, 2013). Do older adults also balance the greater demands on memory in HD decisions by switching to a simpler strategy that curtails search, such as the take-the-best heuristic? Alternatively, do they resort to strategies that, albeit still methodical, are more idiosyncratic, and do not fit the traditional framework of compensatory versus noncompensatory processing (e.g., people integrate across some but no longer all cues)? Or, does older adults' approach to making decisions simply become erratic, for instance, by resorting to guessing instead of executing a methodical strategy?

To examine these possibilities, we conducted a classification of each individual's strategies via a Bayesian estimation of a multinomial processing tree model. Such a model yields the (posterior) probability of an individual's choices predicted by a specific strategy (see Lee, 2015 for details). The predictions made by each strategy are probabilistic (Bergert & Nosofsky, 2007, Rieskamp, 2008) and permit for erroneous responses with probabilities up to .50 (Bröder & Schiffer, 2003a; Hilbig & Moshagen, 2014). In this estimation model, we included the weighted additive strategy (WAAD), tallying (TALLY), and take-the-best (TTB) strategies described above. The estimation model also included a “guessing” strategy, choosing each option with probability .50, and a “non-classified strategy,” imposing no constraints whatsoever on choices and their respective probabilities (*saturated model*). The inclusion of the latter “strategy” is important given that it captures all participants that do not follow any of the other specified strategies but resort to more idiosyncratic one (see Hilbig & Moshagen, 2014).

Table 3 shows the classification results for both age groups and the HD and LD decisions. For young adults the vast majority was classified as following a compensatory strategy in both types of decisions (i.e., WADD or TALLY). Yet, the prevalence of compensatory processes was lower in the taxing HD relative to the less demanding LD decisions (Experiment 1: $z = 2.9$, $p < .01$; Experiment 2: $z = 2.8$, $p < .01$). Similarly, older adults were also more likely to be classified as following a compensatory strategy in LD than in HD decisions (Experiment 1: $z = 4.0$, $p < .01$, Experiment 2: $z = 4.0$, $p < .01$). In the HD decisions, the majority of older adults was classified into the saturated model (60% and 54% of the sample in Experiment 1 and 2), suggesting that with high demands on memory their decision making turned more idiosyncratic.

Discussion

Across two experiments, we found that the recruitment of memory resources in the process of making a decision is a crucial factor that determines decision performance—in younger individuals but especially in older ones. Age differences in accuracy were most amplified when individuals made decisions from memory rather than when information was displayed in front of the decision maker. These results are consistent with the thesis that age differences in task performance rise as a function of increasing complexity of the task to be mastered (Cerella et al., 1980). Our results are also in line with research that investigated this regularity in tasks as diverse as spatial object recognition (Dobson, Kirasic, & Allen, 1995), speed of perception and response time (Birren, 1956), mathematical problem solving (Clay, 1954), and they also complement previous results involving decision making (e.g., Finucane et al., 2005; Queen, Hess, Ennis, Dowd, & Grühn, 2012). One implication from this set of findings is that age differences in decision making will not emerge invariably. Instead, they come and go as a function of the cognitive demands levied by a task, and among those memory demands are likely to be particularly significant.

Our results resonate with findings from the literature on aging and memory. Age effects are more pronounced in tasks requiring the deliberative recollection of information and a high degree of self-initiated processing. We found that individual differences in memory ability mediate the effect of age on performance when decisions invoked high demand on an individual's memory. When retrieval cues are provided in the decision situation, age differences in performance decrease (e.g. Lindenberger & Mayr, 2014).

Our findings for strategy selection suggest that one of the pathways through which memory demands produce age-dependent effects on decision performance is through the triggering of different decision making strategies. One open question concerns the cause behind older adults' highly idiosyncratic decision strategies when memory demand is high (see our strategy classification analysis). In theory, several factors could contribute to older adults' switch to more idiosyncratic strategies such as memory errors during recall of cue cues, reduced information search, or a combination thereof. Past research found that older adults engage in less information search prior to a decision (Mata & Nunes, 2010; Spaniol &

Wegier, 2012) and that the curtailing of information search and/or the selection of simpler decision strategies is one way to reduce cognitive load during decision making (Bröder, 2003b). These findings would suggest that older adults may trade-off the utility of more information versus with the costs of retrieval when making decisions. Our modeling results show that especially older adults resort to strategies that, albeit still methodical, are more idiosyncratic, and do not fit the traditional framework of compensatory versus noncompensatory processing. That said, they might still integrate across some but no longer all cues. Second, older adults may be as good in retrieval processes and quality of recall as younger adults but fail during the online integration of those memories into a compound value during decision making. This fits research showing that older adults make more errors when executing strategies that require extensive integration of information (Bruine de Bruin et al., 2007; Mata et al., 2010; Light, 1991). It is also in line with studies reporting age-related deficiencies in the ability to uphold current task representations in mind which can, in turn, be related to impairments in attention, working memory, and executive control (Ardid, Wang, & Compte, 2007). In order to distinguish between these alternatives—the role of cost-benefit trade-offs versus online retrieval and integration deficits—future investigations may capitalize on additional process-tracing methods such as verbal protocols (Cokely & Kelley, 2009), tracing methods of information search (Renkewitz & Jahn, 2012; Scholz & Helversen, 2015; Pachur, Hertwig, Gigerenzer, & Brandstätter, 2013), or neuroimaging studies (Khader, Pachur, Meier, Bien, Jost, & Rösler, 2011).

Let us not minimize the importance of the results that age differences in decision making are much reduced when memory demands are low. This finding resonates with the notion of environmental support in task calling upon memory (Lindenberger & Mayer, 2014) and with the notion of decision aids (Todd & Benbasat, 1994). Age differences in memory performance are reduced when environment support in terms of hints, reminders, or contextual reinstatement are provided (Bouazzaoui et al., 2010; Craig, 1983). Similarly, decision aids can help individuals to implement strategies by altering the effort required to execute it (Cole & Balasubramanian, 1993; Todd & Banbasat, 2000). In the future decision scientists and cognitive aging researchers may collaborate in developing decision support systems that enable older adults to make good decisions under cognitively (mnemonically) challenging circumstances.

Conclusion

Memory is a resource in increasingly shorter supply with older age. This limiting factor also influences the success of decision making in older age. Across two types of decisions, one strongly taxing memory and the other easing demands on memory, we found that age differences in performance were greatest when a decision required the self-initiated retrieval of cues from memory. Age differences in memory ability, in turn, mediated the age differences in decision making. Older and younger individuals were on more equal footing—in terms of enlisting compensatory strategies—when relevant cue information, on which decisions were to be derived, was represented externally. This suggests that environmental support can boost decision making in old age under cognitively challenging conditions. Finally, our results suggest that further investigations of how and how well older individuals making decisions need to be informed by a task analysis that determines the cognitive demands imposed.

References

Ardid, S., Wang, X.-J., & Compte, A. (2007). An integrated microcircuit model of attentional processing in the neocortex. *The Journal of Neuroscience, 27*(32), 8486–8495. doi:10.1523/JNEUROSCI.1145-07.2007

Badre, D., & Wagner, A. D. (2007). Left ventrolateral prefrontal cortex and the cognitive control of memory. *Neuropsychologia*, *45*(13), 2883–2901. doi:10.1016/j.neuropsychologia.2007.06.015

Bäckman, L., Small, B. J., & Wahlin, Å. (2001). Aging and memory: Cognitive and biological perspectives. In J. E. Birren & K. W. Schaie, *Handbook of the psychology of aging* (pp. 349–377). San Diego, CA: Academic Press.

Beach, L. R., & Mitchell, T. R. (1978). A contingency model for the selection of decision strategies. *Academy of Management Review*, *3*, 439–449.

Bergert, F. B., & Nosofsky, R. M. (2007). A response-time approach to comparing generalized rational and take-the-best models of decision making. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 33*(1), 107–129. doi:10.1037/0278-7393.33.1.107

Birren, J. E. (1956). The significance of age changes in speed of perception and psychomotor skills. In J. E. Anderson (Eds.), *Psychological aspects of aging* (pp. 97–104). Washington, DC: American Psychological Association.

Bouazzaoui, B., Isingrini, M., Fay, S., Angel, L., Vanneste, S., Clarys, D., & Taconnat, L. (2010). Aging and self-reported internal and external memory strategy use: The role of executive functioning. *Acta Psychologica*, *135*(1), 59–66. doi:10.1016/j.actpsy.2010.05.007

Bröder, A., & Schiffer, S. (2003a). Bayesian strategy assessment in multi-attribute decision making. *Journal of Behavioral Decision Making*, *16*(3), 193–213. doi:10.1002/bdm.442

Bröder, A., & Schiffer, S. (2003b). Take The Best versus simultaneous feature matching:

Probabilistic inferences from memory and effects of representation format. *Journal of Experimental Psychology: General*, *132*(2), 277–293. doi:10.1037/0096-3445.132.2.277

Bröder, A., & Schiffer, S. (2006). Stimulus format and working memory in fast and frugal strategy selection. *Journal of Behavioral Decision Making*, *19*(4), 361–380. doi:10.1002/bdm.533

Bruine de Bruin, W., Parker, A. M., & Fischhoff, B. (2010). Explaining adult age differences in decision-making competence. *Journal of Behavioral Decision Making*, *25*(4), 352–360. doi:10.1002/bdm.712

Buckner, R. L. (2004). Memory and executive function in aging and AD: Multiple factors that cause decline and reserve factors that compensate. *Neuron*, *44*(1), 195–208. doi:10.1016/j.neuron.2004.09.006

Cerella, J., Poon, L. W., & Williams, D. M. (1980). Age and the complexity hypothesis. In L. W. Poon, *Aging in the 1980's* (pp. 332–340). Washington, DC: American Psychological Association.

Cokely, E. T., Kelley, C. M. (2009). Cognitive abilities and superior decision making under risk: A protocol analysis and process model evaluation. *Judgment and Decision Making, 4*, 20–33.

Cole, C. A., & Balasubramanian, S. K. (1993). Age differences in consumers' search of information: Public policy implications. *Journal of Consumer Research, 20*(1), 157–169. doi:10.1086/209341

Clay, H. M. (1954). Changes of performance with age on similar tasks of varying complexity. *British Journal of Psychology*, *45*(1), 7–13. doi:10.1111/j.2044-8295.1954.tb01221.x

Craik, F. I. M., Routh, D., & Broadbent, D. E., (1983). On the transfer of information from temporary to permanent memory [and discussion]. *Philosophical Transactions of the Royal Society B: Biological Sciences, 302*(1110), 341–359. doi:10.1098/rstb.1983.0059

Dawes, R. M. (1979). The robust beauty of improper linear models. *American Psychologist, 34*, 571–582. doi:10.1037/0003-066X.34.7.571

Del Missier, F., Mäntylä, T., Hansson, P., Bruine de Bruin, W., Parker, A. M., & Nilsson, L.-G. (2013). The multifold relationship between memory and decision making: An individual-differences study. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *39*(5), 1344–1364. doi:10.1037/a0032379

Denwood, M., & Plummer, M. (2015). *runjags: Interface utilities, model templates, parallel computing methods and additional distributions for MCMC models in JAGS.* R package.

Dobson, S. H., Kirasic, K. C., & Allen, G. L. (1995). Age-related differences in adults' spatial task performance: Influences of task complexity and perceptual speed. *Aging, Neuropsychology, and Cognition, 2*(1), 19–38. doi:10.1080/13825589508256587

Dunlosky, J., & Hertzog, C. (1998). Aging and deficits in associative memory: What is the role of strategy production? *Psychology and Aging*, *13*(4), 597–607. doi:10.1037//0882-7974.13.4.597

Finucane, M. L., Mertz, C. K., Slovic, P., & Schmidt, E. S. (2005). Task complexity and older adults' decision-making competence. *Psychology and Aging*, *20*(1), 71–84. doi:10.1037/0882-7974.20.1.71

Fleischmann, D. A., Wilson, R. S., Garbrieli, J. D. E., Bienias, J. L., & Bennett, D. A. (2004). A longitudinal study of implicit and explicit memory in old persons. *Psychology and Aging, 19*(4), 617–625. doi:10.1037/0882-7974.19.4.617

Frey, R., Mata, R., & Hertwig, R. (2015). The role of cognitive abilities in decisions from experience: Age differences emerge as a function of choice set size. *Cognition*, *142*, 60–80. doi:10.1016/j.cognition.2015.05.004

Gigerenzer, G., & Goldstein, D. (1996). Reasoning the fast and frugal way: Models of bounded rationality. *Psychological Review, 103*, 650–669. doi:10.1037/0033-295X.103.4.650

Hedden, T., & Gabrieli, J. D. E. (2004). Insights into the ageing mind: A view from cognitive neuroscience. *Nature Reviews Neuroscience*, *5*(2), 87–96. doi:10.1038/nrn1323

Henninger, D. E., Madden, D. J., & Huettel, S. A. (2010). Processing speed and memory mediate age-related differences in decision making. *Psychology and Aging*, *25*(2), 262–270. doi:10.1037/a0019096

Hertzog, C., & Dunlosky, J. (2004). Aging, metacognition, and cognitive control. In B. H. Ross (Ed.). The *psychology of learning and motivation: Advances in research and theory* (pp. 215–251). San Diego, CA, US: Elsevier Academic Press.

Hilbig, B. E., & Moshagen, M. (2014). Generalized outcome-based strategy classification: Comparing deterministic and probabilistic choice models. *Psychonomic Bulletin & Review*, *21*(6), 1431–1443. doi:10.3758/s13423-014-0643-0

Horn, S., Pachur, T., & Mata, R. (2015). How does aging affect recognition-based inference? A hierarchical Bayesian modeling approach. *Acta Psychologica, 154,* 77–85. doi:10.1016/j.actpsy.2014.11.001

Hosseini, S. M. H., Rostami, M., Yomogida, Y., Takahashi, M., Tsukiura, T., & Kawashima, R. (2010). Aging and decision making under uncertainty: Behavioral and neural evidence for the preservation of decision making in the absence of learning in old age. *NeuroImage, 52*(4), 1514–1520. doi:10.1016/j.neuroimage.2010.05.008

Insingrini, M., Angel, L., Fay, S., Taconnat, L., Lemaire, P., & Bouazzaoui, B. (2015). Age-realted differences in the reliance on executive control in working memory: Role of task demand. *PloS ONE, 10,* 1–12. doi 10.1371/journal.pone.0145361

Khader, P. H., Pachur, T., Meier, S., Bien, S., Jost, K., & Rösler, F. (2011). Memory-based decision-making with heuristics: evidence for a controlled activation of memory representations. *Journal of Cognitive Neuroscience*, *23*(11), 3540–3554. doi: 10.1162/jocn_a_00059

La Voie, D., & Light, L. L. (1994). Adult age differences in repetition priming: A meta-analysis. *Psychology and Aging, 9*(4), 539–553. doi:10.1037/0882-7974.9.4.539

Lee, M. D. (2015). Bayesian outcome-based strategy classification. *Behavior Research Methods,* 1–13. doi:10.3758/s13428-014-0557-9

Lehrl, S. (1999). *Mehrfachwahl-Wortschatz-Intelligenztest: MWT-B*. Spitta.

Li, Y., Gao, J., Enkavi, A. Z., Zaval, L., Weber, E. U., & Johnson, E. J. (2015). Sound credit scores and financial decisions despite cognitive aging. *Proceedings of the National Academy of Sciences*, *112*(1), 65–69. doi:10.1073/pnas.1413570112

Light, L. L. (1991). Memory and aging: Four hypotheses in search of data. *Annual Review of Psychology*, *42*(1), 333–376. doi:10.1146/annurev.ps.42.020191.002001

Lindenberger, U., & Mayr, U. (2014). Cognitive aging: Is there a dark side to environmental support? *Trends in Cognitive Sciences*, *18*(1), 7–15. doi:10.1016/j.tics.2013.10.006

Lindenberger, U., von Oertzen, T., Ghisletta, P., & Hertzog, C. (2011). Cross-sectional age variance extraction: What's change got to do with it? *Psychology and Aging, 26*(1), 34–47. doi:10.1037/a0020525

Old, S. R., & Naveh-Benjamin, M. (2008). Differential effects of age on item and associative measures of memory: A meta-analysis. *Psychological Aging, 23*, 104–118. doi:10.1037/0882-7974.23.1.104

Marewski, J. N., & Schooler, L. J. (2011). Cognitive niches: An ecological model of strategy selection. *Psychological Review*, *118*(3), 393–437. doi:10.1037/a0024143

Mata, R., & Nunes, L. (2010). When less is enough: Cognitive aging, information search, and decision quality in consumer choice. *Psychology and Aging*, *25*(2), 289–298. doi:10.1037/a0017927

Mata, R., Pachur, T., Helversen, von, B., Hertwig, R., Rieskamp, J., & Schooler, L. J. (2012). Ecological rationality: A framework for understanding and aiding the aging decision maker. *Frontiers in Neuroscience*, *6*, 1–6.

doi:10.3389/fnins.2012.00019/abstract

Mata, R., Schooler, L. J., & Rieskamp, J. (2007). The aging decision maker: Cognitive aging and the adaptive selection of decision strategies. *Psychology and Aging*, *22*(4), 796–810. doi:10.1037/0882-7974.22.4.796

Naveh-Benjamin, M. (2000). Adult age differences in memory performance: Tests of an associative deficit hypothesis. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 26,* 1170–1187. doi: 10.1037//0278-7393.26.5.117

Pachur, T., & Bröder, A. (2013). "Judgement": A cognitive processing perspective. *Wiley Interdisciplinary Reviews: Cognitive Science, 4*(6), 665–681. doi:10.1002/wcs.1259

Pachur, T., Hertwig, R., Gigerenzer, G., & Brandstätter, E. (2013). Testing process predictions of models of risky choice: A quantitative model comparison approach. *Frontiers in Psychology, 4*(646), 1–22. doi:10.3389/fpsyg.2013.00646

Pachur, T., Mata, R., & Schooler, L. J. (2009). Cognitive aging and the use of recognition in decision making. *Psychology and Aging, 24*(4)*,* 901-915. doi:10.1037/a0017211

Payne, J. W., Bettman, J. R., & Johnson, E. J. (1993). *The adaptive decision maker*. New York: Cambridge University Press.

Queen, T. L., Hess, T. M., Ennis, G. E., Dowd, K., & Grühn, D. (2012). Information search and decision making: Effects of age and complexity on strategy use. *Psychology and Aging, 27*(4), 817–824. doi:10.1037/a0028744

R Core Team (2013, March 30). R: A language and environment for statistical computing. Vienna, Austria: R Foundation for Statistical Compting. Retrieved from http://www.R-project.org/

Renkewitz, F., & Jahn, G. (2012). Memory-indexing: A novel method for tracing memory processes in complex cognitive tasks. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 38*(6), 1622–1639. doi:10.1037/a0028073

Riefer, D. M., & Batchfelder, W. H. (1988). Multinomial modeling and the measurement of cognitive processes. *Psychological Review, 95*(3), 318–339. doi:10.1037/0033-295X.95.3.318

Rieskamp, J. (2008). The probabilistic nature of preferential choice. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 34*(6), 1446–1465. doi:10.1037/a0013646

Rosseel, Y., Oberski, D., Byrnes, J., Vanbrabant, L., Savalei, V., Merkle, E., et al. (2014, March 30). lavaan: Latent variable analysis. R package.

Sander, M. C., Lindenberger, U., & Werkle-Bergner, M. (2012). Lifespan age differences in working memory: A two-component framework. *Neuroscience and Biobehavioral Reviews*, *36*(9), 2007–2033. doi:10.1016/j.neubiorev.2012.06.004

Scholz, A., von Helversen, B., & Rieskamp, J. (2015). Eye movements reveal memory processes during similarity- and rule-based decision making. *Cognition, 136*, 228–246. doi:10.1016/j.cognition.2014.11.019

Shah, A. K., & Oppenheimer, D. M. (2008). Heuristics made easy: An effort-reduction framework. *Psychological Bulletin*, *134*(2), 207–222. doi:10.1037/0033-2909.134.2.207

Shing, Y. L., Werkle-Bergner, M., Li, S.-C., & Lindenberger, U. (2008). Associative and strategic components of episodic memory: A life-span dissociation. *Journal of Experimental Psychology: General*, *137*(3), 495–513. doi:10.1037/0096-3445.137.3.495

Singmann, H., Bolker, B., Westfall, J., Højsgaard, S., Fox, J., Lawrence, M. A., & Mertens, U. (2015, January 12). Afex: Analysis of factorial experiments. R package.

Spaniol, J., & Wegier, P. (2012). Decisions from experience: Adaptive information search and choice in younger and older adults. *Frontiers in Neuroscience, 6*(36), 1–9. doi: 10.3389/fnins.2012.00036

Su, Y.-S., & Yajima, M. (2015, March 5). R2jags: A package for running “JAGS” from R. R package.

Todd, P., & Benbasat, I. (1994). The influence of decision aids on choice strategies: An experimental analysis of the role of cognitive effort. *Organizational Behavior and Humen Decision Processes, 60*(1), 36–74. doi:10.1006/obhd.1994.1074

Todd, P., & Benbasat, I. (2000). Inducing compensatory information processing through decision aids that facilitate effort reduction: An experimental assessment. *Behavioral Decision Making, 13*(1), 91–106. doi:10.1002/(SICI)1099-0771(200001/03)13:1<91:.AID-BDM345>3.0.CO;2-A

Touron, D. R., & Hertzog, C. (2004a). Distinguishing age differences in knowledge, strategy use, and confidence during strategic skill acquisition. *Psychology and Aging*, *19*, 452–466. doi:10.1037/0882-7974.19.3.452

Touron, D. R., & Hertzog, C. (2004b). Strategy shift affordance and strategy choice in young and older adults. *Memory & Cognition*, *32*, 298–310. doi:10.3758/BF03196860

Touron, D. R. (2015). Memory avoidance by older adults: When "old dogs" won't perform their "new tricks". *Current Directions in Psychological Science, 24,* 170–176, doi: 10.1177/0963721414563730

Tymula, A., Rosenberg Belmaker, L. A., Ruderman, L., Glimcher, P. W., & Levy, I. (2013). Like cognitive function, decision making across the life span shows profound age-related changes. *Proceedings of the National Academy of Sciences*, *110*(42), 1–6. doi:10.1073/pnas.1309909110/-/DCSupplemental

Unsworth, N., Heitz, R. P., Schrock, J. C., & Engle, R. W. (2005). An automated version of the operation span task. *Behavior Research Methods*, *37*(3), 498–505. doi:10.3758/BF03192720

Wechsler, D. (1981). *WAIS-R manual: Wechsler adult intelligence scale-revised*. Psychological Corporation.

Yoon, C., Cole, C. C., & Lee, M. P. (2009). Consumer decision making and aging: Current knowledge and future directions. *Journal of Consumer Psychology, 19*(1), 2–16. doi:10.1016/j.jcps.2008.12.002

Tables

Table 1
Participant Characteristics

	Younger Adults		Older Adults		*Statistical test*		
	M	*SD*	*M*	*SD*	*t*	*p*	*d*
Experiment 1							
N	40		40				
Age[a]	22.0	3.5	69.9	3.8	-	-	-
Education (years)[a]	13.7	3.0	13.3	3.4	–0.72	.47	0.12
Vocabulary	0.80	0.08	0.92	0.06	8.13	<.01	–1.70
Processing speed	0.68	0.10	0.49	0.10	–8.61	<.01	1.90
Paired recall	0.54	0.25	0.24	0.21	–5.87	<.01	1.29
Operation span	0.93	0.09	0.84	0.14	–3.08	<.01	0.76
Experiment 2							
N	53		50				
Age[a]	22.5	3.4	68.7	3.2	-	-	-
Education (years)[a]	15.3	2.7	15.3	2.8	–0.06	.94	0
Vocabulary	0.84	0.05	0.89	0.07	4.59	<.01	–0.82
Processing speed	0.63	0.11	0.45	0.09	–8.95	<.01	1.79
Paired recall	0.49	0.26	0.21	0.17	–6.43	<.01	1.28
Operation span	0.82	0.13	0.58	0.21	–7.02	<.01	1.38

Note. Vocabulary = Spot-a-Word Test (score range 0–37; Lehrl, 1999), Processing speed = Digit Symbol Substitution (score range 0–93; Wechsler, 1981). [a] These measures report raw scores not proportions. Positive effect sizes indicate worse performance of older adults relative to younger adults negative effect sizes worse performance of young relative to older adults.

Table 2
Decision and Recall Performance

Measure	Younger Adults		Older Adults		*Statistical test*		
	M	*SD*	*M*	*SD*	*t*	*p*	*d*
Experiment 1							
Low memory demand	0.91	0.09	0.84	0.20	–2.25	<.01	0.45
High memory demand	0.77	0.17	0.58	0.23	–4.08	<.01	0.94
Cue profiles	0.83	0.16	0.78	0.13	–1.36	0.18	0.34
Cue ranking	0.99	0.03	0.83	0.24	–4.52	<.01	0.94
Cue directions	1.00	0.00	0.78	0.13	–3.26	<.01	2.39
Experiment 2							
Low memory demand	0.88	0.12	0.84	0.16	–1.23	.22	0.28
High memory demand	0.70	0.19	0.58	0.21	–3.00	<.01	0.60
Cue profiles	0.82	0.14	0.78	0.12	–1.77	0.08	0.31
Cue ranking	0.92	0.19	0.86	0.25	–1.38	0.17	0.27
Cue directions	0.99	0.05	0.95	0.09	–2.41	0.02	0.55

Note. All of these measures report mean proportions of correctly recalled cues. Positive effect sizes indicate worse performance of older adults relative to younger adults negative effect sizes worse performance of young relative to older adults.

Table 3
Strategy Classification

	Younger Adults		Older Adults	
	LD	HD	LD	HD
Experiment 1	*n* = 40		*n* = 40	
WADD	17 (42.5%)	10 (25%)	9 (22.5%)	5 (12.5%)
TALLY	22 (55%)	20 (50%)	22 (55%)	8 (20%)
TTB	–	6 (15%)	1 (2.5%)	–
GUESS	–	–	1 (2.5%)	3 (7.5%)
SAT	1 (2.5%)	4 (10%)	7 (17.5%)	24 (60%)
Experiment 2	*n* = 53		*n* = 50	
WADD	21 (39.6%)	11 (20.8%)	11 (22%)	9 (18%)
TALLY	23 (43.4%)	20 (37.7%)	26 (52%)	8 (16%)
TTB	8 (15.1%)	7 (13.2%)	4 (8%)	3 (6%)
GUESS	–	2 (3.8%)	2 (4%)	3 (6%)
SAT	1 (1.9%)	13 (24.5%)	7 (14%)	27 (54%)

Note. Columns show frequencies as well as the proportion of participants out of the whole sample (in brackets) classified to the respective model. LD = low memory demand, HD = high memory demand, WADD = weighted additive model, TALLY = tallying model, TTB = take-the-best model, SAT = saturated model, GUESS = guessing.

Figures

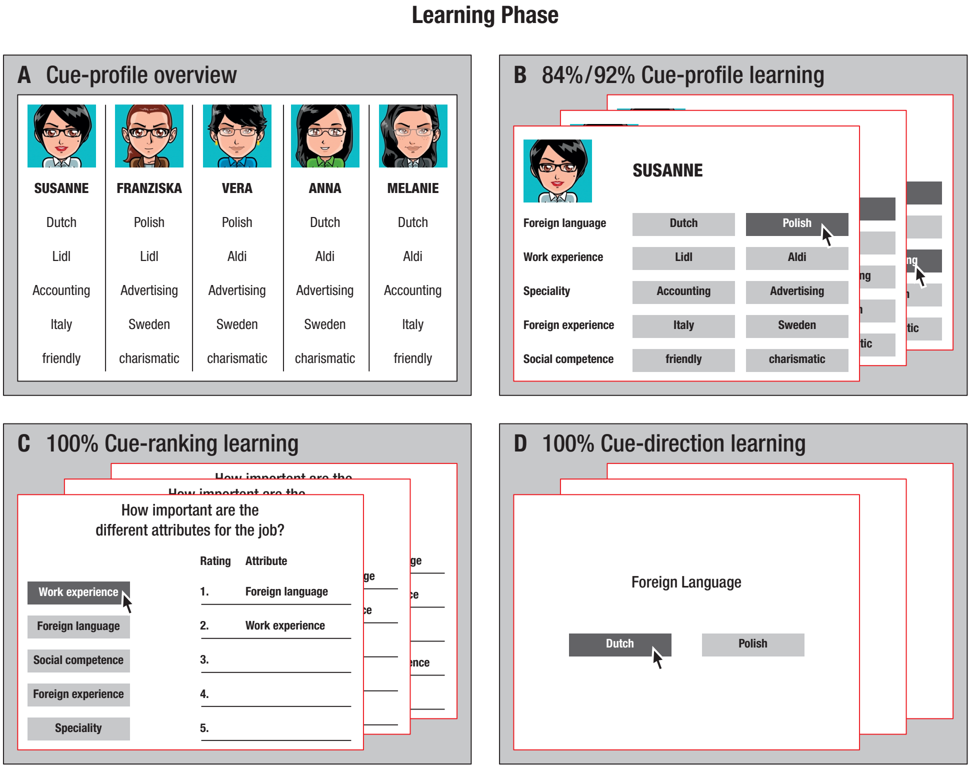

Figure 1. Learning phase of Experiment 1 and 2. **A** = Cue-profile overview, **B** = Cue-profile learning phase, **C** = Cue-ranking learning phase, **D** = Cue-direction learning phase.

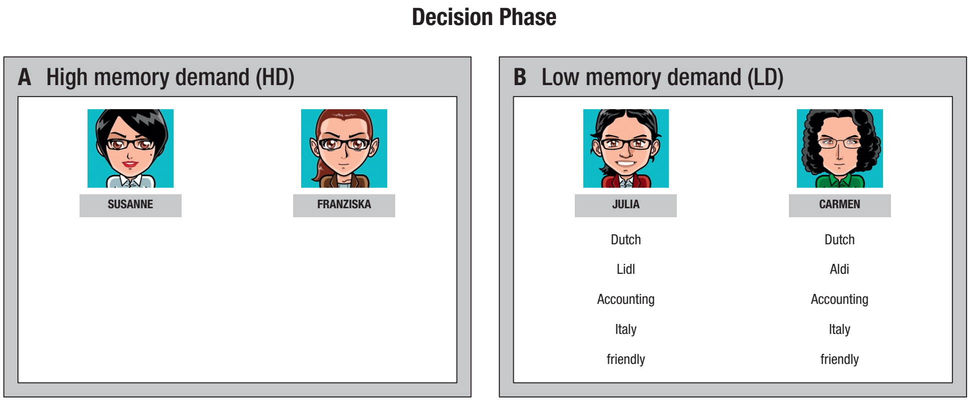

Figure 2. Decision tasks in Experiment 1 and 2. **A** = High memory demand (HD), **B** = Low memory demand (LD). The cue-recall phase was interspersed between the HD and LD decision phase and looked similar to learning phase b–d despite no immediate feedback as given.

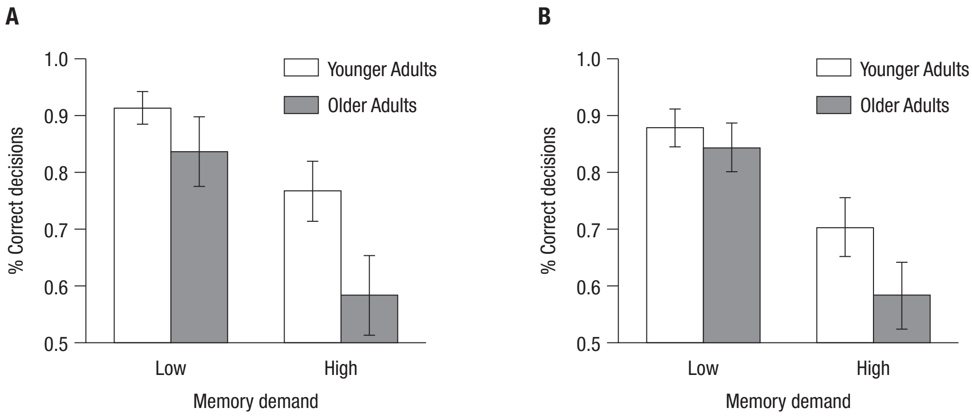

Figure 3. Mean (%) decision performance for younger and older adults in each decision task in Experiment 1 (A) and Experiment 2 (B). The main effect of age group, decision task and their interaction are significant at $p < .05$. 95% confidence intervals are represented in the figure by the error bars attached to each column.

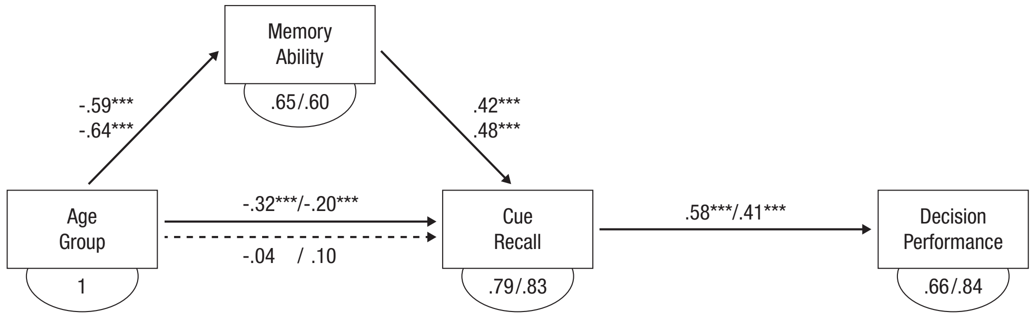

Figure 4. Mediation model estimating the effect of age on decision performance via memory ability and cue recall in the decision task with high memory demand. Figure contains standardized coefficients for each experiment. *** significant at $p < .001$, ** significant at $p < .01$, * significant at $p < .05$.

Appendix

The materials of the decision tasks (trials and objects) were designed such that the decision trials distinguish between compensatory (TALLY) and noncompensatory (TTB) decision making. First, we selected five cue patterns (each representing a job candidate) consisting of five binary cues each. To do this, we created all possible sets of five candidates with five binary cues and computed their predictions for TALLY and TTB. We then chose those five candidates for which the number of trials discriminating between these two strategies as largest (where the two strategies would make opposing predictions). Table A1 shows the final cue patterns of the five decision objects. Table A2 shows the resulting comparisons as well as the predictions of TALLY and TTB. Because WADD is a similar decision strategy that makes slightly different predictions for some of the resultant trials, we also modeled this strategy besides the additional models capturing guessing and idiosyncratic decision strategies.

Table A1
Cue Patterns of the Five Decision Objects

Object	Cue 1	Cue 2	Cue 3	Cue 4	Cue 5
1	–	+	+	+	+
2	+	+	–	–	–
3	+	–	–	–	–
4	–	–	–	–	–
5	–	–	+	+	+

Note. + Positive cue direction; – Negative cue direction.

Table A2
Choice Predictions (i.e. Object 1 or Object 2) for the Weighted-Additive Strategy (WADD), the Tallying Strategy (TALLY), and the Take-the-Best Strategy (TTB)

Trial	Object 1	Object 2	WADD	TALLY	TTB	Guess
1	1	2	1	1	2	?
2	4	5	2	2	2	?
3	2	3	1	1	1	?
4	4	3	2	2	2	?
5	1	5	1	1	1	?
6	5	2	2	1	2	?
7	3	1	2	2	1	?
8	4	2	2	2	2	?
9	5	3	1	1	2	?
10	4	1	2	2	2	?

Note. Given the cue patterns and validities (see Table A1), each model predicts that either object 1 will be chosen, that object 2 will be chosen, or that a choice will be made at random (?). The guessing model assumes random choice on each trial (equal to a probability of .5 of choosing each of the alternatives.

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Mata, R., Josef, A. K., & Hertwig, R. (2016). Propensity for risk taking across the life span and around the globe. *Psychological Science, 27*, 231–243. doi:10.1177/0956797615617811

Mata, R., Josef, A. K., & Lemaire, P. (2015). Adaptive decision-making and aging. In T. M. Hess, J. Strough, & C. E. Loeckenhoff (Eds.), *Aging and decision making: Empirical and applied perspectives* (pp. 105-122). New York: Elsevier.

2011

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Manuskripte in Vorbereitung

Josef, A. K., Hertwig, R., & Mata, R. (in preparation). Age differences in risk-taking propensity are related to perceptions of risk and reward but not perceived control.

Josef, A. K., Kellen, D., Pachur, T., Hertwig, R., & Mata, R. (in preparation). How cognitive aging affects decision making under increased memory demands.

Josef, A. K., Ostwald, D., Shing, Y.-L., & Mata, R. (in preparation). Neuronal correlates of age-differences in decision making under increased memory and control demands.

Samanez-Larkin, G. R., Karrer, T., Josef, A. K., Morris, E., & Mata, R. (in preparation). A meta-analysis of PET imaging studies of adult age differences in the dopamine system.

Josef, A. K., Mata, R., Frey, R., & Hertwig, R. (in preparation). Reckoning with risk and uncertainty across the life span. In R. Hertwig, TP, and the ARC Research Group.

Konferenzteilnahmen

Kongress der Deutschen Gesellschaft für Psychologie 2012/2014 (www.dgpskongress.de)

Tagung Experimentell Arbeitender Psychologen 2011/2013/2014/2015 (www.teap.de)

Society of Judgment and Decision Making 2013/2014 (www.sjdm.org)

Annual Judgment and Decision Making Workshop for Young Researchers 2012/2013

Symposium at the Graduate School of Decision Sciences: "Do I like what I prefer? Integrating research on attitudes and preferences" 2014 (www.dsds.uni-konstanz.de)

Psychonomic Society 2013/2014 (www.psychonomic.org)

International Convention of Psychological Science 2015 (www.icps.psychologicalscience.org)

Cognitive Aging Conference 2014 (www.cac.gatech.edu)

International Conference "Aging and Cognition" 2013 (www.ifado.de)

Lehre und Supervision

seit 7/2015	Chantal Wysocky, Bachelorstudentin an der Medical School Berlin, Bachelorarbeit zum Thema '*Age differences in risk-taking propensity: Preference construction and psychmetric equivalence*
02/2015 – 07/2015	Ursula Goldstein, Bachelor of Arts in Psychology, Praktikum zu Thema '*The neuronal correlates of age differences in memory-based decision making*'
12/2013 – 04/2014	Isabelle Engelhardt, Bachelor of Arts in Psychology, Praktikum zum Thema '*The life span development of memory-based decision making*'

Weiterführende Ausbildung

11/2015	Interview training. Workshop, Marion Koch (Journalistin), Pressehaus am Alexanderplatz, Berlin.
08/2014	Bayesian modeling for cognitive science. Workshop, Prof. Dr. E. J. Wagenmakers, Universität Amsterdam
12/2013	Presentation training for academics. Workshop, Steve Weir (FU Berlin), Max Planck Institut für Bildungsforschung
11/2013	Structural equation modeling with Mplus. Workshop, Dr. Andrea Hildebrandt & Dr. Jenny Wagner, Humboldt Universität Berlin
10/2013	BrainVision Analyzer intermediate user workshop. Workshop,

Brain Products Team, PC College, Berlin

09/2013 SPM: Workshop on functional neuroimaging analysis. Workshop, Prof. Dr. Christian Büchel, Universitätsklinikum Hamburg-Eppendorf, Institut für Systemische Neurowissenschaften, Hamburg

06/2013 Data analysis beyond p-values: A practical introduction to Bayesian statistics. Workshop, Dr. Stefan Herzog (MPIB Berlin). Max Planck Institut für Bildungsforschung, Berlin

04/2013 Structural equation modeling with onyx and openmx. Workshop by Dr. Andreas Brandmaier (MPIB Berlin), Max Planck Institut für Bildungsforschung, Berlin

Academic English: Writing and speaking. Humanities and social sciences seminar series, James Murphy (FU Berlin), Max Planck Institut für Bildungsforschung, Berlin