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Effects of personal characteristics on susceptibility to decision bias: a literature study

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Abstract

Cognitive biases and heuristics are pervasive simplifications and distortions in judgement and reasoning that systematically affect human decision making. Knowledge in this area may enable us to foresee and reduce detrimental effects of biases or to influence others more effectively. We therefore performed a literature study to assess the influence of personal characteristics (cognitive abilities, expertise, personality, cultural background) on the occurrence of cognitive biases. We found that each of the aforementioned factors can affect cognitive biases, though not much is known about the effects of culture. Also, factors that appear to reduce a cognitive bias may in fact mitigate (suppress or override) its behavioral effect rather than preventing the bias from occurring at all. The general picture that arises is that bias susceptibility and the occurrence of biases depend on thinking style (heuristic versus deliberate), where thinking style is associated with an individual's personal characteristics. In general, biases are reduced when a deliberate (analytical) thinking style is applied. However, whether a specific (heuristic or deliberate) thinking style actually reduces or enhances a given type of bias also depends on the context.

Keywords: bias, heuristics, personal characteristics, decision making, judgement.

Introduction

People constantly make judgments and decisions, either conscious or unconscious. Most decisions are made without knowing for sure what the effects of the decision will be and whether the outcome will be positive or not. Making decisions in uncertainty is based upon at least two factors: the desirability and the likelihood of the outcome. Decision theory studies the development of algorithms that, for a given problem and likelihoods, produce the best outcome. Decision theory can thus, in principle, provide recommendations how to best make decisions. However, in real life people often make decisions that deviate from the best solution (Haselton, Nettle, & Andrews, 2005).These deviations are the outcome of systematic distortions in human judgment and reasoning.

Subjective estimations play a significant part in our daily life. Our decisions, conclusions and explanations are based upon our *beliefs* about the likelihood of uncertain events but not on their *objective* likelihood. For example, the decision to stay away from a particular neighborhood is not driven by the *actual* likelihood of being robbed, but by our *perception* of the likelihood of being robbed. The important conclusion of an immense body of research on decision making is that

people do not follow the laws of probability, but instead use relatively simple rules (heuristics). These heuristics often perform well, but under certain conditions may lead to systematic and serious errors. The distortion of human judgment and decision making is called 'cognitive bias', or shortly 'bias'.

The study reported here was performed to acquire further insight into biased (pre-cognitive, automatic, heuristic) judgment and decision processes (that are influenced by intuitions, emotions, biases, or associations) and to investigate whether biased thinking depends on the personal characteristics of individuals. If there are indeed psychological characteristics that predict biased thinking, this knowledge could in principle effectively be used to either mitigate or deploy biased thinking. Knowledge of cognitive biases can for instance be used to:

- develop selection procedures (to develop tests that estimate an individual's susceptibility to biases),
- reduce susceptibility to biases and ameliorate their effects (by training personnel and institutions to recognize and cope with biases appropriately, and by developing fast and frugal decision protocols),
- effectively deploy knowledge of biases against relevant actors (both on a strategic level as part of a doctrine and operationally in the field).

The literature study reported here contributes to this goal by identifying characteristics of individuals (e.g., cognitive abilities, expertise, personality, cultural background) that may predict a person's susceptibility to cognitive biases, and in particular those leading to decision and judgment biases.

The following section discusses the literature search strategy. Next we briefly discuss the origins of human decision biases and factors that may affect the susceptibility to these biases. Then we present a literature review on some personal characteristics that may predict an individual's susceptibility to judgment and decision bias. Finally, we will present the conclusions of this study.

Literature search strategy

Electronic searches were carried out using the databases ScienceDirect, PubMed and PsycINFO. In addition, lliterature searches were also performed with Google Scholar. As search terms we used the names of several well-known biases (Anchoring, Anchoring bias, Attribution error, Base rate neglect, Belief bias, Confirmation bias, Conjunction fallacy, Framing, Halo effect, Hindsight bias, Imaginability bias, Omission bias, Negativity bias, Outcome bias, Over-confidence bias, Sunk cost effect) as well as some general terms (Bias, Cognitive bias, Decision bias, Decision making, Judgement, Heuristic bias, Heuristics: for definitions see Appendix A) and combined them with (conjunction: AND) terms related to personal characteristics (cognitive abilities OR expertise OR personality OR individual differences OR culture OR reasoning OR thinking OR trait) factors. The searches were restricted to articles reporting empirical studies in peer reviewed journals. The relevant papers that were found in this initial search served as a starting point for subsequent searches, that included all later papers referring to papers from the initial set (found by using the 'Cited by' function in Google Scholar. We included studies found using this method in the review only if they involved influences of personal factors on human decision making. The literature searches were performed in the second half of 2016.

Cognitive biases and their origins

The human mind is limited in its capacity to render judgments in a way that is perfectly rational and fully informed. While rational thinking serves well to solve decision problems that allow comprehensive analysis, it may fail in complex real life situations, where it is often very difficult to have access to every relevant piece of information, and where a decision often has to be made quickly. Even if such access were possible, our brains do not operate like computer algorithms, capable of complex and multiple calculations in order to reach logically sound conclusions – not to mention that we hardly have time to perform such rigorous analysis for every judgment that we make. As a result, human decision making tends to rely on a variety of simple heuristic decision rules that can be executed quickly. Oftentimes, heuristics produce judgements and decisions that are 'good enough' when measured against an acceptable cognitive load. However, heuristics can also lead to irrational thinking and problem-solving in ways that produce errors or illogical decisions, known as 'cognitive biases'. This is most likely to occur in complex situations (when relevant information is ignored and/or irrelevant information interferes) or in situations that are mistakenly perceived as familiar (while they are actually unknown). Cognitive biases are pervasive in human reasoning and have important practical implications.

Dual-process heuristic-deliberate theories postulate a distinction between fast, intuitive, automatic, heuristic, emotionally charged and fallible (heuristic or 'Type 1') processes versus slow, conscious, controlled, deliberate and analytic (deliberate or 'Type 2') processes (e.g., Evans, 2006; Kahneman, 2003; Kahneman & Frederick, 2002; Sloman, 1996). When fast responses are required, performance is based on low-effort heuristic processes. Deliberate processes supervise and control the output of the heuristic system. In this view biases occur when deliberate processing either (1) fails to successfully engage (Kahneman, 2003) or (2) fails to override the biased heuristic response (De Neys, 2012). The serial deliberate processes are slower and require more working memory and are therefore constrained by the limited capacity of the brain. Conversely, heuristic processes function implicitly and in parallel and do not claim executive working memory resources (De Neys, 2006). It is generally assumed that heuristic processes result in biased outcomes, unless the analytical system takes over (Evans, 1984, 1989). In this study we adopt the dual-process heuristic-deliberate theory of human decision making as a framework to unify and understand our current findings.

Intuitive (heuristic) decision-making produces quick solutions based on general heuristics (the Fast and Frugal view: Gigerenzer & Gaissmaier, 2010) or on experience-based (pattern-matching) evaluations (Naturalistic Decision Making: G. A. Klein, 1993; see e.g. Kahneman & Klein, 2009; G. Klein, 2015 and Davis, Kulick, & Egner, 2005 for a discussion on the differences and similarities between both views). Intuition can provide access to information that would not be beliedfble through deliberate thinking (Hogarth, 2010). However, intuition cannot generate or acquire new knowledge. Also, since intuition is bias prone, it may lead to potentially dangerous inaccurate perceptions of reality (Dane & Pratt, 2007; Kahneman & Frederick, 2002; Amos Tversky & Kahneman, 1974).

In contrast to intuitive decision-making, deliberation uses abstract thinking and generalizations, and allows the acquisition of additional information in the decision-making process (Söllner, Broeder, & Hilbig, 2013).This is a clear advantage over intuition when problem solving requires the application of complex rules (Kahneman & Frederick, 2002). In the real world, decision makers often have to deal with three critical constraints that limit their opportunities for deliberation: (1) limited access to information, (2) cognitive limitations inherent in the human mind, and (3) limited time. These constraints result in 'bounded rationality' (H. A. Simon, 1972). Deliberation is time consuming and requires cognitive effort. Cognitive resources claimed by deliberation cannot be deployed for other tasks (Kurzban, Duckworth, Kable, &

Myers, 2013). Decision-makers will therefore typically use their intuition when there is no obvious need to use deliberate reasoning to make a good decision.

From a behavioral standpoint cognitive biases may be seen as systematic errors in rational reasoning (Amos Tversky & Kahneman, 1974). However, many cognitive biases that appear irrational from the viewpoint of rational choice theory may in fact be quite rational from the perspective of evolutionary biology (Santos & Rosati, 2015). They may optimize decision making in a given environment (context) by optimally using the available information (ecological rationality: Goldstein & Gigerenzer, 2002). However, decision rules that are completely adapted to a given (natural) environment may of course lead to maladaptive ('biased') behavior in different settings (Fawcett et al., 2014).

Factors affecting human cognitive bias

From a practical viewpoint, it would be useful to understand the factors that predict the occurrence of cognitive biases. This literature review addresses the question whether characteristics of individuals affect susceptibility to cognitive biases. The dual-process heuristic-deliberate theory of human decision making (described above) is adopted as a framework to unify and understand our current findings. This theory states that individuals are less prone to biases if they apply the thinking style (deliberate or heuristic) that is most appropriate for the problem context. Furthermore, an individual's tendency to make biased judgments and decisions may be related to personal characteristics (e.g., cognitive ability, expertise, personality).

Cognitive ability

People differ in their cognitive abilities like intelligence, training (level of expertise), and thinking styles. Studies investigating the correlation between measures of intelligence and a wide range of different cognitive biases have shown that cognitive ability (both fluid and crystalized intelligence) does not predict bias-proneness in general (Stanovich & West, 2008; Teovanovic, Knezevic, & Stankov, 2015). Intelligent people are just as prone to cognitive bias as less intelligent ones. However, highly intelligent people are more able than less intelligent ones to avoid cognitive bias once they have been warned about the bias in advance and are instructed how to avoid it (Stanovich & West, 2008).

Significant negative correlations have been observed between fluid intelligence and several biases. Fluid intelligence is an individual's capacity to think in a logical way and to find solutions for new problems, independent of acquired knowledge (Cattell, 1987). Fluid intelligence has been found to correlate negatively with belief bias, over-confidence bias and base rate neglect and also with the Cognitive Reflection Test (CRT: Frederick, 2005). The CRT is a widely used tool to assess individual differences in intuitive–analytic cognitive styles. The CRT has been found to correlate negatively with the sunk cost effect, belief bias and base rate neglect; Teovanovic et al., 2015).Thus it seems that people with high reflective abilities and a high fluid intelligence are less prone to these cognitive biases.

The literature shows mixed results on the relation between analytic intelligence and proneness to the anchoring bias (for a review see: Furnham & Boo, 2011). While some studies found that individuals with higher cognitive abilities are less susceptible to anchoring (Bergman, Ellingsen, Johannesson, & Svensson, 2010), others observed no - or even the opposite - effect (Oechssler, Roider, & Schmitz, 2009).

There is evidence that an individual's susceptibility to bias relates to structures and emotional processes in the brain. Two key brain structures mediating emotional information

processing are the amygdala and the orbitofrontal cortex (OFC) (e.g., Kim & Hamann, 2007; Zald, 2003). The amygdala can be seen as a primitive structure linking immediate threat with rapid survival responses (Sander, Grafman, & Zalla, 2003). The OFC is associated with deliberate thinking and has the function to gather and update information and use it to predict possible outcomes of-, and to steer, human behavior (Rolls, 2004; Rolls & Grabenhorst, 2008). De Martino et al. (De Martino, Kumaran, Seymour, & Dolan, 2006) examined the neural mechanisms mediating the framing effect and the ability to control it. While placed inside an fMRI scanner their participants performed a financial decision making task. In line with the dual-process theory (i.e., the view that choices are typically affectively loaded and involve heuristic thinking; see Kahneman & Frederick, 2007) this study showed that framing bias during financial decision making correlated with a higher activity in the greater amygdala. In addition, they found that subjects who acted more rationally also exhibited stronger OFC activation. Interestingly, they also found a strong inter-individual variability in susceptibility to framing, which did not correlate with amygdala activity. Instead, they observed a positive correlation between the ability to control framing bias and OFC activation: increased orbital and medial prefrontal cortex activity correlated with a reduced susceptibility to the framing effect (De Martino et al., 2006). Although enhanced OFC activity does not necessarily imply the inhibition of emotional processes (Aron, 2007), this result agrees with the view that controlling decision bias depends on engagement of deliberate, rational thinking.

People who score high on the *Need for Cognition* (NFC: an individual's propensity to enjoy and engage in thought: Cacioppo & Petty, 1982) are just as likely to be 'framed' as anyone else. However, compared to people scoring low on NFC, they are more consistent across different frames of a problem. In accordance with the abovementioned results from brain research, the magnitude of the framing effect is significantly reduced when decision makers are encouraged to reflect on the options and to motivate their choice (Miller & Fagley, 1991; Sieck & Yates, 1997; Takemura, 1993). For people who score high on the *Need for Cognition* this manipulation even eliminates the framing effect altogether (A. F. Simon, Fagley, & Halleran, 2004). NFC has also been found to moderate hindsight bias: hindsight bias is found for persons with low and medium NFC scores, but not for people with high NFC scores (Verplanken & Pieters, 1988).

An individual's thinking style has often been associated with proneness to bias. An individual's preference for an analytic-rational (deliberate processing) or an intuitive-experiential (heuristic processing) thinking style can be assessed through the Rational-Experiential Inventory (REI: Epstein, Pacini, Denes-Raj, & Heier, 1996). The relationship between thinking style and various biases has been investigated in several studies. Persons that dominantly use an analytic/rational thinking style tend to be less susceptible to the base rate neglect bias than people using an intuitive/experiental thinking style (Ohlert & Weißenberger, 2015). There seems to be no relation between thinking style and susceptibility to the conjunction fallacy (Lu, 2015). Thinking style and belief bias appear to be linked: in contrast to people with an intuitive-experiential thinking style, people with an analytic-rational thinking style are less susceptible to belief bias (Svedholm-Häkkinen, 2015; Trippas, Pennycook, Verde, & Handley, 2015).

A specific cognitive ability that appears to be linked with thinking style is *numeracy*, or the proficiency in basic probability and numerical concepts (Peters et al., 2006). An individual's numeracy-competency is determined by (1) the degree of information processing (heuristic or deep elaborative processing), (2) affective numerical intuition (e.g., framing); and (3) intuitive understanding (e.g., gist-based representation and reasoning; see Ghazal, Cokely, & Garcia-Retamero, 2014). Low numeracy is typically linked with intuitive (heuristic) thinking, whereas high numeracy is typically linked with deliberate (analytical) processing (Brust-Renck, Reyna, Corbin, Royer, & Weldon, 2014). In this view people with high numeracy are less susceptible to

biases because they show an analytical thinking style and information seeking behavior (Ghazal et al., 2014). Numeracy has indeed been found to determine decision making quality across a wide range of tasks (Sinayev & Peters, 2015). For instance, people with high numeracy are less susceptible to framing bias (Gamliel, Kreiner, & Garcia-Retamero, 2015; Peters et al., 2006) and conjunctions fallacies (Sinayev & Peters, 2015), are less over/under confident about their decisions (Sinayev & Peters, 2015), and take less risks (Jasper, Bhattacharya, Levin, Jones, & Bossard, 2013). People with higher numeracy are better able to extract the affective 'gist' of a problem and use it to determine the quality of a particular choice (Jasper et al., 2013). These findings cannot be attributed to differences in general intelligence (Peters et al., 2006).

Somewhat in contrast, people using a combination of thinking styles (high deliberate/high heuristic (also called 'complementary thinking') and low deliberate/low heuristic (also called 'poor thinking') are found to be more susceptible to framing than those using a dominant (either rational or intuitive) thinking style (Shiloh, Salton, & Sharabi, 2002). Thus, it seems that people with a clearly dominant heuristic or deliberate thinking style are more resistant to framing. This may be because both decision styles use strong *internal* guides (either logical or experiential) to process information. In contrast, people with a more uniform thinking style (either 'complementary' or 'poor') appear to depend more on coincidental *external situational cues* (e.g., the way the information is formulated) when processing information.

Individuals with high emotional intelligence (the ability to recognize and distinguish between emotions and to identify their causes) are able to reduce (or even eliminate) the effects of decision bias by recognizing that the emotions they experience (for instance anxiety: Yip & Côté, 2013) are irrelevant for the decisions they have to make. For example, military officers with high emotional intelligence make better tactical decisions under stressful condition because they are able to maintain a higher state of attentiveness for social cues and perform a more exhaustive (deliberate) analysis of situational cues (Fallon et al., 2014).

Summarizing, several types of cognitive ability, as well as the ability to engage in deliberate information processing at appropriate times, seem to protect an individual from several cognitive biases (in particular, the sunk cost bias, the base rate fallacy, the over-confidence bias, the belief bias, and framing). For anchoring and conjunction bias the evidence is mixed. Emotional intelligence has been found to reduce the likelihood of falling prey to decision bias. In general it can be concluded that cognitive ability does not safeguard an individual against bias, but it may in some cases help in deploying countering mechanisms that reduce, or prevent subsequent behavioral effects.

Expertise

Whether people deploy a heuristic or a more deliberate decision making mode depends for a large part on the decision-maker's expertise (Fuchs, Steigenberger, & Lübcke, 2015). An expert is an individual who has acquired special skills in a given domain (Chi, Glaser, & Farr, 1988). The main distinction between experts and novices is the extent of their domain-specific knowledge (Chi et al., 1988). Less experienced decision-makers increasingly use deliberative thinking to solve subjectively complex problems while mainly following their preferred (either heuristic or deliberate) decision style. In addition, the thoroughness of their information processing is affected by their mood: a happy mood leads to more superficial (heuristic) processing, while a sad mood leads to more thorough (deliberate) processing (Englich & Soder, 2009). In contrast, more experienced decision makers use deliberation independent of their decision preferences, subjective environmental complexity or mood (Englich & Soder, 2009; Fuchs et al., 2015). Moreover, experts rely more on intuition than on deliberation. They can probably do so because

they have learned to match tools and strategies to problem structures (similar to chess players: Sauter, 1999). For example, expert handball players are more intuitive than non-experts and tend to rely on their first intuitively generated decision option (Raab & Laborde, 2011).

Expertise generally does not significantly reduce the anchoring bias effect (for a review see: Furnham & Boo, 2011). However, expertise in a specific estimation context (task) may reduce susceptibility to anchoring: experience in a card game was inversely correlated with susceptibility to anchoring (Welsh, Delfabbro, Burns, & Begg, 2014). This implies that the exact nature of the expertise should be clearly defined before being able to assess whether 'experts' are less affected by anchors than 'non-experts'. Individual differences in various traits may be more useful for predicting the rate of learning, where it is their level of expertise that indirectly reduces susceptibility to anchoring, rather than direct susceptibility to biases (Welsh et al., 2014).

Summarizing, expertise affects sensitivity to biases since it determines thinking style and the way that information is processed in combination with its context. Expertise can stimulate both deliberate and heuristic thinking. When the context is not appropriate, the latter may lead to biases. Experts are less likely to misinterpret the context than novices. They are therefore more likely to select the thinking style appropriate for the context, and are subsequently less prone to bias than non-experts.

Personality

Personality is often defined in terms of five main personality traits (the 'Big Five': John & Srivastava, 1999): openness, conscientiousness, extraversion, agreeableness, and neuroticism.

The literature shows that individuals with high conscientiousness, agreeableness and openness to experience or with low extraversion are more susceptible to the anchoring bias (Caputo, 2014; Eroglu & Croxton, 2010; McElroy & Dowd, 2007; Teovanovic et al., 2015). It has been suggested that because individuals with high conscientiousness engage in more deliberate thinking when making decisions, they are more likely to perform a confirmatory search for anchor consistent information. Individuals with high agreeableness tend to be more affected by anchors than less agreeable persons. This is probably because individuals with high openness to experience easily 'adjust' their beliefs when considering situational information.

There are some indications that introverts are more susceptible to anchoring bias than extraverts (Eroglu & Croxton, 2010; Furnham, Boo, & McClelland, 2012), but this relation is not robust (Furnham et al., 2012). It has been suggested that low extraversion may be associated with negative affect (Eroglu & Croxton, 2010), which may stimulate more deliberate thinking and thereby activate a confirmatory search for anchor consistent information (Bodenhausen, Gabriel, & Lineberger, 2000; Englich & Soder, 2009).

People scoring high on trait optimism (people who tend to believe in a bright future) (Scheier, Carver, & Bridges, 1994) were more likely to update their judgments in response to desirable information than to undesirable information, particularly for judgments that apply to themselves (Kuzmanovic, Jefferson, & Vogeley, 2015). In other words, people with high trait optimism show a pronounced self-specific optimism bias. It has been argued that the evolution of the healthy mind to (optimistically) mis-predict future occurrences has led to an increased resilience, improved coping behavior and reduced anxiety, resulting in overall improvements of both physical and mental health (Dolcos, Hu, Iordan, Moore, & Dolcos, 2015; Sharot, 2011). Optimism bias may sometimes even lead to better outcomes than do unbiased beliefs (Sharot, 2011). Recent brain studies have identified the OFC with trait optimism: higher OFC gray matter volume (GMV) correlates with increased optimism (Dolcos et al., 2015).

Despite the hypotheses suggested above, it is not easy to determine the mechanisms underlying the relationships between personality traits and susceptibility to cognitive bias. Summarizing, personality appears to relate to bias susceptibility because it determines how people weigh and process information.

Culture

Members of different social cultures may have different ways of thinking, because they have been socialized from birth into different world views. Some researchers hypothesize that these cultural differences affect an individual's susceptibility for bias. For instance, East Asians are believed to have a holistic world view, attending more to contextual factors and assigning causality to them, while they are less inclined to categorize and use formal logic. Westerners, on the other hand, are typically more analytic and are more inclined to use pay attention to objects of interest, to categorize them, and to use rules and formal logic to understand their behavior (Nisbett, Peng, Choi, & Norenzayan, 2001; Strutton & Carter, 2013). As a result, East Asians may for instance be less susceptible to attribution errors, since they see behavior primarily as a product of external factors and not merely of the actor's dispositions. For the same reason, they may be more susceptible to hindsight bias because they are readily able to find some explanation for a given event since everything is connected in their world view (Choi & Nisbett, 2000; Yama et al., 2010). Following this line of thinking, Westerners may be better able to withstand the hindsight bias because they have a more rule-based thinking style.

Only a few studies address the influence of culture on bias susceptibility. Studies on the effects of culture on hindsight bias show mixed results: while some studies confirmed the abovementioned hypotheses (Choi & Nisbett, 2000; Yama et al., 2010) others found no cultural differences in the sensitivity to hindsight bias (Pohl, Bender, & Lachmann, 2002). One study (Scott, Christopher, & John, 1998) found evidence for the hypothesis that self-centered Westerners, with their personal desire to be correct and to fortify one's choices, are more susceptible to the sunk cost bias than collectivist East Asians who are more focused on optimizing outcomes for the group. However, other studies found opposite results (Yoder, Mancha, & Agrawal, 2014). They propose that East Asians may also be prone to sunk cost bias because they are more concerned about saving face, resulting in more commitment to prior decisions.

A recent study on choice framing (Haerem, Kuvaas, Bakken, & Karlsen, 2011) compared military decision makers with business students (difference in organizational cultures). It was found that business students showed the classic framing bias (risk avoidance behavior in the gain frame an risk seeking behavior in the loss frame: A. Tversky & Kahneman, 1981), while military decision makers consistently showed a risk-seeking behavior for both (gain and loss) choice frames. In addition, military officers showed significantly higher levels of self-efficacy than business school students. Self-efficacy correlated with risk seeking in the military group but not in the civil group. This result agrees with the finding that people with little confidence in their own competence do not like to gamble (Heath & Tversky, 1991). Military decision makers, on the other hand, are probably so self-confident (or even over-confident) that they believe that they can beat the odds.

Summarizing, while it is possible that culture affects sensitivity to bias (e.g., as a result of different preferred thinking styles or levels of self-efficacy), only a few studies on this topic have been conducted and their results are mixed.

Discussion and conclusions

The objective of this literature review was to investigate to what extent individual characteristics (cognitive abilities, expertise, personality, cultural background) affect a person's susceptibility to judgment and decision biases. This knowledge may for instance be used to develop strategies to mitigate biased thinking of own personnel, or to deploy strategies to evoke biased thinking in opponent parties.

Our findings indicate that each of the reviewed aspects can affect cognitive biases under certain conditions (though with respect to culture the evidence is scarce). Note that the factors found to reduce cognitive bias may in fact merely mitigate the behavioral effects rather than preventing the bias from occurring at all.

Several types of cognitive ability, as well as employing deliberate information processing may mitigate various cognitive biases (in particular: sunk cost, base rate, over confidence, belief, framing). For anchoring and conjunction bias, the evidence is mixed. Emotional intelligence has been found to reduce some biases. In general, cognitive ability does, by itself, not prevent biases from occurring, but it may help to learn how to prevent or reduce its effects on behavior.

Expertise affects sensitivity to biases, because expertise largely determines thinking style and contextual information processing. Depending on the problem context, expertise may stimulate both deliberate thinking as well as heuristic thinking. Experts are more likely to select the thinking style appropriate for the context, and are subsequently less prone to bias than non-experts.

Personality affects the way people weigh and processes information, which in turn affects the susceptibility to certain (but not all) biases. However, the relationship between personality and susceptibility to cognitive bias is not fully clear. Predicting the occurrence and direction of cognitive bias based on personality traits is therefore very hard.

Limitations of *the present study*

The results reviewed in this study have mostly been obtained in laboratory conditions involving simplified tests that have specially been designed to induce cognitive biases. It is therefore not clear how these results translate into real-life practice.

We used the dual-process heuristic-deliberate framework to summarize, unify and understand our findings. However, not all reported effects fit into this framework. For instance, effects reported on emotional priming are different from studies that demonstrate effects of emotion, indicating a different underlying mechanism. Also, some of the effects upon judgment and decision making seem to be working against each other. For example, people who need to perform under pressure and time constraints are expected to apply heuristics which makes them vulnerable for bias. However, at the same time, it is known that pressure induces a negative mood which often elicits deliberate thinking strategies. And although deliberate thinking tends to guard people against the risk of bias, this is not always the case. Exactly when it does, and when not, is still difficult to quantify. This underlines the need to more fully understand the mechanisms underlying cognitive bias.

Future research

The fact that the effects of cognitive biases on decision making are not completely fixed within and between individuals suggests opportunities to apply this knowledge for selecting (bias free) and training (de-biasing) personnel. Implicit association tests may be effective selection tools (De

Houwer, 2006). How these selection tests should be worked out for a given context (e.g., medical, financial, military, police) requires analysis of the characteristics and requirements of the candidates, the nature of the task, and the contextual demands. The information and insights resulting from the present study may also stimulate the development of new de-biasing techniques to protect own personnel against (self- or externally- induced) cognitive bias in concrete situations. Strategies that promote deeper information processing and thereby stimulate the recruitment of the medial and lateral orbitofrontal cortex (regions associated with the integration of affective and contextual information in decision making) may constrain decision bias (Hughes & Zaki, 2015). Computer games that immerse the user into bias-invoking situations that provide the experience to identify cognitive bias and to practice mitigation strategies, may serve as effective debiasing tools. It has been shown that these types of "serious games" can provide an effective method to train adults how to recognize and mitigate several cognitive biases (confirmation, attribution and blind spot; Clegg et al., 2015; Dunbar et al., 2014; Symborski et al., 2014). Models and decision support systems that provide tools and explicit rules to guide decisions, may also help to counteract the adverse effects of judgement bias. This can for instance be achieved by allowing the user to employ heuristics while warning for the likely biases, and by anticipating the likely use of heuristics and providing information that offsets the effects of such use (Larrick, 2004). In addition, the current findings may initiate innovative methods to exploit biases to manipulate the behavior of opponents and other groups.

References

Aron, A. R. (2007). The neural basis of inhibition in cognitive control. *The Neuroscientist, 13*(3), 214-228. doi:10.1177/1073858407299288

Bergman, O., Ellingsen, T., Johannesson, M., & Svensson, C. (2010). Anchoring and cognitive ability. *Economics Letters, 107*(1), 66-68. doi:10.1016/j.econlet.2009.12.028

Bodenhausen, G. V., Gabriel, S., & Lineberger, M. (2000). Sadness and susceptibility to judgmental bias: The case of anchoring. *Psychological Science, 11*(4), 320-323. doi:10.1111/1467-9280.00263

Brust-Renck, P. G., Reyna, V. F., Corbin, J. C., Royer, C. E., & Weldon, R. B. (2014). The role of numeracy in risk communication. In H. Cho, T. Reimer, & K. A. McComas (Eds.), *The SAGE Handbook of Risk Communication* (pp. 134-145). Thousand Oaks, CA, USA: Sage.

Cacioppo, J. T., & Petty, R. E. (1982). The need for cognition. *Journal of Personality and Social Psychology, 42*(1), 116-131. doi:10.1037/0022-3514.42.1.116

Caputo, A. (2014). Relevant information, personality traits and anchoring effect. *International Journal of Management and Decision Making, 13*(1), 62-76. doi:10.1504/IJMDM.2014.058470

Cattell, R. B. (1987). *Intelligence: Its structure, growth, and action*. New York, USA: Elsevier Science Publishing Comapny, Inc.

Chi, M. T., Glaser, R., & Farr, M. J. (1988). *The nature of expertise*. Hillsdale, NJ, USA: Lawrence Erlbaum Assoiates, Inc.

Choi, I., & Nisbett, R. E. (2000). Cultural psychology of surprise: Holistic theories and recognition of contradiction. *Journal of Personality and Social Psychology, 79*(6), 890-905. doi:10.1037/0022-3514.79.6.890

Dane, E., & Pratt, M. G. (2007). Exploring intuition and its role in managerial decision making. *Academy of Management Review, 32*(1), 33-54. doi:10.5465/AMR.2007.23463682

Davis, P. K., Kulick, J., & Egner, M. (2005). *Implications of modern decision science for military decision-support systems*. Santa Monica, CA, USA: RAND Corporation.

De Houwer, J. (2006). What are implicit measures and why are we using them. In R. W. Wiers & A. W. RStacy (Eds.), *The handbook of implicit cognition and addiction* (pp. 11-28). Thousand Oaks, CA: Sage Publishers.

De Martino, B., Kumaran, D., Seymour, B., & Dolan, R. J. (2006). Frames, biases, and rational decision-making in the human brain. *Science, 313*(5787), 684-687. doi:10.1126/science.1128356

De Neys, W. (2006). Automatic heuristic and executive analytic processing during reasoning: Chronometric and dual-task considerations. *The Quarterly Journal of Experimental Psychology, 59*(6), 1070-1100. doi:10.1080/02724980543000123
De Neys, W. (2012). Bias and conflict: A case for logical intuitions. *Perspectives on Psychological Science, 7*(1), 28-38. doi:10.1177/1745691611429354
Dolcos, S., Hu, Y., Iordan, A., Moore, M., & Dolcos, F. (2015). Optimism and the brain: Trait optimism mediates the protective role of the orbitofrontal cortex gray matter volume against anxiety. *Social Cognitive and Affective Neuroscience, 11*(2), 263-271. doi:10.1093/scan/nsv106
Englich, B., & Soder, K. (2009). Moody experts how mood and expertise influence judgmental anchoring. *Judgment and Decision Making, 4*(1), 41-50.
Epstein, S., Pacini, R., Denes-Raj, V., & Heier, H. (1996). Individual differences in intuitive experiential and analytical rational thinking styles. *Journal of Personality and Social Psychology, 71*(2), 390-405. doi:10.1037/0022-3514.71.2.390
Eroglu, C., & Croxton, K. L. (2010). Biases in judgmental adjustments of statistical forecasts: The role of individual differences. *International Journal of Forecasting, 26*(1), 116-133. doi:10.1016/j.ijforecast.2009.02.005
Evans, J. S. B. T. (1984). Heuristic and analytic processes in reasoning. *British Journal of Psychology, 75*(4), 451-468. doi:10.1111/j.2044-8295.1984.tb01915.x
Evans, J. S. B. T. (1989). *Bias in human reasoning: Causes and consequences*. London, UK: Lawrence Erlbaum Associates, Inc.
Evans, J. S. B. T. (2006). The heuristic-analytic theory of reasoning: Extension and evaluation. *Psychonomic Bulletin & Review, 13*(3), 378-395. doi:10.3758/BF03193858
Fallon, C. K., Panganiban, A. R., Wohleber, R., Matthews, G., Kustubayeva, A. M., & Roberts, R. (2014). Emotional intelligence, cognitive ability and information search in tactical decision-making. *Personality and Individual Differences, 65*(0), 24-29. doi:10.1016/j.paid.2014.01.029
Fawcett, T. W., Fallenstein, B., Higginson, A. D., Houston, A. I., Mallpress, D. E. W., Trimmer, P. C., & McNamara, J. M. (2014). The evolution of decision rules in complex environments. *Trends in Cognitive Sciences, 18*(3), 153-161. doi:10.1016/j.tics.2013.12.012
Frederick, S. (2005). Cognitive reflection and decision making. *Journal of Economic Perspectives, 19*(4), 25-42. doi:10.1257/089533005775196732
Fuchs, H. M., Steigenberger, N., & Lübcke, T. (2015). *Intuition or deliberation how do professionals make decisions in action?* Paper presented at the Proceedings of the 12th International Conference on Information Systems for Crisis Response & Management (ISCRAM 2015), Kristiansand, Denmark.
Furnham, A., & Boo, H. C. (2011). A literature review of the anchoring effect. *The Journal of Socio-Economics, 40*(1), 35-42. doi:10.1016/j.socec.2010.10.008
Furnham, A., Boo, H. C., & McClelland, A. (2012). Individual differences and the susceptibility to the influence of anchoring cues. *Journal of Individual Differences, 33*(2), 89-93. doi:10.1027/1614-0001/a000076
Gamliel, E., Kreiner, H., & Garcia-Retamero, R. (2015). The moderating role of objective and subjective numeracy in attribute framing. *International Journal of Psychology, 51*(2), 109-116. doi:10.1002/ijop.12138
Ghazal, S., Cokely, E. T., & Garcia-Retamero, R. (2014). Predicting biases in very highly educated samples: Numeracy and metacognition. *Judgment and Decision Making, 9*(1), 15-34.
Gigerenzer, G., & Gaissmaier, W. (2010). Heuristic decision making. *Annual Review of Psychology, 62*(1), 451-482. doi:10.1146/annurev-psych-120709-145346
Goldstein, D. G., & Gigerenzer, G. (2002). Models of ecological rationality: The recognition heuristic. *Psychological Review, 109*(1), 75-90. doi:10.1037//0033-295X.109.1.75
Haerem, T., Kuvaas, B., Bakken, B. T., & Karlsen, T. (2011). Do military decision makers behave as predicted by prospect theory? *Journal of Behavioral Decision Making, 24*(5), 482-497. doi:10.1002/bdm.704
Haselton, M. G., Nettle, D., & Andrews, P. W. (2005). The evolution of cognitive bias. In D. M. Buss (Ed.), *The handbook of evolutionary psychology* (pp. 724-746). Hoboken, NJ, USA: John Wiley & Sons Inc.
Heath, C., & Tversky, A. (1991). Preference and belief: Ambiguity and competence in choice under uncertainty. *Journal of Risk and Uncertainty, 4*(1), 5-28. doi:10.1007/BF00057884

Hogarth, R. M. (2010). Intuition: A challenge for psychological research on decision making. *Psychological Inquiry, 21*(4), 338-353. doi:10.1080/1047840X.2010.520260
Jasper, J. D., Bhattacharya, C., Levin, I. P., Jones, L., & Bossard, E. (2013). Numeracy as a predictor of adaptive risky decision making. *Journal of Behavioral Decision Making, 26*(2), 164-173. doi:10.1002/bdm.1748
John, O. P., & Srivastava, S. (1999). The big five trait taxonomy: History, measurement, and theoretical perspectives. In L. A. Pervin & O. P. John (Eds.), *Handbook of personality: Theory and research (2nd ed.)* (Vol. 2, pp. 102-138). New York, NY: Guilford Press.
Kahneman, D. (2003). A perspective on judgment and choice: Mapping bounded rationality. *American Psychologist, 58*(9), 697-720. doi:10.1037/0003-066X.58.9.697
Kahneman, D., & Frederick, S. (2002). Representativeness revisited: Attribute substitution in intuitive judgment. In T. Gilovich, D. Griffin, & D. Kahneman (Eds.), *Heuristics and biases: The psychology of intuitive judgment* (pp. 49-81). New York, NY, US: Cambridge University Press.
Kahneman, D., & Frederick, S. (2007). Frames and brains: Elicitation and control of response tendencies. *Trends in Cognitive Sciences, 11*(2), 45-46. doi:10.1016/j.tics.2006.11.007
Kahneman, D., & Klein, G. (2009). Conditions for intuitive expertise: A failure to disagree. *American Psychologist, 64*(6), 515-526. doi:10.1037/a0016755
Kim, S. H., & Hamann, S. (2007). Neural correlates of positive and negative emotion regulation. *Journal of Cognitive Neuroscience, 19*(5), 776-798. doi:10.1162/jocn.2007.19.5.776
Klein, G. (2015). Naturalistic decision making suggestions for improving intuitive decision making. *Journal of Applied Research in Memory and Cognition, 4*(3), 164-168. doi:10.1016/j.jarmac.2015.07.001
Klein, G. A. (1993). A recognition-primed decision (rpd) model of rapid decision making. In G. A. Klein, J. Orasanu, R. Calderwood, & C. Zsambok (Eds.), *Decision making in action: Models and methods* (pp. 138-147). Norwood, NJ: Ablex Publishing Corporation.
Kurzban, R., Duckworth, A., Kable, J. W., & Myers, J. (2013). An opportunity cost model of subjective effort and task performance. *The Behavioral and brain sciences, 36*(6), 661-679. doi:10.1017/S0140525X12003196
Kuzmanovic, B., Jefferson, A., & Vogeley, K. (2015). Self-specific optimism bias in belief updating is associated with high trait optimism. *Journal of Behavioral Decision Making, 28*(3), 281-293. doi:10.1002/bdm.1849
Lu, Y. (2015). Is experiential-intuitive cognitive style more inclined to err on conjunction fallacy than analytical-rational cognitive style? *Frontiers in Psychology, 6*(Article nr. 85), 1-8. doi:10.3389/fpsyg.2015.00085
McElroy, T., & Dowd, K. (2007). Susceptibility to anchoring effects: How openness-to-experience influences responses to anchoring cues. *Judgment and Decision Making, 2*(1), 48-53.
Miller, P. M., & Fagley, N. S. (1991). The effects of framing, problem variations, and providing rationale on choice. *Personality and Social Psychology Bulletin, 17*(5), 517-522. doi:10.1177/0146167291175006
Nisbett, R. E., Peng, K., Choi, I., & Norenzayan, A. (2001). Culture and systems of thought: Holistic versus analytic cognition. *Psychological Review, 108*(2), 291-310. doi:10.1037//0033-295X.108.2.291
Oechssler, J., Roider, A., & Schmitz, P. W. (2009). Cognitive abilities and behavioral biases. *Journal of Economic Behavior & Organization, 72*(1), 147-152.
Ohlert, C. R., & Weißenberger, B. E. (2015). Beating the base-rate fallacy: An experimental approach on the effectiveness of different information presentation formats. *Journal of Management Control, 26*(1), 51-80. doi:10.1007/s00187-015-0205-2
Peters, E., Västfjäll, D., Slovic, P., Mertz, C. K., Mazzocco, K., & Dickert, S. (2006). Numeracy and decision making. *Psychological Science, 17*(5), 407-413. doi:10.1111/j.1467-9280.2006.01720.x
Pohl, R. F., Bender, M., & Lachmann, G. (2002). Hindsight bias around the world. *Experimental Psychology, 49*(4), 270-282. doi:10.1026//1618-3169.49.4.270
Raab, M., & Laborde, S. (2011). When to blink and when to think. *Research Quarterly for Exercise and Sport, 82*(1), 89-98. doi:10.1080/02701367.2011.10599725
Rolls, E. T. (2004). The functions of the orbitofrontal cortex. *Brain and Cognition, 55*(1), 11-29. doi:10.1016/S0278-2626(03)00277-X
Rolls, E. T., & Grabenhorst, F. (2008). The orbitofrontal cortex and beyond: From affect to decision-making. *Progress in Neurobiology, 86*(3), 216-244. doi:10.1016/j.pneurobio.2008.09.001
Sander, D., Grafman, J., & Zalla, T. (2003). The human amygdala: An evolved system for relevance detection. *Reviews in the Neurosciences, 14*(4), 303-316. doi:10.1515/REVNEURO.2003.14.4.303

Santos, L. R., & Rosati, A. G. (2015). The evolutionary roots of human decision making. *Annual Review of Psychology, 66*(1), 321-347. doi:10.1146/annurev-psych-010814-015310
Sauter, V. L. (1999). Intuitive decision-making. *Communications of the ACM, 42*(6), 109-115. doi:10.1145/303849.303869
Scheier, M. F., Carver, C. S., & Bridges, M. W. (1994). Distinguishing optimism from neuroticism (and trait anxiety, self-mastery, and self-esteem): A reevaluation of the life orientation test. *Journal of Personality and Social Psychology, 67*(6), 1063-1078. doi:10.1037/0022-3514.67.6.1063
Scott, W. G., Christopher, J. R., & John, G., I. (1998). The impact of cultural values on escalation of commitment. *The International Journal of Organizational Analysis, 6*(2), 165-176. doi:10.1108/eb028883
Sharot, T. (2011). The optimism bias. *Current Biology, 21*(23), R941-R945. doi:10.1016/j.cub.2011.10.030
Shiloh, S., Salton, E., & Sharabi, D. (2002). Individual differences in rational and intuitive thinking styles as predictors of heuristic responses and framing effects. *Personality and Individual Differences, 32*(3), 415-429. doi:10.1016/S0191-8869(01)00034-4
Sieck, W., & Yates, J. F. (1997). Exposition effects on decision making: Choice and confidence in choice. *Organizational Behavior and Human Decision Processes, 70*(3), 207-219. doi:10.1006/obhd.1997.2706
Simon, A. F., Fagley, N. S., & Halleran, J. G. (2004). Decision framing: Moderating effects of individual differences and cognitive processing. *Journal of Behavioral Decision Making, 17*(2), 77-93. doi:10.1002/bdm.463
Simon, H. A. (1972). Theories of bounded rationality. In C. B. McGuire & R. Radner (Eds.), *Decision and organization* (pp. 161-176). Amsterdam, The Netherlands: North-Holland Publishing Company.
Sinayev, A., & Peters, E. (2015). Cognitive reflection vs. Calculation in decision making. *Front Psychol, 6*(Article 532), 1-16. doi:10.3389/fpsyg.2015.00532
Sloman, S. A. (1996). The empirical case for two systems of reasoning. *Psychological Bulletin, 119*(1), 3-22. doi:10.1037/0033-2909.119.1.3
Söllner, A., Broeder, A., & Hilbig, B. E. (2013). Deliberation versus automaticity in decision making: Which presentation format features facilitate automatic decision making? *Judgment and Decision Making, 8*(3), 278-298.
Stanovich, K. E., & West, R. F. (2008). On the relative independence of thinking biases and cognitive ability. *Journal of Personality and Social Psychology, 94*(4), 672-695. doi:10.1037/0022-3514.94.4.672
Strutton, D., & Carter, W. (2013). Reducing biases in cross-cultural top management team decision-making processes. *International Journal of Business Administration, 4*(3), 1-13. doi:10.5430/ijba.v4n3p1
Svedholm-Häkkinen, A. M. (2015). Highly reflective reasoners show no signs of belief inhibition. *Acta Psychologica, 154*(0), 69-76. doi:10.1016/j.actpsy.2014.11.008
Takemura, K. (1993). The effect of decision frame and decision justification on risky choice. *Japanese Psychological Research, 35*(1), 36-40. doi:10.4992/psycholres1954.35.36
Teovanovic, P., Knezevic, G., & Stankov, L. (2015). Individual differences in cognitive biases: Evidence against one-factor theory of rationality. *Intelligence, 50*, 75-86. doi:10.1016/j.intell.2015.02.008
Trippas, D., Pennycook, G., Verde, M. F., & Handley, S. J. (2015). Better but still biased: Analytic cognitive style and belief bias. *Thinking & Reasoning, online*, 1-15. doi:10.1080/13546783.2015.1016450
Tversky, A., & Kahneman, D. (1974). Judgment under uncertainty: Heuristics and biases. *Science, 185*(4157), 1124-1131. doi:10.1126/science.185.4157.1124
Tversky, A., & Kahneman, D. (1981). The framing of decisions and the psychology of choice. *Science, 211*(4481), 453-458. doi:10.1126/science.7455683
Verplanken, B., & Pieters, R. G. M. (1988). Individual differences in reverse hindsight bias: I never thought something like chernobyl would happen. Did I? *Journal of Behavioral Decision Making, 1*(3), 131-147. doi:10.1002/bdm.3960010302
Welsh, M. B., Delfabbro, P. H., Burns, N. R., & Begg, S. H. (2014). Individual differences in anchoring: Traits and experience. *Learning and Individual Differences, 29*, 131-140. doi:10.1016/j.lindif.2013.01.002
Yama, H., Manktelow, K. I., Mercier, H., Henst, J.-B. V. d., Soo Do, K., Kawasaki, Y., & Adachi, K. (2010). A cross-cultural study of hindsight bias and conditional probabilistic reasoning. *Thinking & Reasoning, 16*(4), 346-371. doi:10.1080/13546783.2010.526786

Yip, J. A., & Côté, S. (2013). The emotionally intelligent decision maker: Emotion-understanding ability reduces the effect of incidental anxiety on risk taking. *Psychological Science, 24*(1), 48-55. doi:10.1177/0956797612450031
Yoder, C. Y., Mancha, R., & Agrawal, N. (2014). Culture-related factors affect sunk cost bias. *Behavioral Development Bulletin, 19*(4), 105-118. doi:10.1037/h0101086
Zald, D. H. (2003). The human amygdala and the emotional evaluation of sensory stimuli. *Brain Research Reviews, 41*(1), 88-123. doi:10.1016/S0165-0173(02)00248-5

Appendix A : Terminology

Anchoring: a tendency to make decisions biased toward previously presented information (the "anchor").

Attribution error: the tendency to see behavior as a product of the actor's dispositions and to ignore important situational determinants of the behavior.

Base rate neglect: a tendency to ignore statistical information (prior probabilities) and focus on information only pertaining to a certain case.

Belief bias: a tendency to draw conclusions that agree with one's own beliefs - i.e., to evaluate the logical strength of an argument on the basis of the believability of the conclusion.

Bias: errors in decisions that arise due to limitations of cognitive processing. Biases are often explained using dual-process theory, which states that we have two cognitive systems, one that is fast and intuitive, and another that is slow and deliberate. Biases occur when our fast system operates without the oversight of the slow system.

Cognitive bias: a consistent deviation from an accurate perception or judgmentjudgment of the world. Inferences about other people and situations may be drawn in an illogical fashion. Individuals create their own "subjective social reality" from their perception of the input.

Cognitive reflection test: test to assess the ability or disposition to resist reporting the response that first comes to mind.

Confirmation bias: a tendency to search for, interpret, focus on and remember information in a way that confirms one's preconceptions.

Conjunction fallacy: a combination of conditions is considered more likely than a general condition.

Crystallized intelligence: the ability to use skills, knowledge, and experience.

Fluid intelligence: the capacity to think logically and solve problems in novel situations, independent of acquired knowledge. It is the ability to analyze novel problems, identify patterns and relationships that underpin these problems and the extrapolation of these using logic.

Framing: a bias in decision making depending on the way in the information is presented (e.g., whether options are presented in terms of gains or loss).

Halo effect: a tendency to let the perceived valence of a single aspect dominate the overall judgment of a person or situation.
Heuristics: simple decision rules (rules of thumb) that ignore part of the available information but work well in a given environment.

Hindsight bias: the tendency to erroneously perceive events as inevitable or more likely once they have occurred.

Imaginability bias: the tendency to use our imagination to make a subjective premonition of a future event for which no memories of actual instances come to mind.

Need for cognition: an individual's propensity to enjoy and engage in thought.

Negativity bias: a tendency to weigh negative information more heavily than positive information.

Numeracy: the ability to process basic probability and numerical concepts.

Omission bias: the tendency to prefer harm caused by omissions over equal or lesser harm caused by acts.

Optimism bias: the tendency to overestimate the likelihood of positive events (and to underestimate the likelihood of negative events) happening to oneself, compared to others.

Outcome bias: a tendency to evaluate the quality of a decision based on its outcome rather than on what factors led to the decision.

Over-confidence bias: an inclination of individuals to overestimate their own abilities to successfully perform a particular task.

Sunk cost effect: a tendency to persist in an endeavor once an investment of money, effort, or time has already been made.