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Neuro-Evolutionary Bias Framework

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Summary

The present report serves to provide a systematic overview of the large number of cognitive biases (> 200) that have been identified so far. The two main groups of biases are based on their primary origin: neural or evolutionary. Each of these overall groups of biases is sub divided into several (sub-)categories, based on underlying working principles. These principles determine the nature and origin of the multitude of cognitive biases. This explanatory framework is consistent with vested neuroscientific knowledge on the working of our brain as a neural network and with the underlying principles of evolutionary psychology. It can be used as a basis for more insight into the origins of biases and on new ways to mitigate them.

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1 Introduction

Cognitive biases are systematic and universally occurring patterns of thinking that deviate from the tenets of logic, probability reasoning, and plausibility and/or from what may be considered optimal, advisable, or utile. These specific deviations are most commonly seen as tendencies, inclinations, or dispositions that skew or distort information processes in ways that make their outcome inaccurate. So, these deviations are not random, but specific and systematic: in a wide range of different conditions, people show the same, typical tendencies in the way they pick up and process information in order to judge and decide. The intuitive processes that precede biased judgements and decisions are largely implicit and unconscious. Cognitive biases seem to be robust and universal psychological phenomena, extensively described and demonstrated in the literature. They apply to everybody, at all levels and in all parts of society, not only in daily life, but also in professional institutions like politics, government, business, and media. Biased thinking feels quite naturally and self-evident and we typically feel confident about our decisions and judgments, even when evidence is scarce and when we are aware of the operation of cognitive biases. Therefore, cognitive biases are pervasive and persistent phenomena. Understanding their nature and origin, is an important step towards being able to deal with them.

1.1 An explanatory framework for biases

Cognitive biases are mostly described phenomenologically, focusing on the decision processes and outcomes revealing that a bias is at work. Discerning between the different types of biases can be challenging. Many cognitive biases resemble each other. There is much overlap between the descriptions of different biases and one bias may be a more specific example of another, broader-circumscribed, bias. This may suggest that they result from common underlying mechanisms and are representatives of the same broader class.

Until recently, academic literature on biases lacked an explanatory model that describes underlying principles and mechanisms of biases, consistent with neuroscientific knowledge. Because of that, there is little consensus about the origins of biases and why they are so systematic, persistent and consistent over individuals, groups, and contexts. To provide a categorization of biases and more insight into their origin, this paper entails a binding framework based on intrinsic neural mechanisms (or characteristics) and ingrained evolutionary principles of survival. In this framework, biases are categorized on the basis of similar underlying neuro-evolutionary causes. This consistency with vested neurophysiological and evolutionary knowledge provides clarity into the abundance of described bias phenomena and a scientific basis for the development of methods and tools to handle them. More background information about this Neuro-evolutionary Bias Framework and its scientific foundations was previously published by Korteling *cs* (i.e., Korteling, Brouwer & Toet, 2018; Korteling & Toet, 2020).

1.2 The two main groups of biases

The Neuro-Evolutionary Bias framework describes the most prominent and well-known biases that have so far been demonstrated and described in the scientific

literature. At the highest level, biases are classified into two principal groups: 1) Neural and 2) Evolutionary biases.

Neural biases arise from the inherent characteristics (or principles) of the functioning of the brain as a biological neural network ('structural'). These biases distort or skew cognitive information processing in ways that makes its outcomes inaccurate or suboptimal. These processes may be quite similar to perceptual illusions. Evolutionary biases have a different, more functional, origin. They may also affect rational thinking, but these tendencies were once beneficial for the survival and reproduction of our ancestors, like preferring food now over food later. Though once useful, these biases may be neither useful nor adaptive in today's world. Both the neural and evolutionary biases are subdivided into a number of (sub)categories of biases. This has resulted in a total of 8 categories (4 neural and 4 evolutionary) and 5 subcategories of cognitive biases, see Figure 1.

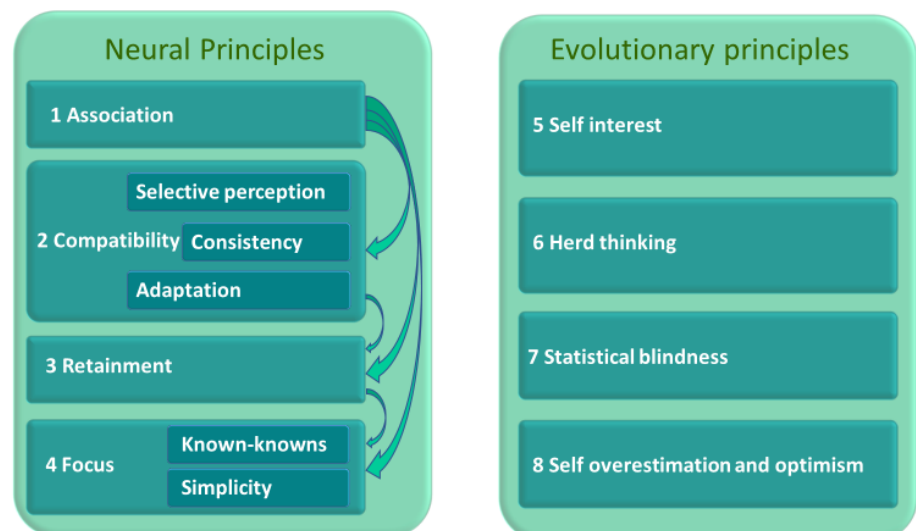


Fig. 1 Framework of 8 main categories and 5 subcategories of neural and evolutionary biases.

All categories are based on specific neurophysiological or evolutionary working principles, which all can be found in the literature. These neuro-evolutionary principles are the building blocks at the basis of the framework. They structure and simplify the high phenomenological diversity of biases. The underlying neuro-evolutionary principles are *additional* and not mutually exclusive. This means that specific biases may have a multifactor origin and thus may originate from more than one underlying principle. In figure 1 this multifactor origin is (partly) shown by the arrows of the neural principles. For instance association, as a most basic and fundamental characteristic of the working of biological neural networks, is involved in all other principles.

2 Neural biases

Our cognitive capacities that involve deliberate or analytic thinking (e.g., calculation, statistics, analysis, reasoning, abstraction, conceptual thinking) have been developed very recently seen from the perspective of the entire evolution of mankind. Neural biases stem from the organization and functioning of the brain as an associative and adaptive biological neural network, primarily designed and optimized to perform basic biological and perceptual-motor functions. This neural network has four main working principles that in some cases can be further differentiated into sub-principles.

These four main principles (1. Association; 2. Compatibility; 3. Retainment; 4. Focus) define four groups of biases. The first category of biases is mainly explained by principle 1, the 'Association principle'. This principle underlies the functioning of every neural network under all circumstances. It determines, for example, coincidence detection and pattern recognition as one of its most fundamental basic operations. The second group of biases is largely determined by principle 2. This second, so-called 'Compatibility principle' determines what pieces of information are (unconsciously) selected or preferred for further processing by the system, and what pieces are ignored. The third 'Retainment' principle pertains to the inability of the brain to (completely) ignore or exclude irrelevant information. Finally, the fourth 'Focus principle' determines how the neural network selectively focuses on dominant information while ignoring relevant information that is not directly activated. At the highest level the neural biases are classified according to these four main principles.

2.1 Association

The brain associatively searches for relationships in the form of coherent, invariant patterns (correlation, coincidences) in the available information.

Establishing and maintaining associative connections (correlations, coherence, patterns) is probably the most basic operation of the brain as a neural network. The brain is strongly inclined to search and find all kinds of connections even if those connections are not correct and/or are based on coincidence. We make connections between coincidences that have no causal relationships (like the color of our underpants and our success in sport). This is how superstition, conspiracy theories, and various kinds of false knowledge (quacks) arise. Many preferences, aversions, or stereotypes are based on (learned) associations. Creating or maintaining positive associations with products for example, is one of the fundamentals of advertising.

There are various biases that follow directly from the associative nature of the brain. The following 15 biases follow from the first principle of Association. As mentioned earlier, some biases are closely related or quite similar to each other. This is indicated by mentioning these related biases in brackets behind the bias-description.

- 1 **Base rate neglect:** the tendency to prefer specific information over general information (cf. Representativeness bias, Stereotyping).
- 2 **Conjunction fallacy:** the tendency to consider a combination of conditions more likely than just one of those conditions.
- 3 **Contagion bias:** the inclination to avoid contact with people or objects that - through earlier contact with someone or something that is considered bad - are perceived as 'contagious'. Or (less common) to make contact with objects that have been in contact with people or things that are considered good.
- 4 **Control illusion¹:** the tendency to believe that you have control over things (or can influence them) even though objectively seen there is no such control. This is related to having difficulty seeing chance as something autonomous and independent (cf. Superstition) or the tendency to see (causal) relations between unrelated events (cf. Spurious causation).
- 5 **Clustering illusion:** the tendency to consider patterns, or clusters, in small samples from random distributions to be non-random (cf. Illusion of validity, Pareidolia).
- 6 **Illusion of validity** (Law of small numbers, Hot hand fallacy, Insensitivity to sample size, anecdotal evidence): the tendency of having faith in assessments if they are based on consistent information and data-agreement with little or no consideration of the factors that can limit their accuracy (cf. Clustering illusion, Inductive reasoning error).
- 7 **Inductive reasoning error:** the tendency to build general conclusions (predictions) on the basis of a small number of separate, but consistent, previous observations (cf. Illusion of validity).
- 8 **Normalcy bias:** the tendency to underestimate both the likelihood of a disaster ('black swans') and its possible consequences, and to believe that things will always function the way they normally function (cf. Inductive reasoning error).
- 9 **Pareidolia:** the tendency to see patterns in vague, random stimuli, e.g. seeing faces or animals in clouds or rock formations (cf. clustering illusion).
- 10 **Reactive devaluation:** the tendency to evaluate an idea (belief, statement etc.) negatively because it comes from an opponent or otherwise negatively valued source.
- 11 **Representativeness bias:** the tendency to judge the likelihood of an entity by the extent to which it 'resembles the typical case' instead of by its simple base rate (cf. Stereotyping, Base rate neglect).
- 12 **Spurious causation** (Illusory causation): the tendency to "see" (causal) relationships where such a relation is lacking (cf. Pareidolia, Control illusion, Superstition).
- 13 **Stereotyping:** the tendency to have over-generalized beliefs about the characteristics of particular categories of people (cf. Representativeness bias).
- 14 **Story bias:** the tendency to accept and remember consistent and believable stories more easily than simple facts.
- 15 **Superstition²:** the tendency to explain chance by the operation of hidden supernatural phenomena (Gods, clairvoyance, fate, karma, miracles) (cf. Spurious causation).

¹ Also categorized under Self-overestimation and optimism.

² Also categorized under Statistical blindness.

2.2 Compatibility

Associative information pick-up and -processing is substantially facilitated by the compatibility (match, consistency, agreement) with the current state of the brain. We accept or prefer information or choices that are compatible with what we already know, understand, expect and/or value. This information is processed easier and more thoroughly.

Input that corresponds to pre-existing, strong, or activated ("priming") circuitry in the brain, provides a stronger activation ("resonance") than input that does not. Information that is new, or that is different from, or in conflict with, the current (neural) frame of reference, does not enter properly and is therefore actually filtered away. Unknown or unfamiliar (patterns of) information or information that is incompatible with our expectations and internal representations of the world ("schemata") require new or adapted neural circuitry. Of course, this takes effort, which may usually be experienced as uneasy or unpleasant. As a result, much of the new information that is presented or available is not picked up or has little effect (and/or does not remain). Because this 'selection process' is so fundamental and literally ingrained in the inner workings of the brain, this leads to very persistent, unconscious and common biases, such as Selective perception and the Confirmation bias ("Mother of all biases"). In line with this, the brain strives for consistency, i.e., maintaining its present state. We avoid contradictions and stick to the status quo and the choices that we have previously made (default).

Finally, the compatibility principle also refers to the fact that nervous systems tend to adapt to continuous inputs or circumstances. Brains are therefore particularly sensitive to (relative) differences, to changes, and to contrasts (saturation, adaptation, homeostasis). This is especially relevant when we perceive changes or differences, when making comparisons, or when we value or assess the magnitude of things or when we evaluate qualities of items. In these cases, we tend to respond more strongly to discrete, saltatory changes (or differences) than to slow and gradual changes. When we evaluate or judge items, we tend to focus on *relative* differences and changes (contrasts) instead of *absolute* values. So we mostly evaluate items or situations by comparing them, instead of by assessing their absolute magnitude or value.

We distinguish three subcategories of biases that follow from the principles of compatibility: Selective perception, Consistency, and Adaptation. Each of these subcategories contain several biases as described below:

2.2.1 *Selective perception*

The brain collects and interprets information selectively based on compatibility with its current state (i.e. views, knowledge, expectations).

The following biases are related to selective perception:

- 1 **Confirmation bias:** the tendency to select, interpret, focus on and remember information in a way that confirms one's preconceptions, views, and expectations.
- 2 **Fluency effect:** the tendency to regard easily understandable information as plausible, important or true (cf. Familiarity bias).
- 3 **Frequency illusion:** information that has recently been attended to, seems to appear with improbable high frequency.

- 4 **Placebo effect** (Expectation bias): observed outcomes are partly determined by our expectations.
- 5 **Selective perception**: the tendency to perceive what we 'want to' (and/or expect to) perceive.

2.2.2 Consistency

The brain strives for consistency, i.e., maintaining its integrity, identity, and existence. We therefore prefer to avoid contradictions in our views and we persist in maintaining the present situation and previous (behavioral) choices. As such, we easily accept, prefer, or continue the current situation or status quo (default options).

The following biases are related to consistency:

- 1 **Acquiescence**: the tendency not to correct a detected 'thinking-error' or bias (e.g. Superstition), or to agree instead of disagree when in doubt ('yea-saying').
- 2 **Cognitive dissonance**: the tendency to search for and select consistent information in order to try to reduce discomfort when confronted with facts that contradict own choices, beliefs, and values.
- 3 **Conservatism** (belief perseverance): the tendency to insufficiently adapt one's own belief when new (and conflicting) evidence is revealed.
- 4 **Consistency bias**: the tendency to see one's own attitudes and behavior as more consistent than they are and to adapt memories about past ideas, opinions, choices, or attitudes to the current ones.
- 5 **Default effect**: the tendency to favor the option that would be obtained if the actor does nothing when given a choice between several options (cf. Fear for regret).
- 6 **Effort justification**: the tendency to attach more value to a result or product as more effort is made (cf. Sunk-cost fallacy; special case of Cognitive dissonance, House-money effect).
- 7 **Fear for regret**: feeling extra regret for a wrong decision if it deviates from the default (cf. Default effect, Omission bias).
- 8 **Motivation repression**: reduction of willingness to make a sacrifice for non-financial reasons (eg decency, pride, social duty etc.) by giving a financial reward (payment, bonus).
- 9 **Not invented here**: the tendency to reject ideas or products that have an external origin .
- 10 **Reactance**: a counter-reaction if one feels thwarted in his or her choices and/or if one feels 'pushed' in a certain direction (cf. Backfire effect, Continued influence).
- 11 **Semmelweis reflex**: tendency to reject new evidence or knowledge when it contradicts ones beliefs.
- 12 **Status Quo bias**: the tendency to maintain the current state of affairs.
- 13 **Sunk cost fallacy** (Irrational escalation, Concorde effect): the tendency to consistently continue a chosen course or investment with negative outcomes rather than alter it. What has already been invested at some point becomes a motive in itself to continue with it (cf. Cognitive dissonance).
- 14 **System justification**: the tendency to believe that the current or prevailing systems are fair and just, justifying the existing inaccuracies or inequalities within them (social, political, legal, organization, economics).

2.2.3 *Adaptation (Contrast)*

The brain adapts to continuous situations (homeostasis) and is (hyper-) sensitive to jump-like changes and differences (contrasts). We have difficulty with noticing gradual changes. Because of our sensitivity for relative differences, changes and contrast, we like to base our judgements and evaluations on relative comparison instead of absolute values.

The following biases are related to adaptation:

- 1 **Contrast effect:** having difficulty with perceiving and appreciating gradual changes (instead of leaps).
- 2 **Decoy effect** (Attraction effect, Asymmetric dominance effect): a potential preference for option A or B shifts to option B by introducing option C, when option C is clearly inferior (in all respects) to option B, but not clearly to option A.
- 3 **Distinction bias:** the tendency to see options as more different in simultaneous (instead of separate) evaluations.
- 4 **Hedonic adaptation**³: the tendency to quickly return to a relatively stable level of happiness despite major positive or negative life events.
- 5 **Weber-Fechner's law:** the tendency to perceive the difference between stimuli as proportional to the size of the initial stimuli. Having difficulty seeing small differences between large quantities.

2.3 **Retainment ('Cognitive anchor')**

Once received (irrelevant or counterproductive) information is anchored in the neural circuits of the brain, such that it cannot simply be 'erased', denied, undone or ignored. Having to 'remove' or ignore information once captured and integrated into neural circuitry takes effort, feels uncomfortable (loss), and/or is hardly possible.

The brain not only 'searches' for (relevant) information but also receives multiple irrelevant inputs through its senses. With a logical system, such as a computer program, such irrelevant information can easily be denied, excluded, or deleted. For example, irrelevant information can be set to "zero" in a calculation. As an associative neural network, the brain has much more difficulty with these kinds of negating operations. Everything that comes in is processed to a certain degree and affects the network ('Don't think of a pink elephant!'). This is the case because information in a nervous system is "embedded" in its physical-chemical structure (its wiring, or 'wetware'). In a wetware system, hardware and software are one. They are not independent of each other like in computers. Because of this integration of hard- and software, biological systems do not allow that software can be copied from one biological substrate to another. So, whatever has entered or has been activated cannot simply be (temporarily) discarded, deleted, or ignored. This principle applies more and more as the information is dominant, lively, or for whatever reason 'loaded' with emotions.

³ Also categorized under Individual self-interest.

The following biases underly the third principle of retainment:

- 1 **Anchoring bias:** Biasing decisions towards previously acquired information. In this way, the early arrival of irrelevant information can seriously affect the outcome.
- 2 **Context effect:** the tendency of cognition and memory to be highly dependent on context, for example 'cued recall'.
- 3 **Endowment effect:** the tendency to value or prefer objects that are already owned over those that are not. (cf. Loss aversion).
- 4 **Framing bias:** the tendency to base decisions on the way the information is presented (with positive or negative connotations), as opposed to just on the facts themselves.
- 5 **Halo effect:** One perceived (positive or negative) characteristic of a person or product determines the (subsequent) perception of characteristics in other areas.
- 6 **Hindsight bias:** the tendency to erroneously perceive events as inevitable or more likely once they have occurred.
- 7 **Moral luck:** the tendency to assign more or less moral value based on the (positive or negative) outcome of an event (cf. Outcome bias).
- 8 **Outcome bias:** the tendency to evaluate a decision based on its outcome rather than on what factors led to the decision (cf. Moral luck).
- 9 **Primacy effect:** the first information that is received has more impact (a larger weight) than the information received later. This works especially if judgments or decisions must be made immediately.
- 10 **Recency effect:** the last information received has more impact (a higher weight) than previously received information.
- 11 **Self-generation effect:** the tendency to remember information that is self-generated relatively well.
- 12 **Sleeper effect:** the tendency to remember the information (or message) itself better than (the credibility) of the underlying source.

2.4 Focus (Blind spot)

The brain associatively focuses on dominant information, i.e. 'known knowns' that easily pop up in the formation of judgments, ideas and decisions. The fact that there is other (possibly relevant) information ('unknowns') is insufficiently recognized ('blind spot'). This typically leads to somewhat one-sided and simplistic ways of judgement and decision making, conform Kahneman's principle: "What you see is all there is".

By the process of association, the brain 'searches' for patterns of information and integrates it in its associative structure. The impact of the information is determined by its activation characteristics, such as the amount of attention paid to it, the subjective impression made by something, how long ago something happened (retention, decay), or how often and how clear something occurred. These factors determine the amount of neural activity and with that, how many connections are activated and/or adjusted in the network. In addition, relevant information that is only weakly represented (memory) in the network has little impact on the outcome of a neural activation process. Finally, due to lateral inhibition, small differences in neural activation may be amplified. This means that weakly represented or activated information is further suppressed. As a result, there is a strong tendency to trust and focus on a limited set of consistent (correlated) information. If an idea or

thought clearly comes to mind (for whatever reason), it must be important! This attention works like a magnifying glass. At the same time, we have little regard for (random) factors that we do not see clearly and/or that can undermine the reliability of our judgments. We simply cannot be aware of things that we are not aware of (like a “Blind spot”). In addition, there appears little room in our brain for the meta-cognitive awareness of this blind spot and it takes effort to take this into consideration. We therefore focus on the known-knowns and tend to ignore the known-unknowns (and even more the unknown-unknowns).

This means that the brain is not a logical system that systematically and properly adds and weighs all information, and statistically accounts for everything it does not know. What is not, or weakly, represented or activated in the network also has little effect. In line with this, Kahneman (2011) formulated the principle : "What You See Is All There Is" (WYSIATI) as one of the most typical basic characteristic of human cognition. This principle has two consequences:

- 1 We tend to over-focus on certain (striking, familiar, well-known etc.) information, ignoring the rest (the unknowns).
- 2 We thereby tend to rely on a rather simplistic conception of reality; a one-sided, black-and-white perspective, without much ambiguity, and with simple and straightforward relationships.

We distinguish two subcategories of biases that follow from the fourth Focus principle: ‘cognitive nearsightedness’, and simplism. Each of these subcategories contain several biases as described below:

- 2.4.1 *Focus on known-knowns (‘cognitive nearsightedness’)*
We tend to trust and focus on what is clearly visible, activated, or (emotionally) charged, what we (accidentally) know or have experienced, what we understand and what thus easily comes to mind (associatively). In making decisions we tend to ignore information that does not clearly occur to us, that we do not see easily, and that we have not experienced. We also ignore easily the fact that there may be a lot that we do not know (The known- and unknown-unknowns).

The following biases are related to cognitive nearsightedness:

- 1 **Attention bias** (Attentional illusion, Gorilla-in-the-room effect). By concentrating our attention, we tend to ignore other important (and noticeable) information or (cf. Focalism, Focusing illusion).
- 2 **Automation bias**: the tendency to depend excessively on automated technological systems, not sufficiently acknowledging that this may exclude relevant aspects of an issue.
- 3 **Availability bias**: the tendency to judge the frequency, importance, or likelihood of an event by the ease with which relevant instances come to mind. (cf. Experience effect, Primacy- Recency- effect, Fluency-, Familiarity bias, Salience effect, Focusing illusion, Recency effect and Mere-exposure effect).
- 4 **Bias blind spot** the tendency to recognize biased reasoning in others, while failing to notice one's own biases.
- 5 **Blindness for alternatives**: the tendency to compare a new option A with the status quo (which is often the continuation of an existing situation, or the default), instead of with other possible good alternatives, B, C, D, E etc.

- 6 **Bloodletting effect:** The tendency to stick to proven wrong ideas, theories, and/or methods as long as no new or better alternative is available (cf. Ambiguity intolerance).
- 7 **Cherry picking** (Anecdotal evidence): the tendency to focus on positive results (and to present them as the previously intended goal), while ignoring or concealing goals that have not been achieved. Painting the target around the arrow (cf. Compare Feature-positive effect).
- 8 **Domain dependence:** The tendency to believe that knowledge and skills (e.g. creativity, flexibility, problem solving) in a certain area (e.g. writing, playing chess, furnishing a home, econometrics) are easily transferable to other areas (in truth, knowledge is largely based on associative pattern recognition and therefore domain-specific).
- 9 **Ego-centric bias:** the tendency to rely too heavily on one's own point of view and to fail to consider situations from other people's perspectives (cf. Ego-centric memory bias).
- 10 **Ego-centric memory bias:** the tendency to see a personal contribution (responsibility) to the result of a joint effort as greater than objectively (from the point of view of a third party) is justified (cf. Ego-centric bias).
- 11 **Experience bias:** the tendency to believe and remember things easier when they are experienced directly with our physical body and senses (or concrete pictures) instead of abstract representations (tables and statistics).
- 12 **Familiarity bias:** (Illusion of truth, recognition bias): the tendency to favor familiar items over unfamiliar ones with regard to aspects like plausibility or importance (cf. Fluency effect, Availability bias).
- 13 **Feature-positive effect:** The tendency to base a judgment too much on characteristics, aspects or elements that are presented instead of also taking into consideration other relevant information. (cf. Compare Forer effect, Cherry picking).
- 14 **Forer effect:** the tendency to attach value and belief to descriptions of own characteristics (personality) that are actually vague and apply to a wide range of people (such as with horoscopes).
- 15 **Focalism:** the tendency to focus strongly on one dominant aspect of a situation. This can be an initial piece of information (cf. Anchoring bias, Primacy effect) or a focus on one striking aspect of the information (cf. Salience effect, Focusing illusion).
- 16 **Focusing illusion:** the tendency to put too much emphasis on one or a limited number of aspects of an event or situation when estimating the utility of a future outcome (cf. Focalism, Salience effect).
- 17 **Knowledge illusion** (Illusion of understanding, Dunning-Kruger Effect) ⁴: the tendency in laymen to over-estimate their own competence.
- 18 **Law of the instrument** (Professional deformation, The-man-with-the-hammer effect): the tendency to overvalue a known tool or method and to ignore alternatives to it. "If your only tool is a hammer, then every problem is a nail".
- 19 **Neomania:** the tendency to overestimate the role or importance of new things (e.g., technology) for the future (cf. Availability bias).
- 20 **Omission bias:** the tendency to favor an 'error of omission' over an 'error of commission'.

⁴ Also categorized under Simplism and Self-overestimation and optimism.

- 21 **Outgroup homogeneity bias**: the tendency to better recognize the differences between the members of the own group than those between the members of other groups (cf. Stereotyping).
- 22 **Overconfidence effect**⁵ (prognosis illusion): the tendency to overestimate our chances of success when making estimates.
- 23 **Planning fallacy**⁶: the tendency to underestimate the effort/time required to complete a task (e.g. by not taking the unknowns into consideration).
- 24 **Reification**: the tendency to consider a concept or idea as more real and plausible if it gets a name, no matter how vague or unclear it may be.
- 25 **Salience effect**: the tendency to pay much attention and attach much importance to salient or striking details, for example, when coming up with causes or explanations for an event (cf. Focalism, Focusing illusion).
- 26 **Survivorship bias**: the tendency to focus on the elements that survived a selection process, while overlooking those that were eliminated. Since success is usually more visible than failure, the chance of success may be overestimated.

2.4.2 *Simplism*

We tend to see the world too simplistic in terms of black and white, with simple straightforward relationships, and without too many contradictions, nuances, and ambiguity.

The following biases are related to simplism:

- 1 **Actor-observer bias**: the tendency to overestimate the influence of personality and to underestimate the importance of situational factors when explaining behaviors of other people, while doing the opposite for one's own behavior (cf. Fundamental attribution error, Ultimate attribution error).
- 2 **Asymmetrical insight illusion**: the tendency to estimate your own personal insight about others higher than that of others about yourself.
- 3 **Belief bias**: the tendency to base the power or relevance of an idea on the credibility of the conclusion instead of on the argument.
- 4 **Curse of knowledge**: having difficulty in taking the perspective of people who are less well educated or informed on a subject.
- 5 **Defensive attribution bias**: the tendency to attribute less blame or responsibility to a harm-doer as you recognize more personal or situational similarity between yourself and the harm-doer.
- 6 **End of history bias**: the tendency to underestimate future changes for your own life (cf. Projection bias).
- 7 **Fundamental attribution error**: the tendency to overestimate the influence of personality, while underestimating the importance of situational factors when explaining events or behaviors of other people (cf. Actor-observer bias, Ultimate attribution error).
- 8 **Group attribution error**: the tendency to project characteristics of a group member onto the group and vice versa (cf. Fundamental attribution error).
- 9 **Introspection illusion**: the tendency to believe that truth or correctness will be encountered when we consult ourselves. When people disagree we see the other as the one who lacks knowledge, lacks intelligence, or lacks ethics.
- 10 **Just world hypothesis**: the tendency to attribute injustice that is hard to explain (bad luck) as the fault of victims (cf. Control illusion, Fundamental attribution error, Actor-observer bias, Defensive attribution bias).

⁵ Also categorized under Self overestimation and optimism.

⁶ Also categorized under Self overestimation and optimism.

- 11 **Knowledge illusion**⁷ (Illusion of understanding, Dunning-Kruger Effect): the tendency in laymen to over-estimate own competence.
- 12 **Motivation justification**: the tendency to become benevolent and accommodating just by the fact that a reason is given for a behavioral request, without taking into consideration the meaningfulness or relevance of this reason.
- 13 **Surrogation (means-goal)**: the tendency to concentrate on the an intervening process instead of on the final objective or result, e.g. concentrating on means vs goals or on measures vs intended objectives (perverse incentives).
- 14 **Naive realism**: the belief that we see reality as it really is objectively and without prejudice; that the facts are clear to everyone; that rational people agree with us; and that those who do not do so are not informed, lazy, irrational or biased.
- 15 **Peak-end rule**: the tendency to evaluate experiences on the basis of their most extreme moment (the peak experience) and how it was like at the end, while not including the duration of the different parts of the experience in relation to its total duration.
- 16 **Priority heuristic**: the tendency to base decisions on only one dominant piece of information.
- 17 **Projection bias**: the tendency to overestimate the extent to which we think our future selves will remain the same and share our current thoughts, beliefs, values, and preferences (cf. End of history bias).
- 18 **Proportionality bias**: the tendency believe that big and influential things must have big causes.
- 19 **Single cause fallacy**: the tendency to believe that cases or events have one single deeper reason or underlying cause.
- 20 **Trait ascription bias**: the tendency to see yourself as more flexible and variable in terms of personality, behavior and moods and others as more predictable.
- 21 **Transparency illusion**: the tendency to overestimate person insight of others over yourself and that of yourself over others.
- 22 **Ultimate attribution error**: the tendency to attribute positive outgroup behaviors to external causes and negative outgroup behaviors to dispositional factors (fixed group traits), while doing the opposite for explaining in-group behaviors (cf. Fundamental attribution error, Actor-observer bias).

⁷ Also categorized under Focus on known-knowns and Self-overestimation and optimism.

3 Evolutionary biases

The evolutionary view provides a simple and consistent explanation for a number of cognitive biases that are difficult to explain from the inherent characteristics of neural networks. The core of these evolutionary biases is formed by genetically transmitted behavioral characteristics or capacities of our ancestors that worked out positively for them in their struggle for existence. We tend to use survival principles that were adaptive in the living conditions of our hunter-gatherer ancestors. This means that our ability to reason rationally and objectively is drowned out by our primordial instincts that are focused on surviving and transferring our own genes. For example, our reasoning is not primarily focused around truth, correctness, or honesty. More important is what (pragmatically and in terms of safety and security) is best for oneself with regard to survival and genetic reproduction as a hunter-gatherer.

We distinguish four main principles that follow from our evolutionary nature; individual self-interest, herd thinking, statistical blindness, and self-overestimation & optimism. These evolutionary principles define four categories of cognitive biases that will be described below.

3.1 Individual self-interest

For the sake of genetic reproduction, human behavior is basically aimed at maintaining the integrity and survival of the own organism. This is often expressed in a need to maintain or strengthen the current situation or condition of the individual. So, humans tend to prioritize personal interests relative to those of others.

Natural selection is the replication of one's genes, which often comes at the expense of the survival of others' genes. It has favored humans who prioritize their personal interests over collective interests⁸. Research on social dilemmas has also indicated that we prioritize self-interest by demonstrating that most individuals make selfish choices when they interact with other people in one-shot encounters. All organisms need to be aware of possible threats and need to avoid and protect themselves from physical harm. This self-preservation is a very basic emotional category, i.e., maintaining the own physical integrity in order to survive and reproduce. Cognitive processes are strongly intertwined with emotional processes that are aimed at avoiding danger and risk (fear) and at the elimination of threat (flight, fight). For this ultimate goal of (physical) survival *per se* it is always important to focus on obtaining other instrumental (lower-order) goals and positive outcomes for oneself. So we strive for all possible capacities and resources that may contribute to these ultimate goals of survival and reproduction, e.g., social and political power. Other behavioral characteristics contributing to these instrumental goals are: cautiousness (avoiding danger and loss), continuously striving for more, and quick fading satisfaction once a goal has been obtained.

⁸ Self-interest may also benefit (indirectly) from pro-social behavior, supporting the group and ones position in the group (See also Herd thinking).

The following biases are related to individual self-interest:

- 1 **Anthropocentrism**: the tendency to take the human perspective as the starting point for interpreting and reasoning about all sorts of things.
- 2 **Action bias**: the tendency to prefer action even when there is no rational justification to deviate from the default option of no-action.
- 3 **Affective forecasting** (Hedonic forecasting, Impact bias): overestimating the duration and intensity of our future emotions and feelings regarding events, encouraging putting effort into favorable results (greed) and into avoiding threats (cf. Hedonic adaptation, Hedonic treadmill).
- 4 **Hedonic adaptation**⁹: the tendency to quickly return to a relatively stable level of happiness despite major positive or negative life events (cf. Affective forecasting, Hedonic treadmill).
- 5 **Hedonic treadmill** (Greed): the tendency to exaggerate expected favorable results of one's efforts (cf. Affective forecasting, Hedonic adaptation).
- 6 **Hyperbolic (time) discounting** (Short-term thinking, Time inconsistency): the tendency to prefer a smaller reward that arrives sooner over a larger reward that arrives later, which, for instance, may result in having difficulty withholding the temptation of immediate reward in order to get a larger reward later (cf. Procrastination, Present bias, Current moment bias).
- 7 **Incentive super response**: the tendency to respond to incentives in a way that best serves our own interests and that does not align with the goal or idea behind the incentives, which may lead to 'perverse behaviors' (when incentive and purpose don't match).
- 8 **Intentional stance**: the tendency to suspect a deliberate intention behind every important change (a basis for 'conspiracy thinking').
- 9 **Loss aversion**: the tendency to prefer avoiding losses to acquiring equivalent gains. Loss counts heavier (emotionally) than a profit of the same size (cf. Endowment effect).
- 10 **News bias** ('Information obesity'): the tendency to pay attention to new information (news) that is not or hardly relevant.
- 11 **Present (moment) bias**: the tendency to attach relatively much importance to, and have an eye for, the present in relation to future (or past) issues (cf. hyperbolic time discounting and Procrastination).
- 12 **Procrastination**: the tendency to postpone unpleasant, but important, actions (cf. hyperbolic time discounting; present bias; current moment bias).
- 13 **Scarcity bias**: the tendency to attribute greater subjective value to items that are more difficult to acquire or in greater demand.
- 14 **Social comparison bias** (Envy): the tendency to dislike or feel competitive towards peers who are seen as physically or mentally better than oneself, especially when they resemble us in terms of lifestyle, age, social background, etc. ('neighbors').
- 15 **Social loafing**: if individual performance is not immediately visible and merges with that of the collective, the performance (motivation) decreases ("diffusion of responsibility").
- 16 **Tragedy of the commons** (Selfishness and self-interest): the tendency to prioritize one's own interests over the common good of the community.

⁹ Also categorized under Adaptation.

3.2 Herd thinking

Humans aim at the survival of their own group and on their own strong position within that group. This means that they have to align their collective thinking and behavior without centralized direction. This is accomplished by being kind and polite, moving along with the majority, copying other people's behavior, being susceptible to status and authority, aversion to strangers, and paying back favors.

People have had an evolutionary advantage in belonging to well-functioning groups that are in many ways stronger than the individual. In line with this, psychologists have clearly demonstrated that we are sensitive to all kinds of peer behavior and peer influence. We tend to copy what others are doing and to conform to group standards, norms, and behavior. Imitation and following the majority are shown to be common strategies in any group living species. This may be so because the costs of individual learning, through trial and error, are substantial. Also, in ancestral environments with high levels of uncertainty it would pay to follow what others were doing rather than to find out things for oneself. This is therefore probably an ancient and natural adaptive tendency which may help to maintain or strengthen our position within the social group. We thus easily adapt to people around us with which we feel connected and we follow leaders in groups. This can lead, for example, to the blind copying of the behavior of others and to the faithful following of persuasive and charismatic others.

The following biases are related to herd thinking:

- 1 **Affinity bias:** The tendency to be biased toward people like ourselves (cf. Ingroup bias, Xenophobia).
- 2 **Authority bias:** the tendency to attribute greater accuracy to the opinion of an authority figure (unrelated to its content) and to be more influenced by that opinion.
- 3 **Bandwagon effect:** the tendency to adopt beliefs and behaviors more readily when they have already been adopted by others.
- 4 **Conformity bias:** the tendency to adjust one's thinking and behavior to that of a group standard.
- 5 **Courtesy bias** (social desirability bias): the tendency to express yourself more socially desirable or politically correct than your true belief.
- 6 **False consensus bias:** the tendency to overestimate the extent to which others agree with us, or have the same views and beliefs. (cf. shared information bias).
- 7 **Groupthink:** the practice of thinking or making decisions as a group, resulting typically in unchallenged, poor-quality decision-making.
- 8 **Herd behavior:** the alignment of thinking and behavior of individuals in a group without centralized direction.
- 9 **Identifiable victim bias** (personification): the tendency to expend greater resources to a specific, identifiable person ('victim') than to a large, vaguely defined group with the same need.
- 10 **Ingroup (-outgroup) bias:** the tendency to favor one's own group above that of others (cf. Affinity bias, Xenophobia).
- 11 **Liking bias:** the tendency to help or support another person the more sympathetic you feel towards this person based on his/her kindness, attractiveness and affinity/similarity (cf. Affinity bias).

- 12 **Reciprocity**: the tendency to respond to a positive action with another positive action ("You help me, I help you") and having difficulty being indebted to the other person.
- 13 **Shared information bias**: the tendency to spend relatively much time and energy on dealing (talking about) with shared knowledge (cf. false consensus bias).
- 14 **Social proof**: the tendency to mirror or copy the actions and opinions of others, causing (groups of) people to converge too quickly upon a single distinct choice (cf. Bandwagon effect, Conformity bias).
- 15 **Tabooization**: the implicit prohibition of an expression or behavior based on a cultural feeling that it is either too disgusting or too sacred for ordinary people ('Elephant in the room').
- 16 **Xenophobia** (Hostile attribution bias): harboring fear or distrust towards strangers or strangers. To regard the behavior of others too quickly as hostile (cf. Affinity bias, Ingroup bias).

3.3 Statistical blindness

Humans have poor capacities for logical reasoning and calculation and a poor intuitive sense for coincidence, randomness, statistics, and probability reasoning.

In the primeval times, dangers and opportunities were clear and real. There was no evolutionary advantage in being able to make estimates based on available quantitative data. In line with this ordinary people (as opposed to experts in a certain domain) have marginally evolved cognitive capacities for calculus and logical reasoning and our intuitions for randomness, probability and statistics are poor. This has resulted in various tendencies to draw erroneous conclusions on the basis of poor probabilistic and logical reasoning. The amount of cognitive information that our brain can consciously process (our 'working memory') is very limited. Of the approximately 10 million bits of sensory information that our brain receives every second, only about 10-50 bits can be processed consciously. Most tasks involving probabilistic and logical reasoning also require our full attention and we usually need a lot of time to execute them correctly and accurately. Despite this fact, we have to draw inferences and build conclusions from complex, incomplete, or inconsistent (often numerical and probabilistic) data. Instead of logically accounting for this fact by adjusting the confidence of our judgements downward, we are typically oversensitive to the *consistency* of the (limited) information we have, while being rather insensitive to possible random effects.

The following biases are related to statistical blindness:

- 1 **Ambiguity intolerance**: The tendency to avoid or ignore ambiguous, uncertain, unknown options, i.e. options for which the probability of success / failure is unknown. For this reason, we may stick to proven wrong methods.
- 2 **Chance neglect**: the tendency to ignore opportunities in an uncertain situation. This can result in attaching too much importance to large, striking, emotionally charged events or effects (cf. Availability bias) in combination with ignoring their improbability.
- 3 **Distribution blindness**: the tendency to think in terms of averages for uneven (skew) distributions. "Don't cross a river if it is four feet deep on average".

- 4 **Regression to the mean:** the tendency of not realizing that many outcomes are strongly determined by unknown, random and fluctuating factors. So, when, after an intervention in response to an extreme situation, subsequent situations statistically tend to move in the direction of the average, this change is mistakenly attributed to the intervention.
- 5 **Regressive bias:** the tendency to overestimate high chances and to underestimate small chances (especially if they are cumulative).
- 6 **Sub-sensitivity effect:** the tendency to estimate the probability of the whole smaller than the added (small) probabilities of the parts.
- 7 **Superstition¹⁰:** the tendency to explain chance by the operation of hidden supernatural phenomena (Gods, clairvoyance, fate, karma, miracles).
- 8 **Swimmer body illusion** (Intention-to-threat fallacy): the tendency to confuse selection effects with results. That is, not taking into consideration initial differences between samples to be compared.
- 9 **Tail-risk blindness:** the tendency to ignore possible rare events at the edges of a statistical distribution that often carry the greatest consequences, yet are also the most unpredictable. These “Black Swans” are big events that have never happened before and cannot be predicted, but still need our attention because the potential consequences may be huge.
- 10 **Zero-risk bias:** the tendency to assess a probability reduction to 0% as more valuable than an equal or greater probability reduction to a value above zero.

3.4 Self-overestimation and optimism

Humans generally (but not always) tend to have an optimistic attitude and self-image. They tend to overestimate the degree of control they have and the chance of pleasing results while underestimating the likelihood of negative outcomes or events. Optimism may also be a consequence of our neural tendency to focus on known-knowns.

Our sense of optimism may have its roots in the related evolutionary benefits. Ancestors who believed they were in control and who could successfully strive for favorable outcomes in their lives may have been more successful in passing on their genes than those who had a more *laissez-faire* attitude. This tendency towards optimism is even reported in non-human animals such as rats and birds.

The following biases are related to self-overestimation and optimism:

- 1 **Better-than-average effect:** the tendency to consider oneself “above average” in positive qualities or skills (cf. Illusion of superiority).
- 2 **Choice supporting bias** the tendency to consider one's choices as more favorable, or better informed, than they actually were.
- 3 **Control illusion¹¹:** the tendency to believe that you can control, or influence, things over which there is objectively no power. This is related to having difficulty seeing chance as something autonomous and independent (cf. Superstition) or to see causal relations in correlated events (cf. Spurious causation).

¹⁰ Also categorized under Association.

¹¹ Also categorized under Association.

- 4 **Illusion of superiority**: the tendency to overestimate one's own positive qualities with respect to others and to underestimate those of others compared to yours (cf. Better better-than-average effect).
- 5 **Knowledge illusion** (illusion of understanding, Dunning-Kruger Effect)¹²: the tendency in laymen to over-estimate their own competence.
- 6 **Optimism bias** (Positive outcome bias, Wishful thinking): the tendency to overestimate the probability of positive events and to underestimate the probability of negative events.
- 7 **Overconfidence effect**¹³: the tendency to overestimate our chances of success when making estimates (cf. prognosis illusion).
- 8 **Planning fallacy**¹⁴: the tendency to underestimate the effort/time required to complete a task (e.g. by not taking the unknowns into consideration).
- 9 **Prognosis illusion**: the tendency to overestimate our forecasting abilities when making predictions (cf. Overconfidence effect).
- 10 **Self-serving bias**: the tendency to attribute success to ourselves and failures to circumstances.
- 11 **Self-control bias**: the tendency to overestimate our self-control or control during a temptation.
- 12 **Ostrich effect** (Ostrich policy): the tendency to ignore negative, unwelcome, information.
- 13 **(Pro-) Innovation bias**: the tendency to see and overvalue only the (positive) utility aspects of a renewal, and not to recognize (possible) limitations.

¹² Also categorized under Focus on known-knowns.

¹³ Also categorized under Focus on known-knowns.

¹⁴ Also categorized under Focus on known-knowns.

4 Epilogue

Cognitive biases may form impediments to acting wisely, hampering the adequate realization of the ultimate goal of wellbeing that people should set for themselves. Scientific literature shows that we are only at the beginning of developing an approach and tools for mitigating and handling cognitive biases. Such a methodology can only be developed if we thoroughly understand the underlying working mechanisms of action. The present neuro-evolutionary framework which is based on actual cognitive neuroscience and evolutionary psychology may provide a firm basis for innovations focusing on how to improve and provide methods and tools for policy making, steering towards human wellbeing.

5 Key references

In order to facilitate the readability and comprehensibility we have not provided the scientific references in the text of this memorandum. These references can be found in a TNO report and two publications, that have been written to ground the present bias framework (Korteling, Brouwer & Toet, 2018; Korteling, Sassen-van Meer & Toet, 2020; Korteling & Toet 2020). Below, we provide some more overall relevant references.

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