ARTICLE IN PRESS

Personality and Individual Differences xxx (xxxx) xxx–xxx

Contents lists available at ScienceDirect

Personality and Individual Differences

journal homepage: www.elsevier.com/locate/paid

Dimensions of decision-making: An evidence-based classification of heuristics and biases

Andrea Ceschi[a,*], Arianna Costantini[a], Riccardo Sartori[a], Joshua Weller[b], Annamaria Di Fabio[c]

[a] Department of Human Sciences, Verona University, Verona, Italy
[b] Department of Developmental Psychology, Tilburg University, Tilburg, Netherlands
[c] Florence University, Department of Psychology, Florence, Italy

ARTICLE INFO

Keywords:
Heuristics and Biases
Decision-Making
Individual differences
Mindware gaps
Positive Illusions
Negativity effect
Anchoring and Adjustment

ABSTRACT

Traditionally, studies examining decision-making heuristics and biases (H&B) have focused on aggregate effects using between-subjects designs in order to demonstrate violations of rationality. Although H&B are often studied in isolation from others, emerging research has suggested that stable and reliable individual differences in rational thought exist, and similarity in performance across tasks are related, which may suggest an underlying phenotypic structure of decision-making skills. Though numerous theoretical and empirical classifications have been offered, results have been mixed. The current study aimed to clarify this research question. Participants (N = 289) completed a battery of 17 H&B tasks, assessed with a within-subjects design, that we selected based on a review of prior empirical and theoretical taxonomies. Exploratory and confirmatory analyses yielded a solution that suggested that these biases conform to a model composed of three dimensions: Mindware gaps, Valuation biases (i.e., Positive Illusions and Negativity effect), and Anchoring and Adjustment. We discuss these findings in relation to proposed taxonomies and existing studies on individual differences in decision-making.

Studies in the tradition of Kahneman and Tversky's (1973) pioneering heuristics and biases (H&B) research program have demonstrated that individuals may violate rules and axioms stated by models of normative rationality, such as Expected Utility Theory (Von Neumann & Morgenstern, 1947). Such findings suggest that decisions are often bounded by a limited set of information that is available to the decision-maker (Kahneman, Slovic, & Tversky, 1982; Kahneman & Tversky, 1972, 1979; Stanovich & West, 2007; Stanovich & West, 2008a; Tversky & Kahneman, 1974). This "Bounded Rationality" is considered to be adaptive, frequently resulting in accurate, expeditious and sometimes even superior choices and judgements (Gigerenzer, 1996; Simon, 1956). However, applying these heuristics indiscriminately can lead to judgmental errors and suboptimal decision-making, which may prove to be costly at either a personal or societal level (Simon, 1991).

Although the examination of robust effects in the decision-making literature, such as Framing effect and the Representativeness heuristic, has increased our understanding of human decision processes (Kahneman et al., 1982), these studies have largely been conducted from a between-subjects experimental design. Moreover, these biases rarely have been studied in relation to one another. To the best of our knowledge, only a few attempts have been made to investigate the associations across disparate H&B paradigms. In the limited research available, factor-analytic studies have often reported the emergence of two latent factors, but usually belonging to different cognitive models. For example, Weaver and Stewart (2012) distinguished two clusters of competence in judgment and decision-making tasks that they labeled "Correspondence" (i.e., accuracy in responses) and "Coherence" (i.e., consistency in responses). In contrast, Teovanović, Knežević, and Stankov (2015), using another battery of H&B tasks, presented a different distinction between other two rationality forms (i.e., "Normative" and "Ecological"; Gigerenzer, 1996; Gilovich, Griffin, & Kahneman, 2002).

These and other empirical bi- or single-factor solutions (e.g., Bruine de Bruin, Parker, & Fischhoff, 2007; Slugoski, Shields, & Dawson, 1993), present varying interpretations about the degree to which different H&B relate to one another. Indeed, these studies have been mainly designed to advance the literature of individual differences, by integrating intelligence measures with few bias tasks. For such a reason, individuated solutions appear to be the result of theoretical appropriateness more than evidence in support of a solid bias structure. This finds confirmation in the low variance explained by the rotated

* Corresponding author at: Department of Human Sciences, Verona University, Lungadige Porta Vittoria 17, 37129 Verona, Italy.
E-mail addresses: andrea.ceschi@univr.it (A. Ceschi), arianna.costantini@univr.it (A. Costantini), riccardo.sartori@univr.it (R. Sartori), j.a.weller@uvt.nl (J. Weller), annamaria.difabio@unifi.it (A. Di Fabio).

https://doi.org/10.1016/j.paid.2018.07.033
Received 1 November 2017; Received in revised form 19 July 2018; Accepted 21 July 2018
0191-8869/

solutions (see Teovanović et al., 2015). The missing explained variance suggests the presence of several underlying processes, which are intrinsically related to H&B tasks used to detect them. Often the battery of tasks in these studies is purely indicative and non-exhaustive of all biases present in the literature. Furthermore, these empirical studies exclude the theoretical approach of bias taxonomies (Arnott, 2006; Baron, 2000; Carter, Kaufmann, & Michel, 2007; Gilovich et al., 2002; Oreg & Bayazit, 2009; Stanovich, Toplak, & West, 2008) as a starting point for developing a comprehensive battery of bias tasks.

On the contrary, the present work, starting from taxonomic studies of biases, overcome these limits by first theoretically examining the degree to which specific inter-related dimensions of H&B are common in the literature, and next to empirically confirm them. This study advances research on individual differences in reasoning in several ways. First, identifying relationships between different H&B could lead to the detection of common underlying mechanisms that drive these biases. Second, even though this study was not designed to test a specific theoretical framework, the breadth of the decision tasks used offers the potential to support assertions from several cognitive models. Ultimately, adopting a wider categorization of H&B may allow future research to investigate more precisely the predictive validity of specific decision processes that may impact real-world decision outcomes.

1. Literature review

Before introducing the dimensions found, we shortly describe different approaches present in the literature for grouping H&B. We start with some classic studies on individual differences and biases since they allowed detecting the first decision-making categories present in literature (e.g., “Positive Illusions”, “Negativity effect”, “Mindware gaps”). Cognitive models (e.g., “Dual process theory”) used to support empirical classifications are briefly introduced in the second section of the review. The third section presents theoretical taxonomies, featured by more than two classes of H&B. Finally, the last part of the review resumes the few empirical studies which attempted to detect a latent structure behind some bias effects.

In order to illustrate the structure of the present literature review, Table 1 shows the different study's methodologies for clustering H&B with their respective pros and cons.

1.1. Individual differences and categories of H&B: the role of cognitive skills, inclinations and personality

Although it has led to novel and valuable insights about human decision processes, the traditional between-subjects experimental approach used to assess H&B has minimized the potential role of individual differences. However, research has suggested that a great deal of heterogeneity of responses on these tasks exists, and these differences may reflect stable dispositional characteristics in the tendency to respond in a normative manner (e.g., Levin, Gaeth, Schreiber, & Lauriola, 2002; Parker & Fischhoff, 2005; Slugoski et al., 1993). Considering this perspective, researchers have used several well-known decision-making paradigms, utilizing within-subjects designs by combining them with individual differences measures. Such research aimed to identify the tendency to apply heuristic processing across a variety of H&B tasks and measure of intelligence, personality traits or behavioral inclinations.

1.1.1. Cognitive ability and reasoning fallacies

Consistent evidence has been found on the performance between tasks involved in some biases and different cognitive ability measures. Stanovich and his colleagues have deeply contributed to enlighten the role of individual differences in H&B (Stanovich & West, 2003; Stanovich & West, 2008b; Toplak, West, & Stanovich, 2011; West & Stanovich, 2003). In their studies, decision problems, such as the “Linda problem” (i.e., Conjunction fallacy; Tversky & Kahneman, 1983) and Framing effects such as the “Asian Disease” problem (i.e., Risky-Choice Framing; Tversky & Kahneman, 1981), or the “80% Lean/20% Fat Ground Beef” (i.e., Attribute Framing; Levin & Gaeth, 1988), have been used. Results have shown that individuals high in general academic achievement (measured via SAT scores) were substantially less likely to exhibit biases such as the Conjunction fallacy or Base rate fallacy (Stanovich & West, 1998a, 1998b). Certaintly, cognitive ability can be particularly helpful for avoiding certain kinds of biases, which emerge in probabilistic reasoning and in processing complex information. These cognitive fallacies are known as Mindware gaps (Stanovich, 2009) or Simplification biases (Oreg & Bayazit, 2009), and they are the result of a substitution of an analytic process for a more accessible heuristic one (Kahneman & Frederick, 2002). Basically, these choices are systematic departures from what is normatively considered to be rational behavior.

1.1.2. Biases as result of symmetrical coping strategies

Research on the role of individual differences in H&B does not limit just to cognitive skills and reasoning fallacies. Several studies have demonstrated relationships between character's dispositions and distorsions such as “Self-Serving biases” (Giesler, Josephs, & Swann, 1996; Kobayashi & Brown, 2003; Paulhus, Harms, Bruce, & Lysy, 2003; Suls, Lemos, & Stewart, 2002; Wood, Heimpel, & Michela, 2003). A large portion of research has shown how people with high self-esteem are more likely to show Self-Serving biases than those who report lower

Table 1
Different approaches present in the literature for grouping H&B with respective potentials and limits.

	Definition and notable examples	Potentials (+) and Limitations (−)
Single decision-making categories	Single categories of H&B usually composed between one and seven biases featured by similar effects or a common theoretical cause (e.g., Self-Serving or Positive Illusions by Taylor & Brown, 1988; Negativity effect by Rozin & Royzman, 2001; Mindware gaps by Stanovich, 2009).	+ Mostly based on individual differences evidence − They include just few biases without considering them in relation to other H&B categories − Lack of multicausality on the bias generation process
Cognitive models	The decision-making literature often suggests models based on (mostly two) separable but interdependent reasoning systems (e.g., Hammond's, 1996, theory; Dual process theory by Kahneman, 2003b; Tripartite model by Stanovich, 2009).	+ Strong theoretical grounding − Oversimplification of H&B processes − Mostly cognitive oriented
Theoretical taxonomies	Theoretical classifications of biases which consider more than just two H&B categories (see Arnott, 2006; Baron, 2000; Carter et al., 2007; Gilovich et al., 2002; Oreg & Bayazit, 2009; Stanovich et al., 2008).	+ Larger list of H&B − Lack of multicausality − Presence of different labels for similar biases and categories − Absence of a common criteria of categorization
Empirical classifications	Empirical studies based on the examination of relationships between H&B tasks (see Bruine de Bruin et al., 2007; Slugoski et al., 1993; Teovanović et al., 2015; Weaver & Stewart, 2012)	+ Evidence based-approach + Multicausality allowed − Small number of tasks usually submitted to factor analyses − Limited consistency among the different tasks selected in each study

self-esteem (for a review see Oreg & Bayazit, 2009). Self-Serving biases are also known as Positive Illusions by Taylor and Brown (1988) and they consist of fallacies such as Optimism bias, Illusion of Superiority (as known as Better than average effect) and of Control, related to a form of an unrealistic optimism and trust about future events and personal skills. Opposite to them, the dimension, labeled the Negativity effect by Rozin and Royzman (2001) was created to include biases associated by an exaggerated reaction toward the avoidance of negative outcomes caused by self-depreciation. This adaptive coping strategy neutralizes the greater negative potency of losses by anticipating negative feelings, such as regret or delusion, for minimizing effects of potential failings (Carver & Scheier, 1990; Leone, Perugini, & Bagozzi, 2005; Loomes & Sugden, 1982).

1.1.3. Personality and multicausality in H&B

Personality has been also considered a possible predictor of some H &B. For instance, considering the Anchoring heuristic, the change in judgment, which is based upon external cues, seems particularly relevant and related to the openness-to-experience personality trait (Furnham & Boo, 2011). Literature reviews that investigated the effect of personality traits on anchoring demonstrated that participants high in openness to experience are more susceptible to the effect of the anchor (McElroy & Dowd, 2007). On the other hand, biases can be the results of multiple underlying factors, since the same anchoring effect seems to decrease with higher cognitive abilities (Bergman, Ellingsen, Johannesson, & Svensson, 2010). It is possible that people with higher cognitive abilities would be more likely to understand the psychology behind an anchoring task (Oechssler, Roider, & Schmitz, 2009). Sometimes even the same bias, in its multiple forms, can be due to different predictors. For instance, different types of framing (e.g., Attribute framing, Goal framing, Risky choice framing) derive from different processes and they seem to depend differently to personality predictors as well (e.g., people scoring high on neuroticism show the largest Risky choice framing effect, compare to Goal framing for instance; see Levin, Schneider, & Gaeth, 1998). Overall, while this research has helped to gain more and more information over these effects, these studies are isolated, and categories detected lack an all-embracing theory that incorporates a larger spectrum of biases.

1.2. Cognitive models and H&B origins

From a theoretical perspective, the H&B literature often relies on dual-process theories, which suggest the existence of separable, but interdependent reasoning systems, now commonly labeled “System 1” and “System 2” to reflect associative versus controlled processes, respectively (Evans & Stanovich, 2013; Smith & DeCoster, 2000). Whereas System 2 processing is abstract, slow and computationally expensive, System 1 processing contributes to decision-making by evoking images (often emotionally-laden), stereotypes and heuristics. As a result, System 1 generates efficient responses that allow the decision-maker to arrive at judgments without expending a large amount of cognitive resources, but often with less accuracy and missing of analytical processes governed by System 2.

This distinction regarding the presence of two systems is important for several reasons. First, this difference represents the theoretical backdrop of the H&B tradition, with the demonstration that bias effects are often viewed as evidence of System 1 processes. Second, research shows a distinction between H&B that more heavily recruit either System 1 or System 2 processes (Stanovich et al., 2008). Even if it is a common error to consider that only System 1 is responsible of all possible H&B, the rapid System 1 is indeed implicated with most known biases. Stanovich, West, and Toplak (2011) distinguish different processes in this system that can lead to different types of biases, and they are: hard-wired processes (i.e., grounded on evolutionary adaptation and mostly based on heuristics), emotion regulation processes which reflect biases typically based on impulsively associative thinking and vividness effects, and finally processes which belong to behavioral repertoires or developed through implicit learning. In contrast, cognitive processes which sustain the computationally-taxing System 2 can be affected, for instance, by Mindware gaps, incorrect/incomplete probability, and statistical knowledge, hence, leading to other biases (e.g., Base rate fallacy and Conjunction fallacy). Nevertheless, Kahneman (2013a) recognized that both System 1 and System 2 together can reinforce non-normative reasoning. For instance, System 1 often produces inferences based on limited evidence, which then can be endorsed by System 2.

Kahneman (2003a) on the other hand – based on Hammond's (1996) theory – recognized in another main distinction two forms of rationality differently able to prevent the emergence of H&B. Namely: “Reasoning rationality” and “Coherence rationality”. The former prevents inaccuracy in judgment and the latter is related to low frequency in biases caused by logical inconsistency (i.e., non-normative reasoning). Conversely, the ABC research group, historically counterposed to the Kahneman and Tversky H&B thesis, has proposed “Ecological rationality” as an additional and different perspective to redefine the normative standards (Gigerenzer, 1998; Gigerenzer & Brighton, 2009; Gigerenzer & Selten, 2001). Ecological rationality is seen as the result of the adaptive fit between the environment and human mind. Within this evolutionary paradigm focusing on adaptive behavior, H&B are not considered as errors deriving from cognitive processing, but the result of highly constrained conditions due to experimental settings. Cognitive biases would emerge as a natural form of adaptive rationality, due to responsiveness to feedbacks, adjustive processes toward external information, and calibration in confidence judgments (Teovanović et al., 2015).

Considering the presence of multiple expressions of rationality, H&B performance can be conceptualized as a collection of processes themselves than the merely expression of two cognitive processes. In light of this, Stanovich (2009), has proposed the “Tripartite model”, which includes System 1 as “Autonomous” processes, but also subdivided System 2 into “Reflective” and “Algorithmic” processes. In this conceptualization, the Reflective processes are involved in general knowledge structures, person's beliefs, and in the reflective development of goal structure, whereas the Algorithmic mind manages cognitive strategies and ordinated behavioral rules. Such structure, as the author stated, would represent also: “*the beginning of a way of considering a taxonomy of the causes of cognitive failure related to rational behavior that would consider more-than two processes*” (p. 71).

1.3. Across theoretical taxonomies of multiple distinguished processes of H&B

Apart from cognitive models, as seen mostly dichotomous, a number of theoretical taxonomies of H&B suggest that the universe of H&B is heterogeneous, and probably they imply more than just two categories. Arnott (2006)[1] established the first theoretical review of basic classifications of biases (e.g., Einhorn & Hogarth, 1987; Remus & Kottemann, 1986; Tversky & Kahneman, 1974), focusing on the departures from rationality in order to cluster them. The review was developed for a specific field such as the computer science domain, with the aim of establishing all the normative violations executed by human beings compared to machines. The Arnott's taxonomy is not the only classification of H&B developed for a specific field. Carter et al. (2007) established one, concerning decision biases that can affect managerial decision-making, whereas Zhang, Patel, Johnson, and Shortliffe (2004)

[1] The first classifications' review by Arnott was developed in 1996 and it was mostly based on “classic H&B” such as Availability, Representativeness and Anchoring heuristics and connected biases. It was published as a discussion paper by the Monash University, School of Information Management and Systems, Caulfield (AU).

developed one related to medical errors. Such taxonomies reported similar H&B categories beyond fields of study, by highlighting the presence of a possible common structure. On the other hand, in developing independent theoretical taxonomies based on more than two classes, a common potential difficulty emerged. As noted by Baron (2008) about this issue: "*is the possibility that biases could be present in more than one category*" (p. 55). For instance, some H&B may be due to multiple processes (Baron, 2008; Stanovich et al., 2008). As an example, the Framing effect is considered a bias of "Presentation" (i.e., responses dependent on the way in which information is perceived and processed) in more than one taxonomy (Arnott, 2006; Carter et al., 2007), but it is also related to the Prospect Theory's value function (Kahneman & Tversky, 1979). Thus, Framing effects may involve multiple underlying processes. Beyond the reference point dependence of the Framing effect, the inference that motivates the choice is typically emotional and it is connected to concepts such as gains and losses. Moreover, theoretical classifications present a second and opposite issue, that is the presence of two biases in different classes for what concern a taxonomy, and where the same biases might belong to a unique category in another taxonomy. For instance, in Arnott (2006) taxonomy, the Conjunction and the Base rate fallacy were collocated in a category named "Statistical biases", instead, in the taxonomy proposed by Carter et al. (2007) these two biases are included in two different and distinct classes (i.e., "Control illusion", "Base rate"). In the end, a common issue among all the classifications is that the same bias, or the same conceptual dimension may assume different names in different taxonomies (e.g., concerning dimensions: "Reference point" and "Adjustment", or about biases: Illusion of Superiority and Better than average effect. See Arnott, 2006; Carter et al., 2007).

The absence of common criteria for theoretical categorization makes the process of comparison between biases very difficult. For this reason, Stanovich et al. (2008) called for greater methodological analyses to support theoretical taxonomies. Starting from the Tripartite model (Stanovich, 2009), they developed a taxonomy of thinking errors combining biases with different cognitive processes. For example, they investigated Mindware gaps by avoiding to circumscribe them to just one class of belonging, but as the result of two processes: a lack of alternative thinking and of probability knowledge. Following Stanovich's tradition, the taxonomy relies on multicausality of biases thanks to several empirical studies carried out by the authors in the last decades with the aim of understanding the different origins of H&B (Stanovich, 1999; Stanovich & West, 1998a, 1998b, 2002, 2008a, 2008b; Toplak et al., 2011). Similarly, a classification by Oreg and Bayazit (2009) relies on a review of individual differences studies in H&B and it presents three main dimensions as well, "Simplification biases", "Verification biases", "Regulation biases". Whereas Simplification biases may be considered elements similar to Mindware gaps, the novelty is represented by the other two categories. Verification biases are distortions in people's perceptions – either in a positive or in a negative way – of themselves and of the world around them. Regulation biases instead are defined as inclinations toward coping behaviors well examined in the risky decision-making literature, such as Endowment effect or the Framing effect. A peculiarity of such a taxonomy is the presence of casual order between these classes. For instance, Verification biases are involved in the Regulation biases development, since they influence the interpretation of events they can have an impact on resulting reactions and behaviors.

1.4. Presence and limits of empirical dimensions in H&B (two, one, none?)

Similar to the heterogeneity of theoretical classifications, schemes, empirical studies have also yielded mixed results. To our knowledge, the first study investigating such an issue is Slugoski et al. (1993), which included a battery of seven H&B tasks and three measures of conditional reasoning. Results indicated a two-factor solution, which they were labeled as the two heuristics: "Availability" and "Representativeness", and biases loaded moderately onto these two factors. Based on another H&B battery, also Weaver and Stewart (2012) distinguished the presence of two factors, but they interpreted them the two underlying rational competences distinguished by Hammond (1996): Coherence and Correspondence (as known as Reasoning rationality in Kahneman, 2003a). As Hammond (1996) argued both Correspondence and Coherence competences are necessary for good judgment and decision-making. Still, they can be conceived as two independent cognitive processes, in which Coherence, as the study showed, is negatively associated to H&B based on probabilistic information, such as Base rate fallacy or Conjunction fallacy. On the other hand, the Correspondence factor was less explained by H&B tasks' variance and it loaded more on digit span test score, which is closer to the traditional intelligence idea. Results were in line with Hammond's (1996) theory which states that Correspondence competence, as intelligence, is mostly an inborn quality, whereas Coherence competence is usually learned across the lifespan and it is more depend by the environment. Authors concluded that, although more than one factor is required to account for judgment and decision-making, individual differences represented by cognitive skills are involved to some extent (although not equally) in different judgment tasks. Using different H&B tasks, Teovanović et al. (2015) also reported a two-factor solution, which they labeled Normative and Ecological rationality (Gigerenzer, 1998; Tversky & Kahneman, 1974). In this conceptualization, higher scores on the first factor (i.e., Normative rationality) were believed to indicate higher rates of predictably irrational responses, whereas subjects high on the second factor (i.e., Ecological rationality) were more prone to change their initial answers toward subsequently given external information, such as in the Anchoring heuristic and Hindsight bias.

Deviating from results suggesting coherent patterns of interrelationships, Aczel, Bago, Szollosi, Foldes, and Lukacs (2015) suggested that a robust factor of H&B may not exist, citing poor reliability across presumably equivalent items of the same construct. Contrary to multidimensional solutions, studies have reported significant intercorrelations between different H&B tasks, indirectly suggesting that they may occupy unidimensional space (Klaczynski, 2001). More directly, the "Decision-Making Competence" approach has reported that a one-factor solution may reasonably account for variation across decision-making tasks (Bruine de Bruin et al., 2007). Although illuminating, it is important to note that the Decision-Making Competence battery does not represent a test for the entire universe of H&B. The instrument only partially embodies traditional H&B tasks (e.g., like the Kahneman and Tversky's original "Big 3": Representativeness, Availability, and Anchoring with insufficient adjustment; see Kahneman & Tversky, 1973). Although "Resistance to Framing" and "Resistance to Sunk-Costs" are included in Decision-Making Competence inventory, it presents also other measures such as "Applying Decision Rules" and "Recognizing Social Norms" (even if they are not easily characterized as H&B). Moreover, the Decision-Making Competence battery was not developed in order to provide an exhaustive account of the phenotypic structure of normative responding, rather they may be considered as a representative collection of measures believed to assess several core abilities.

Taken together, the existing literature currently shows some level of disagreement regarding the number of factors that can optimally account for different types of bias. Although these empirical classifications have provided valuable insights into the understanding of the interrelations between H&B tasks, two methodological limitations must be considered. First, across research, there has been limited consistency among the different tasks assessed in each study (I). This inconsistency precludes the ability to make robust generalizations about the factor structure of rational thought. The second limitation regards the small number of tasks usually submitted to factor analyses (II). Most of the studies have used about seven to ten tasks. Considering that best practices in factor analytic interpretation suggest that independent factors have a minimum of three indicators to define a dimension, a factor analysis with seven items can only maximally be able to interpret meaningfully two factors (Russell, 2002).

2. Scope and strategy of analysis

Considering the various empirical and theoretical classifications and respective methodological weaknesses, the current study, with the aim of overcoming such limits, introduced a three-step analysis procedure in order to develop more inclusive H&B dimensions. We started from theoretical bias classifications. Since the current literature presents > 100 types of biases, often studied in isolation, taxonomies were certainly a good starting point for sampling H&B categories. Therefore, a Multiple Correspondence Analysis (MCA) for determining the presence of common H&B classes among taxonomies was initially performed. The Multiple Correspondence approach allows addressing taxonomical limits concerning the lack of a common criterion for theoretical categorization and the presence of different labels among classes. In this way, through a replicable procedure of bias selection we managed also to overcome the first abovementioned empirical limitation (I). Hence, at least two biases for every detected MCA dimension were selected with the intention of covering a larger range of biases from existing taxonomies by addressing the second empirical limit above reported (II). An exploratory Principal Components Analysis (PCA) was next conducted for testing interrelations between bias of the extracted MCA dimensions. This procedure was particularly suggested since it allows considering multicausality of biases due to overlapping in the extracted components. Finally, we tested the identified PCA solution using a Confirmatory Factor Analysis (CFA) for enhancing results' consistency.

2.1. Participants and procedure

Two-hundred eighty-nine volunteer students (age range 18–35 years, 65% females) were recruited from a mid-sized Italian university. Participants were asked to complete a battery of decision-making problems. The survey was designed using the opensource platform Limesurvey. Respondents expressed their preferences for every task. When they had to choose between two options, the preference was distributed along a digital visual analogue scale based on 100 points. This procedure is particularly indicated for decision-making tasks, especially for the measurement of susceptibility to Anchoring heuristic (Guyatt, Townsend, Berman, & Keller, 1987; Slugoski et al., 1993). Moreover, task order was randomized for avoiding priming effects and learning effects (see Khorramdel & Frebort, 2011). The survey was divided across two sessions since some tasks (Type-B)[3] presented two versions of the same problem. The use of separate sessions was instituted to minimize memory effects between parallel versions of the task (Kahneman & Frederick, 2002; Levin et al., 1998). Each section lasted approximately 1 h, there was a one-hour break between the sessions.

3. Results and discussion

3.1. Multiple Correspondence Analysis (MCA)

In order to perform a MCA, existing taxonomies and classifications with more than two dimensions were used to select H&B on the most comprehensive dimensions (i.e., Arnott, 2006; Baron, 2000; Carter et al., 2007; Gilovich et al., 2002; Oreg & Bayazit, 2009; Stanovich et al., 2008). Multiple Correspondence Analysis is an exploratory descriptive method; the multivariate extension of the Correspondence Analysis for analyzing tables containing three or more variables. It can be considered as a generalization of PCA for categorical variables which reveal patterning in complex data sets without requiring an assumption of underlying normality (Ayele, Zewotir, & Mwambi, 2014). We first created a contingency table through the row and column profiles, in which rows correspond to the relative frequencies for the different taxonomy's categories for each H&B selected. Expect for biases identical but different in labels (e.g., Illusion of Superiority and Better than average effect; Base rate fallacy and Base rate neglect; Distinction bias and Presentation bias, etc.) all biases present in chosen taxonomies were retained (n = 119). The resulted multiple correspondence pattern showed that with 70% of cumulative inertia,[2] seven dimensions could explain much of the variance. Based on this preliminary result, we selected at least two representative H&B for each MCA's dimension (see Table 2). Moreover, such a selection of biases was based on the possible measurability and adaptability for a within-subjects study (see Table 3). This led to a total of 17 H&B and related tasks investigated.

3.2. Principal Component Analysis (PCA)

All selected H&B tasks showed the overall significant effect in the direction of the predicted bias. H&B scores were calculated by the degree to which a participant demonstrated a heuristic or bias response (i.e., deviation from the normative solution) for each task (Aczel et al., 2015).[3] Scores were standardized and then subsequently used for the PCA. Descriptive statistics are shown in Table 4.

Principal Component Analysis was preferred over other reduction techniques because of the heterogeneity of theoretical models, leaving us with a lack of prior knowledge regarding variables load on any given dimension (Conway & Huffcutt, 2003). Analyses were conducted with an oblique rotation to allow for component intercorrelations with a one-, two-, three-component solution until seven components (as suggested by the MCA results) in order to determine the most interpretable solution. Based on a visual inspection of the scree plot, a three or four-factor solution seemed reasonable, where the first three components (with eigenvalues > 1.5) explained the 32.10% of variance. The four-component included only two items decomposed from the first principal factor, which makes that interpretability of the dimension constrained (Russell, 2002). Beyond this difference, the factor loadings and components included in each recovered dimension were relatively unchanged. Moreover, the three components showed no significant correlations between them (see Table 5).

We next conducted a parallel analysis, a Monte-Carlo simulation of eigenvalues, in order to determine the optimal number of components to retain. In the current analysis, 1000 random dataset were generated (95% CI) with the same number of cases and variables as the original dataset. According to the comparison between mean eigenvalues obtained with the observed eigenvalues from study, we retained the three-component solution over the four-component solution. Besides such reasons, the three-component solution was preferred for the theoretical interpretation of the dimensions found.

In next section, we describe the extracted components and provide a brief interpretation of each. We discuss the interpretation of these components, along with how they relate to the individual differences approach, in the General discussion.

[2] General rules in MCA suggest that the number of dimensions retained should be higher of 70% of the inertia explained or correspond to the number right before the "elbow" of the eigenvalues by dimension number of scree plot (see Sourial et al., 2010).

[3] Aczel et al. (2015) suggest three ways for calculating biases' score (here we present the main two, i.e., Type-A and Type-B). Type-A: In this type of task, a single question is diagnostic to the person's susceptibility to violating the given normative rule by indicating suboptimal reasoning; Type-B: For these tasks, the answer to the given question can be regarded as indicating the person's decision bias only in relation to a similar version of the same question. Therefore, the task is made of two questions in a within-subjects design. For both types, if several versions of the same task are used, the sum of scores corresponds to the total score.

Table 2
H&B tested based on theoretical classifications and taxonomies (italic style has been used for those H&B which are not strictly mentioned but they present a similar bias in the same dimension, parentheses for second belonging dimension).

Study's selected H&B	H&B theoretical taxonomies					
	Baron (2000)	Gilovich et al. (2002)	Arnott (2006)	Carter et al. (2007)	Stanovich et al. (2008)	Oreg and Bayazit (2009)
Gambler's fallacy	Representativeness	Representativeness and Availability	Statistical	Control illusion	Probability knowledge (Mindware gaps)	Simplification biases
Conjunction fallacy	Representativeness	Representativeness and Availability	Statistical	Control illusion	Probability knowledge (Mindware gaps)	Simplification biases
Representativeness heuristic	Representativeness	Representativeness and Availability	Statistical	Base rate	Probability knowledge (Mindware gaps)	Simplification biases
Base rate fallacy	/	Representativeness and Availability	Statistical	Base rate	Probability knowledge (Mindware gaps)	Simplification biases
Framing	/		Presentation	Presentation	Focal Bias	Regulation biases
Distinction bias	/		*Presentation*	*Presentation*		
Availability heuristic	Availability	Representativeness and Availability	*Memory*	Availability cognition	Mindware gaps	Simplification biases
Imaginability bias	Availability	Representativeness and Availability	Memory	Availability cognition	Mindware gaps	Simplification biases
Better than average effect	*Myside bias*	*Optimism*	*Confidence*	Output evaluation	*Self and egocentric processing*	Verification biases
Optimism bias	Effect of desire on belief	Optimism	Confidence	Output evaluation		Verification biases
Anchoring heuristic	Underadjustment	Anchoring contamination and Compatibility	Adjustment	Reference point	Focal bias	
Reference price	*Underadjustment*	*Anchoring contamination and Compatibility*	Adjustment	Reference point	*Focal bias*	
Regression toward the mean			Adjustment	Reference point		
Extra cost effect	Utility theory			*Commitment*		*Regulation biases*
Sunk costs fallacy	Utility theory			Commitment		*Regulation biases*
Endowment effect	Diminishing sensitivity			Commitment		Regulation biases
Time discounting	Diminishing sensitivity					

3.2.1. Characterizing three empirical H&B dimensions

3.2.1.1. First dimension. In this category, a common feature of H&B is that normative responses differ from recalled representations when making a judgment. This includes the accessibility of examples and the comparative similarity to a generated representation (e.g., Representativeness heuristic, Imaginability bias). These biases share a common theme; they appear to be dependent on using information that is recalled easily and relevant for comparative judgments. For such a reason, biased responding includes both the Availability heuristic and Imaginability bias. The recovery of this dimension reinforces what previously observed concerning the presence of a possible association between the Availability and Representativeness heuristics (Slugoski et al., 1993). However, we also found that violations of statistical rules due to representativeness (e.g., the Base rate fallacy, Conjunction fallacy, Gambler's fallacy) loaded on the present component.

Stanovich et al. (2008) classifies these H&B as deriving from Mindware gaps. Mindware gaps long have been implicated in the H&B as a source of judgmental errors and are related to the underuse or lack of reasoning strategies such as probabilistic reasoning or logical inference, rather than a conflict between System 1 and System 2 processes (see Stanovich, 2009). We discuss this relationship and implications with individual differences further in the General Discussion.

3.2.1.2. Second dimension. The second extracted component reflected a bipolar dimension. At one pole, there were the Endowment effect, Time discounting, and biases based on costs sustained (i.e., Extra cost effect and Sunk costs effect). These fallacies share some aspects such as the tendency to overvalue costs sustained and overestimate the intrinsic value of the losing experience. Some studies have suggested this pattern of association between the loss experience and the sensitivity toward sunk costs. For instance, Frisch and Jones (1993) found that young adults reported an aversion to losses as the main reason they were prone to the Sunk costs effect. Additionally, Soman and Cheema (2001) considered an aversion to losses (i.e., Endowment effect) as a potential explanation for the Sunk costs effect. On the other pole, with opposite sign, we found biases related to an overly optimistic view of the world, which bear similarity to the dimension of Positive Illusions (Taylor & Brown, 1988).

Further, this bipolar configuration resonates with prior research supporting the association between optimistic-approach tendencies and an avoidance inclination strictly connected to loss and risk avoidance (Chapman & Polkovnichenko, 2009; De Palma et al., 2008; Lee, Aaker, & Gardner, 2000). According to the literature on Negativity effect (Rozin & Royzman, 2001), the greater consideration of costs and losses comes with the principle of negative potency and with Prospect Theory. Those with this avoidance orientation will be more likely to make biased decisions – as predicted by Prospect Theory – by exhibiting risk-averse behavior with respect to avoid losses and in general negative outcomes (e.g., Sunk costs fallacy, Endowment effect). On the other hand, those with an approach orientation will be more likely to make decisions aimed at enhancing gains and risks, by manifesting biases featured by an unrealistic optimistic vision of reality and of themselves (e.g., Optimism bias, Better than average effect).

Finally, consistent with Oreg and Bayazit (2009), these biases belong to the two interconnected dimensions, labeled Verification and Regulation biases. As stated by authors "*individuals' biased interpretations of their situation (i.e., Verification biases) directly relates to their choices and actions with respect to how they approach pleasure or avoid pain (i.e., Regulation biases)*" (p. 189). For instance, people who tend to perceive optimistically even low probability of success would be more inclined to assume risks for seeking rewards and positive emotions. Based on the present theoretical support, as combination between the two Oreg and Bayazit's categories, we named this dimension "Valuation biases". Moreover, as reported by the PCA, this category, in turn, is composed of other two opposite classes on the same continuum: Positive Illusions and Negativity effect.

Table 3
Description of H&B tasks used. Task scoring is based on the Aczel et al. (2015) bias effect computing.[3]

H&B and representative citations	Task description and type scoring method used
Anchoring heuristic (Epley & Gilovich, 2006; Tversky & Kahneman, 1974)	The Anchoring heuristic was tested by using a task created by Tversky and Kahneman (1974). Participants were asked five questions requiring a numeric answer. Later on, the same task was presented again but changing the value in the first question in order to assess the effect of both high and low anchors. For instance: "*Is the percentage of African countries in the United Nations greater or < 65?*" and then "*how many African countries are represented in the United Nations?*" Later on, in the survey, the same task was presented again but changing the value in the first question. The sum of the differences between the two versions quantified the degree to which individuals showed the effect (Type B).
Availability heuristic (Tversky and Kahneman, 1973)	Starting from an experiment by Tversky and Kahneman (1973) to study this heuristic we asked with three items to rate the chance of death by two causes. The sum of the scores of more available options has been used to estimate the degree of the heuristic effect (Type-A).
Base rate fallacy (Kahneman et al., 1982)	We used another well-known experiment: the Taxicab problem; A cab was involved in a hit and run accident at night. "*Two cab companies, the Green and the Blue, operate in the city. 85% of the cabs in the city are Green and 15% are Blue. A witness identified the cab as Blue. The court tested the reliability of the witness under the same circumstances that existed on the night of the accident and concluded that the witness correctly identified each one of the two colors 80% of the time and failed 20% of the time. What is the probability that the cab involved in the accident was Blue rather than Green knowing that this witness identified it as Blue?*" (Type-A).
Better than average effect (McKenna, 1993)	Participants were asked to rate the likelihood of being in three different types of car incident, and in two different situations: one where they had car control and in a situation in which control was given to a hypothetic average driver. The sum of the differences between the two versions quantified the degree to which individuals showed the effect (Type-B).
Conjunction fallacy (Tversky & Kahneman, 1983)	We presented the classical Linda problem and asked participants which option was the most likely. "*Linda is 31 years old, single, outspoken, and very bright. She majored in philosophy. As a student, she was deeply concerned with issues of discrimination and social justice, and also participated in anti-nuclear demonstrations: a. Linda is a bank teller; b. Linda is a bank teller and is active in the feminist movement.*" (Type-A).
Distinction bias (Hsee & Zhang, 2004)	To test this bias we adapted a scenario from Hsee and Zhang (2004) in which participants were asked to quantify their level of satisfaction in four imagined situation where stimuli were presented in joint versus separate evaluation. "*Imagine that their favorite hobby is writing poems and that they had compiled a book of their poems and were trying to sell it on campus. So far no one has bought your book/So far 240 people have bought your book.*" (Type-B).
Endowment effect (Gächter, Johnson, & Herrmann, 2007)	To test for Endowment effect, we adopted a specific task created to relieve the individual level of endowment in choices. Materials resembled those previously used by Gächter et al. (2007). Participants had to state their willingness to buy and sell hypothetical objects at nine different prices. WTA-WTP difference has been used to compute the magnitude effect (Type-B).
Extra cost effect (Tversky & Kahneman, 1981)	The Extra-cost effect was tested by using a scenario from Tversky and Kahneman (1981): "*Imagine that you have decided to see a play where admission is $10 per ticket. As you enter the theater you discover that you have lost a $10 bill. Would you still pay $10 for a ticket for the play?*" Participants were presented an alternative version of the scenario where they have lost the ticket. We computed the difference between the two responses given by participants (Type-B).
Framing effect (Tversky & Kahneman, 1981)	It was tested by using the Asian disease risky choice problem in two different sessions. "*The first group of participants was presented with a choice between programs: In a group of 600 people: Program A: "200 people will be saved"; Program B: "there is a one-third probability that 600 people will be saved, and a two-thirds probability that no people will be saved." 72 percent of participants preferred program A*" Then the second version negative framed was used (Type-B).
Gambler's fallacy (Hogarth, 1987; Tversky & Kahneman, 1973)	Participants were asked to estimate the chance of obtaining the head face of a coin after a sequence of 20 tosses in which the results were always tail. The score was obtaining by considering the deviation from the normative response, equal to 50% of probability (Type-A).
Imaginability bias (Sherman, Cialdini, Schwartzman, & Reynolds, 1985)	Imaginability was tested by using a manipulated version of the experiment carried out by Sherman et al. (1985). Participants were asked to rate the likelihood of being contaminated by a more or less imaginable disease. "*An illness called Hypo-A is becoming increasingly prevalent in your city. The symptoms of this disease are: low energy level, muscle aches, and frequent severe headaches. Now judge how likely it you could contract Hypo-A in the future. 'An illness called Scenia-B is becoming increasingly prevalent in your city. The symptoms of this disease are: vague sense of disorientation, a malfunctioning nervous system and an inflamed liver.' Now judge how likely it you could contract Scenia-B in the future.*" (Type-B).
Optimism bias (Sharot et al., 2011)	In order to estimate the tendency of each participant to be optimist or pessimist, we adapted an experiment proposed by Sharot et al. (2011). Authors presented a set of questions with the aim of registering the change of estimation for a particular event, before and after presenting information about the average probability of incurring in similar events. We presented seven questions used in the original experiment across two different sessions. The aim was to record participants' change of estimation for a particular event, before and after presenting information about the average probability of incurring in similar events (Type-B).
Reference price (Thaler, 1985)	To test this bias we used an adapted version of the scenario previously proposed by Thaler (1985). Participants were asked what price they were willing to pay for a drink bought in a grocery store. In the second scenario, the grocery store was changed with a fancy resort hotel. Then, the difference between prices that participants were willing to pay in the two versions, was measured. "*You are lying on the beach on a hot day. All you have to drink is ice water. For the last hour you have been thinking about how much you would enjoy a nice cold bottle of your favorite brand of beer. A companion gets up to make a phone call and offers to bring back a beer from the only nearby place where beer is sold, a small, run-down grocery store. He says that the beer might be expensive and so asks how much you are willing to pay for the beer. He says that he will buy the beer if it costs as much or less than the price you state. But if it costs more than the price you state he will not buy it. You trust your friend, and there is no possibility of bargaining with the store owner. What price do you tell him?*" (Type-B).
Regression toward the mean (Ferguson, 1987)	On the basis of the studies run by Tversky and Kahneman (1974) and of Kahneman's experience with flight instructors, the Regression toward the mean was tested presenting participants with a simulation story of pilots and asking them the possible causes of decrement on pilot performance between two flight sessions (Type-A).

(*continued on next page*)

Table 3 (*continued*)

H&B and representative citations	Task description and type scoring method used
Representativeness heuristic (Tversky & Kahneman, 1973)	To test this heuristic, a problem used by Tversky and Kahneman (1973) was re-adapted. In the original experiment, participants were asked to judge what kind of job a person is more likely to do. The judgment is based on a description of the person and participants are also provided with the statistics about jobs across the population (Type-A).
Sunk costs fallacy (Arkes & Blumer, 1985)	This fallacy was tested using a simple scenario created by Arkes and Blumer (1985) on a realistic life experience. "*On your way home you buy a TV dinner on sale for $3 at the local grocery store. Then you get an idea. You call up your friend to ask if he would like to come over for a quick TV dinner and then watch a good movie on TV. Your friend says, 'Sure.' So you go out to buy a second TV dinner. However, all the on-sale TV dinners are gone. You therefore have to spend $5 (the regular price) for a TV dinner identical to the one you just bought for $3. You go home and put both dinners in the oven. When the two dinners are fully cooked, you get a phone call. Your friend is ill and cannot come. You are not hungry enough to eat both dinners. You cannot freeze one. You must eat one and discard the other. Which one do you eat?*" (Type-B).
Time discounting (Laibson, 1997; Read, 2001)	Participants chose between receiving several bigger rewards in the future or smaller at present. For example: "*Do you prefer receive 50$ now or 100$ after a year/Do you prefer receive 50$ after 5 years or 100$ after 6 years.*" (Type-B).

Table 4
Descriptive statistics of H&B tested.

H&B	Min	Max	Mean	S.D.	Skewness	Kurtosis
Anchoring heuristic	10	263	108.34	47.63	0.55	−0.05
Availability heuristic	0	248	131.20	49.53	−0.36	−0.16
Base rate fallacy	0	98	50.77	31.28	−0.10	−1.63
Better than average effect	−176	215	1.76	63.18	0.03	0.23
Endowment effect	–51	955	14.84	21.20	−0.71	0.67
Conjunction fallacy	0	100	66.87	30.89	−0.83	−0.61
Distinction bias	−132	180	52.46	57.66	−0.27	0.14
Extra cost effect	−100	98	13.30	34.36	0.23	0.51
Framing effect	−100	100	25.47	41.16	−0.58	0.33
Gambler's fallacy	0	100	70.13	31.78	−0.92	−0.47
Imaginability bias	–59	91	16.51	30.38	0.04	−0.12
Optimism bias	−286	136	−54.22	76.61	−0.56	0.36
Reference price	–4.8	5	0.19	1.52	−0.01	1.33
Regression toward the mean	0	100	74.93	22.75	−1.00	0.72
Representativeness heuristic	0	98	62.52	17.58	−0.77	0.43
Sunk costs fallacy	0	100	63.86	30.43	−0.57	−0.62
Time discounting	−197	200	86.00	83.45	−0.44	−0.37

3.2.1.3. Third dimension. Heuristics and biases belonging to the last component share a common theme of reference point dependence, for such a reason it was named "Anchoring and Adjustment". Anchoring and insufficient adjustment is the tendency of subjects to be influenced by a reference point. Anchoring processes may also influence Regression toward the mean effect. Regression toward the mean is often considered a statistical bias due to a non-consideration of the statistical phenomenon of regression, which may reflect a tendency of people to exclude other points of view and different options that may increase adjustment from the salient extreme score. In contrast, Stanovich (2009) included this bias in the proposed "Focal bias" class with other Anchoring and Adjustment biases. Focal bias is a useful concept to explain why people focus on reference points without considering alternatives; reference points and all subsequent thought allow economizing cognitive resources compared to alternative strategies that require more computationally taxing operations. Overall, the presence of this dimension is not surprising, since that several taxonomies, included such biases in the same class but with different names (e.g., "Underadjustment", "Anchoring contamination and Compatibility", etc.). Somewhat surprising instead is that the Framing effect primarily loaded on this component, rather than on Valuation biases. However, consistent with one of the primary tenets of Prospect Theory, prospects are compared to the reference point, with steeper curvatures of the utility function for losses compared to gains (Kahneman & Tversky, 1979).

3.3. Confirmatory Factor Analysis (CFA)

Confirmatory Factor Analysis (CFA) was performed on the relationships indicated in the PCA. Since there was not sufficient

Table 5
Rotated component matrixes (four-components on the left and three-components on the right) of the H&B tested and Screen Plot of solutions extracted.

H&B	1	2	3	4	H&B	1	2	3
Imaginability bias	.697				Conjunction fallacy	.566		
Gambler's fallacy	.573				Gambler's fallacy	.552		
Conjunction fallacy	.554				Availability heuristic	.530		
Availability heuristic	.515				Representativeness heuristic	.523		
Distinction bias	.511				Base rate fallacy	.521		
Sunk costs fallacy		.596			Imaginability bias	.516		
Time discounting		.587			Distinction bias	.512		
Better than average effect		-.570			Sunk costs fallacy		.597	
Optimism bias		-.558			Time discounting		.587	
Endowment effect		.459			Better than average effect		-.569	
Extra-cost effect		.448		.	Optimism bias		-.558	
Anchoring heuristic			.725		Endowment effect		.457	
Reference price			.676		Extra-cost effect		.453	
Regression toward the mean			.460		Anchoring heuristic			.689
Framing effect			.445		Reference price			.660
Representativeness heuristic				.697	Regression toward the mean			.497
Base rate fallacy				.632	Framing effect			.481

Note. N = 289. Extraction method: Principal Component Analysis. Rotation method: Oblimin with Kaiser Normalization. Preliminary assessment revealed a KMO value of 0.59, and Bartlett's Test of Sphericity was significant, indicating that the minimum criteria for the PCA were met. None of the off-diagonal items presented correlations of > 0.90, suggesting no evidence of multicollinearity. The communality estimate resulted in an average of 0.39. Coefficient values below 0.40 were suppressed.

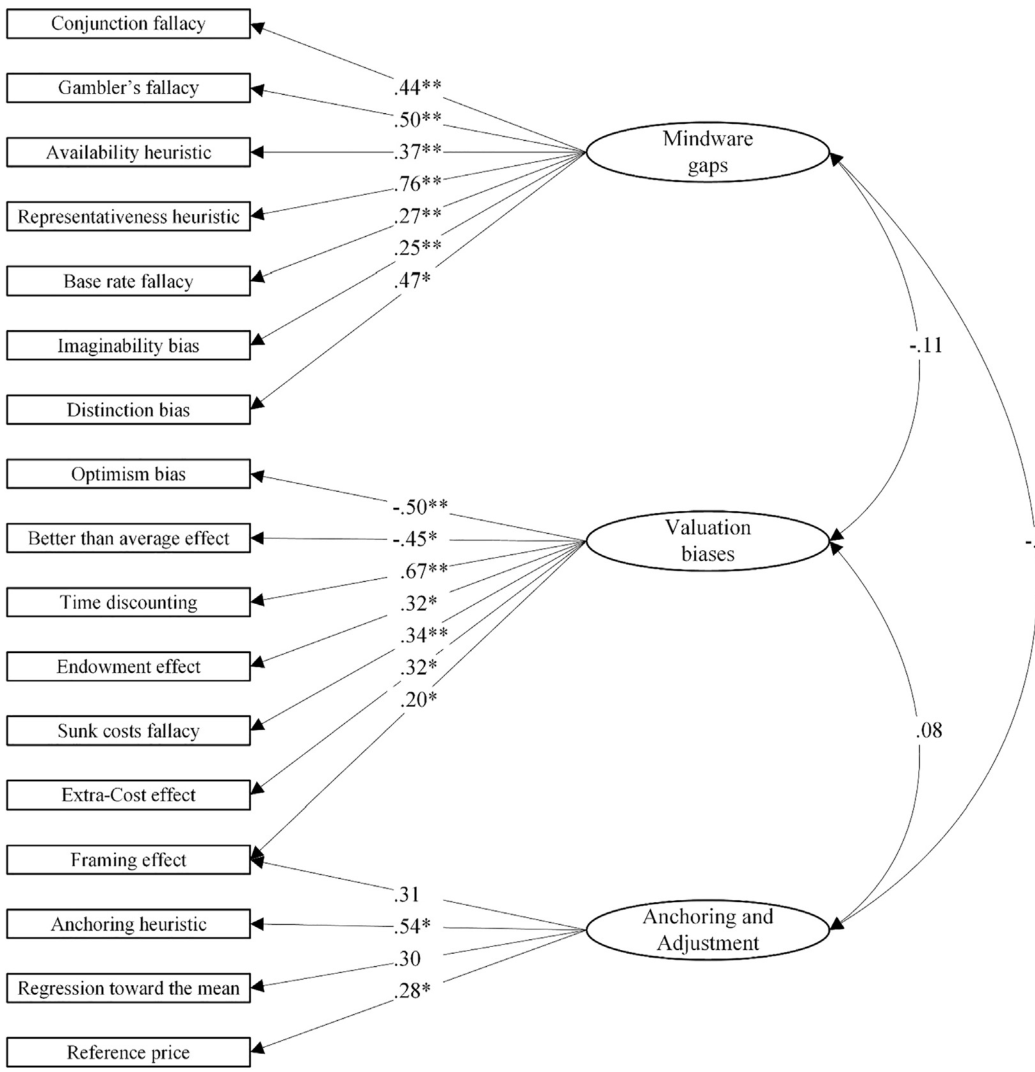

Fig. 1. Confirmatory factor analysis of the three H&B dimensions: Mindware gaps, Valuation biases, Anchoring and Adjustment.
Note. N = 289. *p < .05. **p < .01.

theoretical basis, we tested the same data for cross-validation purposes (see Fabrigar, Wegener, MacCallum, & Strahan, 1999; Van Prooijen & Van Der Kloot, 2001). Indeed, we tested the validity of the solution found with the restrictions implied by the CFA (e.g., fixed cross-loadings, measurement errors, etc., see Worthington & Whittaker, 2006). The first CFA performed showed adequate fit indexes: $\chi^2(103) = 120.72$ ($p = .112$), CFI = 0.938, TLI = 0.918, RMSEA = 0.024 (Cheung & Rensvold, 2002). On the other hand, even if the first model resulted statistically acceptable, we preferred test a different configuration. As reported in the theoretical interpretation, since the Framing effect was expected to load in the Valuation biases dimension, we modeled the relationship between these variables. Results of the new configuration showed a better model fit: $\chi^2(102) = 115.69$ ($p = .167$), CFI = 0.952, TLI = 0.936, RMSEA = 0.022. Moreover, we confirmed the consistency and the independence of the dimensions found together with the significativity of most the H&B relationships found (Fig. 1).

4. General discussion

This research aimed to empirically identify underlying relationships between different H&B for clustering them. Such findings are in line with several theorizations on the H&B taxonomies (Arnott, 2006; Baron, 2000; Carter et al., 2007; Gilovich et al., 2002; Oreg & Bayazit, 2009; Stanovich et al., 2008) and cognitive models which suggest the presence of more than two dimensions of biases (see Stanovich, 2009). Our dimensional account is strictly connected to the H&B tasks selected to compose the resulted solution, which it is based on a more comprehensive set of cognitive biases in comparison with the previous studies (Teovanović et al., 2015; Weaver & Stewart, 2012).

A peculiarity of this research relies in the procedure adopted. Since the definitive number of cognitive biases was not known (e.g., Baron, 2008; Tversky & Kahneman, 1974), random sampling from the domain was not possible. To enhance sample representativeness, a heterogeneous set of phenomena that covered various dimensions in alternative theoretical taxonomies was selected (Arnott, 2006; Baron, 2000; Carter et al., 2007; Gilovich et al., 2002; Oreg & Bayazit, 2009; Stanovich et al., 2008). Following, starting from multiple correspondence patterns, a multi-item instrument collecting measures of individual differences in various cognitive biases was developed. All surveyed tasks were based on examples found in previous studies and adapted to within-subject study design (e.g., Arkes & Blumer, 1985; Bruine de Bruin et al., 2007; Hsee & Zhang, 2004; Sharot, Korn, & Dolan, 2011; Thaler, 1985; Tversky & Kahneman, 1974). The mixed method used (MCA/PCA/CFA) for this classification has the potential of overcoming to limits of empirical solutions and theoretical taxonomies present in the literature. Moreover, it embodies qualities of different approaches and evidence of H&B clusters. In this sense, the solution obtained is important, as a confirmation of some theoretical H&B dimensions, but also for other two reasons. Within-subject design in H&B can be used to detect different response patterns among individuals, considering that "*for a long time they were largely ignored and treated as noise*" (Oreg & Bayazit, 2009, p. 175). But more importantly, individual differences in H&B appear to exist, and conform to a dimensional account which may shed light on common processes that thread certain biases together.

4.1. Studies on H&B and individual differences: considerations in support of the dimensions detected

4.1.1. Mindware gaps, simplification processes, System 2 failing and the role of cognitive skills

We found that the first dimension of H&B was composed of Mindware gaps, the result of shortcuts easy to retrieve (i.e., Availability heuristic) or of judgments based on similarity (i.e., Representativeness heuristic). Likely occurrences or similar ones are easier to imagine than unlikely ones, and associate connections are strengthened when two events frequently co-occur, these findings reinforce theoretical assertions that such biases represent common underlying mechanisms. Mindwares represent common evaluations processes, often inaccurate and suboptimal, that individuals make when they are trying to understand daily events in their lives. They represent the mechanism through which people try to achieve an easier and comprehensible (even if not always accurate) image of the world. For example, the Base rate fallacy happens when people attribute some illustrative qualities to general sample's characteristics by neglecting the sample's size in favor of representativeness. In doing so, the individual discards relevant probabilistic information, whereas available descriptive information and easily accessible one is more accounted in such a process.

Oreg and Bayazit (2009) suggest that individuals incur in these biases by simplifying environmental information through the use of some classic heuristics. Basically, by paying more attention to information that is readily available or is most representative of target stimuli, classic mental errors would be prompted. These Simplification biases (also present in this dimension) stem from the misuse of these processes, such as: Conjunction fallacy, Gambler's fallacy, Base rate fallacy, and deviations in Bayesian reasoning, such as Base rate fallacy, but also two important heuristics such as Availability and Representativeness. Indeed, Tversky and Kahneman (1973) already thought that when people are judging how likely an event is by availability, one treats the most easily recalled characteristics of an event as being diagnostic of the frequency that it will occur.

Overall, these fallacies are basically outcomes of the failing of rationality in its forms (i.e., Coherence or Normative) which sustains the System 2 (Stanovich, 2009). These types of biases rely mostly on insufficient application or knowledge retrieved by System 2, such as logic, statistical knowledge, and scientific reasoning. Stanovich et al. (2008) sustain that people can show less or more inclination toward mindware gaps in relation to their cognitive skills. Indeed, the occurrence of these biases would be mostly dependent by the availability of cognitive resources that regulate the capacity to process complex information using analytical processes, which is almost the definition of cognitive ability (Oechssler et al., 2009).

4.1.2. Valuation biases between avoidance and approach orientations

If we consider the Valuation biases category, we can establish the presence of biases based on affective judgments regarding negative outcomes (i.e., Negativity effect), or characterized by unrealistic optimism (i.e., Positive Illusions). The pole featured by the presence of cost and loss biases is resumable by the "Do Not Waste" heuristic, which is defined as the perception of being more efficient in cost management, to attribute high importance to the costs sustained, and an aversion toward waste of resources (Arkes, 1996; Arkes & Ayton, 1999). The disposition toward high-perception of losses is also present in time management. The aversion is documented in a study conducted by Fox (2013). In conducting an empirical experiment, he showed that people who report loss aversion manifest the same condition when they have to choose between different situations over time. Overall, findings showed that the difference in measured time preference between frames increases based on the person's degree of monetary loss aversion. This evidence could explain the presence of Time discounting in the same Valuation biases component.

Indeed, the disposition of feeling an aversion toward wasting is strictly connected to some emotional states. Sunk-costs and losses elicit negative emotions in people who feel fear or a sense of guilt regarding violations of a No-Waste principle (Fujino et al., 2016). Moreover, neuroscience research has shown how Cost biases elicit stronger negative emotions in individuals engaged to follow norms (Hafenbrack, Kinias, & Barsade, 2014). People who are exhibiting higher insula activation during decision-making show higher loss avoidance, specifically in the dorsal anterior, which plays a role in negative emotional processing (Chua, Gonzalez, Taylor, Welsh, & Liberzon, 2009; Kuhnen & Knutson, 2005; Samanez-Larkin, Hollon, Carstensen, & Knutson, 2008). On the contrary, the imagination of positive events, compared to negative ones, is enhanced by the activation in the amygdala of the rostral anterior cingulate cortex (Sharot, Riccardi, Raio, & Phelps, 2007), and where the same brain region is implicated in optimism trait development and preservation toward negative thinking (Nunes, Sullivan, & Levin, 2004). Such results would be in line with the Gray's (1990) theory which presents an approach-and avoidance-related motivation derived by two distinct neuro-subsystems. Whereas the behavioral inhibition system is believed to control an avoidance-motivation toward to negative outcomes, the behavioral activation system controls an approach-motivation responsible for the experience of positive emotions such as optimism and hope and willingness to accept risks (Gray, 1982).

In light of this, considering the presence of opposite poles in this dimension, it is possible to have people that present opposite characteristics and different H&B as well. If negative emotional processing induces people to evaluate more possible losses, at the other side of the continuum, optimism can affect people's judgments inducing to an under-evaluation of costs and a willingness to accept risks. Studies showed how optimism bias correlates with perceptions of lower risk in different domains (e.g., health, driving, financial, etc.), and less concern and less taking precautions against such risks (Davidson & Prkachin, 1997; DeJoy, 1989; Hoorens & Buunk, 1993; Klein, 1996; Radcliffe & Klein, 2002; Sharot, 2011; Weinstein, 1989). On the other hand, the motivation to self-verify exists also when people prefer to maintain negative self-views than to adopt a positive, yet incongruent, view of the self (Giesler et al., 1996). A negative and accurate self-view can often serve to protect the individual from engaging in activities in which is likely to fail. These differences suggest that given the same decision situation involving risk or uncertainty, people can actually exhibit different biases based on their approach and avoidance inclinations which will distort their ways of perceiving the reality and subsequent outcomes.

4.1.3. Anchoring and Adjustment and not only individual differences

The third dimension (Anchoring and Adjustment) is based uniquely on a reference-point dependence expressed through numeric information. This component might reflect the presence of differences in dealing with numbers (Welsh, Delfabbro, Burns, & Begg, 2007). Unexpectedly, even if most anchoring tasks involve numeric estimation, the literature on anchoring and individual differences does not show consistent evidence on the role of numeric competences (Yoon & Fong, 2010). More in general, studies which investigated the relationship between cognitive ability and anchoring found that anchoring decreases with higher cognitive ability (Bergman et al., 2010). Another ascertained role in individual differences and anchoring effect is due to personality and big five traits (e.g., subjects high in conscientiousness and in agreeableness are more susceptible to the anchoring effect; see Furnham & Boo, 2011). In particular, individuals with high levels of openness to experience trait are more sensitive to anchor cues. Judgments of those individuals high in this trait are more influenced by anchors previously presented, whereas those individuals low in this trait are less influenced by the anchor (McElroy & Dowd, 2007). This is in line with Teovanović et al. (2015) results' study, who recognize in it the disposition in changing the initial answers, toward subsequently given external information, the expression of feedback responsiveness and calibrated judgments. Such an explanation relies on the definition of Ecological rationality (i.e., the ability to exploit the structure of the information in natural environments; Gigerenzer, Hoffrage, & Kleinbölting, 1991) which may involve also some personality dispositions. On the other hand, an effect such as anchoring cannot be explained only by individual differences, but also by other general knowledge (Blankenship, Wegener, Petty, Detweiler-Bedell, & Macy, 2008), expertise about the topic used to test the bias (Wegener, Petty, Detweiler-Bedell, & Jarvis, 2001), mood, self-regulation (Englich & Soder, 2009) and in general by less stable characteristics.

5. Future directions and limitations

Although these results are promising, we must acknowledge several limitations that could represent the focus of future research. First, to reduce participant burden, our individual indicators for each H&B were limited to a small set, or a single-item. This limits our ability to address the internal consistency of the underlying tasks used in this study. However, it is important to note that repeated-measures of H&B often show acceptable internal consistency when multiple items are used to assess the same construct (Bruine de Bruin et al., 2007). Second, we were able to include only a subset of H&B that are present in the literature. Future research can help to clarify further the content validity of each dimension. Third, as individual differences capable of explaining dimensions found, we mostly considered personality, inclinations or cognitive skills and we showed also how they can even interact together to determine such processes (e.g., cognitive and personality traits in Anchoring and Adjustment). On the other hand, socio-demographic characteristics such as age or gender, education level, work experiences, etc. which might have a role in H&B emergence were not explored as possible bias predictors. Expect for the relationship between gender and H&B – which it has not showed consistent results in literature yet – for variables such as age or education, the motivation relies on low variability of these variables, since the sample is composed of students. Finally, a replication of this dimensional account is needed in an independent sample in order to test its robustness. This is an important and needed step before beginning to establish convergent and predictive associations between these specific dimensions and other variables of interest.

6. Conclusion and practical implications

The utility of this study and its contribution on individual-difference decision-making paradigm in the academic research is related to the possibility of developing a wider and more comprehensive taxonomy of H&B, still grounded on an evidence-based approach. Adopting evidence-based categories of H&B may allow future research to investigate more precisely the presence of multiple processes in decision-making against the idea of a single Decision-Making Competence (see Ceschi, Costantini, Phillips, & Sartori, 2017; Ceschi, Demerouti, Sartori, & Weller, 2017). On the other hand, even if the present study showed the presence of consistent relationships between some traits and H&B, most of the variance still remains unexplained by leaving room to other possible predictors (e.g., expertise, tacit knowledge, self-regulation mood, etc. Which have proved to have a role in the Anchoring and Adjustment). Such variables, in comparison to individual differences, may be developable characteristics, which would be possible to train in order to avoid certain H&B (i.e., Debiasing program; see Larrick, 2004). Understanding strategies by which individuals approach decisions and improve them has relevant implications for physical, mental, and financial well-being. It is important to recall how several studies have shown that the tendency to respond irrationally is associated with problematic behaviors and outcomes across the lifespan (Bruine de Bruin et al., 2007; Peters, Dieckmann, & Weller, 2011; Weller, Levin, Rose, & Bossard, 2012). Programs designed to promote better decision-making through teaching debiasing strategies might consider present evidence-based dimensions of H&B for organizing the training and have better in impact on real-world decision outcomes.

References

Aczel, B., Bago, B., Szollosi, A., Foldes, A., & Lukacs, B. (2015). Measuring individual differences in decision biases: Methodological considerations. *Frontiers in Psychology, 6*, 1770.

Arkes, H. R. (1996). The psychology of waste. *Journal of Behavioral Decision Making, 9*(3), 213–224.

Arkes, H. R., & Ayton, P. (1999). The Sunk-Cost and Concorde effects: Are humans less rational than lower animals? *Psychological Bulletin, 125*(5), 591–600.

Arkes, H. R., & Blumer, C. (1985). The psychology of Sunk-Cost. *Organizational Behavior and Human Decision Processes, 35*(1), 124–140.

Arnott, D. (2006). Cognitive biases and decision support systems development: A design science approach. *Information Systems Journal, 16*(1), 55–78.

Ayele, D., Zewotir, T., & Mwambi, H. (2014). Multiple correspondence analysis as a tool for analysis of large health surveys in African settings. *African Health Sciences, 14*(4), 1036–1045.

Baron, J. (2000). *Thinking and deciding* (3rd ed.). Cambridge: Cambridge University Press.

Baron, J. (2008). *Thinking and deciding* (4th ed.). New York: Cambridge University Press.

Bergman, O., Ellingsen, T., Johannesson, M., & Svensson, C. (2010). Anchoring and cognitive ability. *Economics Letters, 107*(1), 66–68.

Blankenship, K. L., Wegener, D. T., Petty, R. E., Detweiler-Bedell, B., & Macy, C. L. (2008). Elaboration and consequences of anchored estimates: An attitudinal perspective on numerical anchoring. *Journal of Experimental Social Psychology, 44*(6), 1465–1476.

Bruine de Bruin, W., Parker, A. M., & Fischhoff, B. (2007). Individual differences in adult decision-making competence. *Journal of Personality and Social Psychology, 92*(5), 938–956.

Carter, C. R., Kaufmann, L., & Michel, A. (2007). Behavioral supply management: A taxonomy of judgment and decision-making biases. *International Journal of Physical Distribution and Logistics Management, 37*(8), 631–669.

Carver, C. S., & Scheier, M. F. (1990). Origins and functions of positive and negative affect: A control-process view. *Psychological Review, 97*(1), 19.

Ceschi, A., Costantini, A., Phillips, S. D., & Sartori, R. (2017). The career decision-making competence: a new construct for the career realm. *European Journal of Training and Development, 41*(1), 8–27.

Ceschi, A., Demerouti, E., Sartori, R., & Weller, J. (2017). Decision-making processes in the workplace: how exhaustion, lack of resources and job demands impair them and affect performance. *Frontiers in Psychology, 8*, 313.

Chapman, D. A., & Polkovnichenko, V. (2009). First-order risk aversion, heterogeneity, and asset market outcomes. *The Journal of Finance, 64*(4), 1863–1887.

Cheung, G. W., & Rensvold, R. B. (2002). Evaluating goodness-of-fit indexes for testing measurement invariance. *Structural Equation Modeling, 9*(2), 233–255.

Chua, H. F., Gonzalez, R., Taylor, S. F., Welsh, R. C., & Liberzon, I. (2009). Decision-related loss: Regret and disappointment. *NeuroImage, 47*(7), 2031–2040.

Conway, J. M., & Huffcutt, A. I. (2003). A review and evaluation of exploratory factor analysis practices in organizational research. *Organizational Research Methods, 6*(2), 147–168.

Davidson, K., & Prkachin, K. (1997). Optimism and unrealistic optimism have an interacting impact on health-promoting behavior and knowledge changes. *Personality and Social Psychology Bulletin, 23*(6), 617–625.

De Palma, A., Ben-Akiva, M., Brownstone, D., Holt, C., Magnac, T., McFadden, D., ... in Wakker, P., & Wakker, J. (2008). Risk, uncertainty and discrete choice models. *Marketing Letters, 19*(3–4), 269–285.

DeJoy, D. M. (1989). The optimism bias and traffic accident risk perception. *Accident Analysis & Prevention, 21*(4), 333–340.

Einhorn, H. J., & Hogarth, R. M. (1987). Decision making: Going forward in reverse. *Harvard Business Review, 65*, 66–70.

Englich, B., & Soder, K. (2009). Moody experts — How mood and expertise influence judgmental anchoring. *Judgment and Decision making, 4*(1), 41–50.

Epley, N., & Gilovich, T. (2006). The anchoring-and-adjustment heuristic: Why the adjustments are insufficient. *Psychological Science, 17*(4), 311–318.

Evans, J. S. B., & Stanovich, K. E. (2013). Dual-process theories of higher cognition advancing the debate. *Perspectives on Psychological Science, 8*(3), 223–241.

Fabrigar, L. R., Wegener, D. T., MacCallum, R. C., & Strahan, E. J. (1999). Evaluating the use of exploratory factor analysis in psychological research. *Psychological Methods, 4*(3), 272–299.

Ferguson, S. (1987). Regression toward the mean? *Archives of Neurology, 44*(5), 474–475.

Fox, C. R. (2013). *Loss aversion for time and money. Oral presentation at the 24th Subjective Probability, Utility, and Decision Making Conference (SPUDM), Barcelona, ES*.

Frisch, D., & Jones, S. K. (1993). Assessing the accuracy of decisions. *Theory & Psychology,*

3(1), 115–135.
Fujino, J., Fujimoto, S., Kodaka, F., Camerer, C. F., Kawada, R., Tsurumi, K., & Sugihara, G. (2016). Neural mechanisms and personality correlates of the Sunk-Cost effect. *Nature Scientific Reports, 6*, 33171.
Furnham, A., & Boo, H. C. (2011). A literature review of the anchoring effect. *The Journal of Socio-Economics, 40*(1), 35–42.
Gächter, S., Johnson, E. J., & Herrmann, A. (2007). Individual-level loss aversion in riskless and risky choices. *CeDEx discussion paper series*. Nottingham: University of Nottingham.
Giesler, R. B., Josephs, R. A., & Swann, W. B., Jr. (1996). Self-verification in clinical depression: The desire for negative evaluation. *Journal of Abnormal Psychology, 105*(3), 358.
Gigerenzer, G. (1996). On narrow norms and vague heuristics: A reply to Kahneman and Tversky. *Psychological Review, 103*(3), 592–596.
Gigerenzer, G. (1998). Ecological intelligence: An adaptation for frequencies. In D. D. Cummins, & C. Allen (Eds.). *The evolution of mind* (pp. 9–29). New York: Oxford University Press.
Gigerenzer, G., & Brighton, H. (2009). Homo heuristicus: Why biased minds make better inferences. *Topics in Cognitive Science, 1*(1), 107–143.
Gigerenzer, G., Hoffrage, U., & Kleinbölting, H. (1991). Probabilistic mental models: A Brunswikian theory of confidence. *Psychological Review, 98*, 506–528.
Gigerenzer, G., & Selten, R. (2001). Rethinking rationality. In G. Gigerenzer, & R. Selten (Eds.). *Bounded rationality: The adaptive toolbox* (pp. 1–12). Cambridge: The MIT Press.
Gilovich, T., Griffin, D., & Kahneman, D. (Eds.). (2002). *Heuristics and biases: The psychology of intuitive judgment*. UK: Cambridge University Press.
Gray, J. A. (1982). On mapping anxiety. *Behavioral and Brain Sciences, 5*(3), 506–534.
Gray, J. A. (1990). Brain systems that mediate both emotion and cognition. *Cognition & Emotion, 4*(3), 269–288.
Guyatt, G. H., Townsend, M., Berman, L. B., & Keller, J. L. (1987). A comparison of Likert and visual analogue scales for measuring change in function. *Journal of Chronic Diseases, 40*(12), 1129–1133.
Hafenbrack, A. C., Kinias, Z., & Barsade, S. G. (2014). Debiasing the mind through meditation mindfulness and the Sunk-Cost bias. *Psychological Science, 25*(2), 369–376.
Hammond, K. R. (1996). *Human judgment and social policy: Irreducible uncertainty, inevitable error, unavoidable injustice.* New York, NY, US: Oxford University Press.
Hogarth, R. M. (1987). *Judgement and choice: The psychology of decision.* Oxford: John Wiley & Sons.
Hoorens, V., & Buunk, B. P. (1993). Social comparison of health risks: Locus of control, the person-positivity bias, and unrealistic optimism. *Journal of Applied Social Psychology, 23*(4), 291–302.
Hsee, C. K., & Zhang, J. (2004). Distinction bias: Misprediction and mischoice due to joint evaluation. *Journal of Personality and Social Psychology, 86*(5), 680–695.
Kahneman, D. (2003a). A perspective on judgment and choice: Mapping bounded rationality. *American Psychologist, 58*(9), 697–720.
Kahneman, D. (2003b). Maps of bounded rationality: Psychology for behavioral economics. *American Economic Review, 93*(5), 1449–1475.
Kahneman, D., & Frederick, S. (2002). Representativeness revisited: Attribute substitution in intuitive judgment. In T. Gilovich, D. Griffin, & D. Kahneman (Eds.). *Heuristics and biases* (pp. 49–81). New York: Cambridge University Press.
Kahneman, D., Slovic, P., & Tversky, A. (1982). *Judgment under uncertainty: Heuristics and biases.* Cambridge: Cambridge University Press.
Kahneman, D., & Tversky, A. (1972). Subjective probability: A judgment of representativeness. *Cognitive Psychology, 3*(3), 430–454.
Kahneman, D., & Tversky, A. (1973). On the psychology of prediction. *Psychological Review, 80*(4), 237–251.
Kahneman, D., & Tversky, A. (1979). Prospect theory: An analysis of decision under risk. *Econometrica: Journal of the Econometric Society, 47*(2), 263–291.
Khorramdel, L., & Frebort, M. (2011). Context effects on test performance. *European Journal of Psychological Assessment, 27*, 103–110.
Klaczynski, P. A. (2001). Analytic and heuristic processing influences on adolescent reasoning and decision making. *Child Development, 72*(3), 844–861.
Klein, W. M. (1996). Maintaining self-serving social comparisons: Attenuating the perceived significance of risk-increasing behaviors. *Journal of Social and Clinical Psychology, 15*(1), 120–142.
Kobayashi, C., & Brown, J. D. (2003). Self-esteem and self-enhancement in Japan and America. *Journal of Cross-Cultural Psychology, 34*(5), 567–580.
Kuhnen, C. M., & Knutson, B. (2005). The neural basis of financial risk taking. *Neuron, 47*(5), 763–770.
Laibson, D. (1997). Golden eggs and hyperbolic discounting. *The Quarterly Journal of Economics, 112*(2), 443–478.
Larrick, R. P. (2004). Debiasing. In D. J. Koehler, & N. Harvey (Eds.). *Blackwell handbook of judgment and decision making* (pp. 316–338). Hoboken: Blackwell Publishing.
Lee, A. Y., Aaker, J. L., & Gardner, W. L. (2000). The pleasures and pains of distinct self-construals: The role of interdependence in regulatory focus. *Journal of Personality and Social Psychology, 78*(6), 1122.
Leone, L., Perugini, M., & Bagozzi, R. (2005). Emotions and decision making: Regulatory focus moderates the influence of anticipated emotions on action evaluations. *Cognition & Emotion, 19*(8), 1175–1198.
Levin, I. P., & Gaeth, G. J. (1988). How consumers are affected by the framing of attribute information before and after consuming the product. *Journal of Consumer Research, 15*(3), 374–378.
Levin, I. P., Gaeth, G. J., Schreiber, J., & Lauriola, M. (2002). A new look at framing effects: Distribution of effect sizes, individual differences, and independence of types of effects. *Organizational Behavior and Human Decision Processes, 88*(1), 411–429.
Levin, I. P., Schneider, S. L., & Gaeth, G. J. (1998). All frames are not created equal: A typology and critical analysis of framing effects. *Organizational Behavior and Human Decision Processes, 76*(2), 149–188.
Loomes, G., & Sugden, R. (1982). Regret theory: An alternative theory of rational choice under uncertainty. *The Economic Journal, 92*(368), 805–824.
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.
McKenna, F. P. (1993). It won't happen to me: Unrealistic optimism or illusion of control? *British Journal of Psychology, 84*(1), 39–50.
Nunes, E. V., Sullivan, M. A., & Levin, F. R. (2004). Treatment of depression in patients with opiate dependence. *Biological Psychiatry, 56*, 793–802.
Oechssler, J., Roider, A., & Schmitz, P. W. (2009). Cognitive abilities and behavioral biases. *Journal of Economic Behavior & Organization, 72*(1), 147–152.
Oreg, S., & Bayazit, M. (2009). Prone to bias: Development of a bias taxonomy from an individual differences perspective. *Review of General Psychology, 13*(3), 175.
Parker, A. M., & Fischhoff, B. (2005). Decision-making competence: External validation through an individual-differences approach. *Journal of Behavioral Decision Making, 18*(1), 1–27.
Paulhus, D. L., Harms, P. D., Bruce, M. N., & Lysy, D. C. (2003). The over-claiming technique: Measuring self-enhancement independent of ability. *Journal of Personality and Social Psychology, 84*(4), 890.
Peters, E., Dieckmann, N. F., & Weller, J. A. (2011). Age differences in complex decision making. In K. W. Schaie, & S. L. Willis (Eds.). *Handbook of the psychology of aging* (pp. 133–151). Burlington: Burlington Academic Press.
Radcliffe, N. M., & Klein, W. M. (2002). Dispositional, unrealistic, and comparative optimism: Differential relations with the knowledge and processing of risk information and beliefs about personal risk. *Personality and Social Psychology Bulletin, 28*(6), 836–846.
Read, D. (2001). Is time-discounting hyperbolic or subadditive? *Journal of Risk and Uncertainty, 23*(1), 5–32.
Remus, W. E., & Kottemann, J. E. (1986). Toward intelligent decision support systems: An artificially intelligent statistician. *MIS Quarterly,* 403–418.
Rozin, P., & Royzman, E. B. (2001). Negativity bias, negativity dominance, and contagion. *Personality and Social Psychology Review, 5*(4), 296–320.
Russell, D. W. (2002). In search of underlying dimensions: The use (and abuse) of factor analysis in Personality and Social Psychology Bulletin. *Personality and Social Psychology Bulletin, 28*(12), 1629–1646.
Samanez-Larkin, G. R., Hollon, N. G., Carstensen, L. L., & Knutson, B. (2008). Individual differences in insular sensitivity during loss anticipation predict avoidance learning. *Psychological Science, 19*(4), 320–323.
Sharot, T. (2011). The optimism bias. *Current Biology, 21*(23), 941–945.
Sharot, T., Korn, C. W., & Dolan, R. J. (2011). How unrealistic optimism is maintained in the face of reality. *Nature Neuroscience, 14*(11), 1475–1479.
Sharot, T., Riccardi, A. M., Raio, C. M., & Phelps, E. A. (2007). Neural mechanisms mediating optimism bias. *Nature, 450*(7166), 102–105.
Sherman, S. J., Cialdini, R. B., Schwartzman, D. F., & Reynolds, K. D. (1985). Imagining can heighten or lower the perceived likelihood of contracting a disease. *Personality and Social Psychology Bulletin, 11*(1), 118–127.
Simon, H. A. (1956). Rational choice and the structure of the environment. *Psychological Review, 63*(2), 129–138.
Simon, H. A. (1991). Bounded rationality and organizational learning. *Organization Science, 2*(1), 125–134.
Slugoski, B. R., Shields, H. A., & Dawson, K. A. (1993). Relation of conditional reasoning to heuristic processing. *Personality and Social Psychology Bulletin, 19*(2), 158–166.
Smith, E. R., & DeCoster, J. (2000). Dual-process models in social and cognitive psychology: Conceptual integration and links to underlying memory systems. *Personality and Social Psychology Review, 4*(2), 108–131.
Soman, D., & Cheema, A. (2001). The effects of windfall gains on the Sunk-Cost effect. *Marketing Letters, 12*(1), 51–62.
Sourial, N., Wolfson, C., Zhu, B., Quail, J., Fletcher, J., Karunananthan, S., ... Bergman, H. (2010). Correspondence analysis is a useful tool to uncover the relationships among categorical variables. *Journal of Clinical Epidemiology, 63*(6), 638–646.
Stanovich, K. E. (1999). *Who is rational? Studies of individual differences in reasoning.* Mahwah, NJ, US: Lawrence Erlbaum Associates Publishers.
Stanovich, K. E. (2009). Distinguishing the reflective, algorithmic, and autonomous minds: Is it time for a tri-process theory? In J. Evans, & K. Frankish (Eds.). *In two minds: Dual processes and beyond* (pp. 55–88). Oxford: Oxford University Press.
Stanovich, K. E., Toplak, M. E., & West, R. F. (2008). The development of rational thought: A taxonomy of heuristics and biases. *Advances in Child Development and Behavior, 36*, 251–285.
Stanovich, K. E., & West, R. F. (1998a). Individual differences in framing and conjunction effects. *Thinking and Reasoning, 4*(4), 289–317.
Stanovich, K. E., & West, R. F. (1998b). Individual differences in rational thought. *Journal of Experimental Psychology: General, 127*(2), 161–188.
Stanovich, K. E., & West, R. F. (2002). Individual differences in reasoning: Implications for the rationality debate? In T. Gilovich, D. W. Griffin, & D. Kahneman (Eds.). *Heuristics and biases: The psychology of intuitive judgment* (pp. 421–444). New York: Cambridge University Press.
Stanovich, K. E., & West, R. F. (2003). Evolutionary versus instrumental goals: How evolutionary psychology misconceives human rationality. In D. Over (Ed.). *Evolution and the psychology of thinking: The debate* (pp. 171–230). Hove, England: Psychology Press.
Stanovich, K. E., & West, R. F. (2007). Natural myside bias is independent of cognitive ability. *Thinking and Reasoning, 13*(3), 225–247.
Stanovich, K. E., & West, R. F. (2008a). On the failure of cognitive ability to predict

myside and one-sided thinking biases. *Thinking and Reasoning, 14*(2), 129–167.
Stanovich, K. E., & West, R. F. (2008b). On the relative independence of thinking biases and cognitive ability. *Journal of Personality and Social Psychology, 94*(4), 672–695.
Stanovich, K. E., West, R. F., & Toplak, M. E. (2011). The complexity of developmental predictions from dual process models. *Developmental Review, 31*, 103–118.
Suls, J., Lemos, K., & Stewart, H. L. (2002). Self-esteem, construal, and comparisons with the self, friends, and peers. *Journal of Personality and Social Psychology, 82*(2), 252.
Taylor, S. E., & Brown, J. D. (1988). Illusion and well-being: A social-psychological perspective on mental health. *Psychological Bulletin, 103*(2), 193–210.
Teovanović, P., Knežević, G., & Stankov, L. (2015). Individual differences in cognitive biases: Evidence against one-factor theory of rationality. *Intelligence, 50*, 75–86.
Thaler, R. (1985). Mental accounting and consumer choice. *Marketing Science, 4*(3), 199–214.
Toplak, M. E., West, R. F., & Stanovich, K. E. (2011). The Cognitive Reflection Test as a predictor of performance on heuristics-and-biases tasks. *Memory & Cognition, 39*(7), 1275–1289.
Tversky, A., & Kahneman, D. (1973). Availability: A heuristic for judging frequency and probability. *Cognitive Psychology, 5*(2), 207–232.
Tversky, A., & Kahneman, D. (1974). Judgment under uncertainty: Heuristics and biases. *Science, 185*(4157), 1124–1131.
Tversky, A., & Kahneman, D. (1981). The framing of decisions and the psychology of choice. *Science, 211*(4481), 453–458.
Tversky, A., & Kahneman, D. (1983). Extensional versus intuitive reasoning: The conjunction fallacy in probability judgment. *Psychological Review, 90*(4), 293–315.
Van Prooijen, J. W., & Van Der Kloot, W. A. (2001). Confirmatory analysis of exploratively obtained factor structures. *Educational and Psychological Measurement, 61*(5), 777–792.
Von Neumann, J., & Morgenstern, O. (1947). *Theory of games and economic behavior.* Princeton: Princeton University Press.
Weaver, E. A., & Stewart, T. R. (2012). Dimensions of judgment: Factor analysis of individual differences. *Journal of Behavioral Decision Making, 25*(4), 402–413.
Wegener, D. T., Petty, R. E., Detweiler-Bedell, B. T., & Jarvis, W. B. G. (2001). Implications of attitude change theories for numerical anchoring: Anchor plausibility and the limits of anchor effectiveness. *Journal of Experimental Social Psychology, 37*(1), 62–69.
Weinstein, N. D. (1989). Optimistic biases about personal risks. *Science, 246*(4935), 1232–1234.
Weller, J. A., Levin, I. P., Rose, J. P., & Bossard, E. (2012). Assessment of decision-making competence in preadolescence. *Journal of Behavioral Decision Making, 25*(4), 414–426.
Welsh, M. B., Delfabbro, P. H., Burns, N. R., & Begg, S. H. (2007). Individual differences in anchoring: Traits and experience. *Learning and Individual Differences, 29*, 131–140.
West, R. F., & Stanovich, K. E. (2003). Is probability matching smart? Associations between probabilistic choices and cognitive ability. *Memory & Cognition, 31*(2), 243–251.
Wood, J. V., Heimpel, S. A., & Michela, J. L. (2003). Savoring versus dampening: Self-esteem differences in regulating positive affect. *Journal of Personality and Social Psychology, 85*(3), 566.
Worthington, R. L., & Whittaker, T. A. (2006). Scale development research: A content analysis and recommendations for best practices. *The Counseling Psychologist, 34*(6), 806–838.
Yoon, S., & Fong, N. (2010). *Numeric competencies and anchoring biases.* (Working paper).
Zhang, J., Patel, V. L., Johnson, T. R., & Shortliffe, E. H. (2004). A cognitive taxonomy of medical errors. *Journal of Biomedical Informatics, 37*(3), 193–204.

Further Reading

Levin, I. P., Weller, J. A., Pederson, A. A., & Harshman, L. A. (2007). Age-related differences in adaptive decision making: Sensitivity to expected value in risky choice. *Judgment and Decision making, 2*(4), 225–233.

Andrea Ceschi is a post-doc Work and Organizational Psychology at Verona University (Italy), Department of Human Sciences. His field of work deals with organisational dynamics related to decision-making processes in the workplace.

Arianna Costantini is a Ph.D. Candidate in Psychology at Verona University, Department of Human Sciences, Italy. Her field of work is job crafting, behavior change and workplace innovation.

Riccardo Sartori is Associate Professor in Work and Organizational Psychology at Verona University (Italy), Department of Human Sciences. His field of work is organizational innovation and the assessment processes linked to this topic, included psychological assessment and human resources management.

Joshua Weller is an Assistant Professor of Developmental Psychology at Tilburg University, The Netherlands. His research focuses broadly on individual differences in decision making and risk taking.

Annamaria Di Fabio is full professor of Work and Organizational Psychology and director of the two International Laboratories for Research and Intervention Cross-Cultural Positive Psychology, Prevention, and Sustainability (CroCPosPsychP&S) and Psychology for Vocational Guidance, Career Counseling and Talents (LabOProCCareer&T) at the University of Florence. Recently she was elected in the Board of Directors of the International Association of Applied Psychology (IAAP).