Everything from investment fiascos to medical error has been linked to 'contaminated mindware'. Facing up to it is the first step towards better decisions.

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# CONTAMINATED MINDWARE: THINKING BIASES OF THE COGNITIVE MISER

By Keith Stanovich, Maggie Toplak and Richard West

**RESEARCH IN COGNITIVE PSYCHOLOGY** and the relatively new field of NeuroEconomics consistently demonstrates that people violate the strictures of rationality on a regular basis. Pioneered by the seminal work of Nobel Laureate **Daniel Kahneman** and **Amos Tversky**, this literature has generated a lengthy list of irrational behaviours to which many of us are subject on any given day, whether we like to admit it or not.

These well-documented violations of rationality have, in turn, spawned a list of biases that can be used to define 'rational thinking'. That is, we can assess degrees of rational thinking in terms of the number and severity of cognitive biases that an individual displays. In this article we will describe some of the most common biases that challenge rational thinking, with the hope that a better understanding of them will foster more bias-free decision making.

## Dual-Process Theory: Type 1 vs. Type 2

Our mental functioning is characterized by two types of cognition: 'Type 1' and 'Type 2' processing. The defining feature of Type 1 processing is its autonomy. Type 1 processes are termed autonomous because: their execution is rapid; their execution is mandatory when the triggering stimuli are encountered; they do not require conscious attention; they do not depend on input from high-level control systems; and they can operate in parallel without interfering with each other or with Type 2 processing.

We often make the easiest (incorrect) inference from the information given and do not proceed with the more difficult (but correct) inference that would follow from considering all of the possibilities.

Type 1 processing includes the automatic firing of over-learned associations, behavioural regulation by the emotions and processes of implicit learning. In contrast, Type 2 processing is relatively slow and computationally 'expensive', making it the focus of our awareness when it occurs. While many Type 1 processes can operate at once in parallel, only one (or very few) Type 2 thoughts can be executing at once.

One of the most critical functions of Type 2 processing is to 'override' automatic Type 1 reactions. To accomplish this, Type 2 processing must interrupt Type 1 processing and suppress its response tendencies. However, this only gets the job half done: suppressing one response is not helpful unless a better response is available to substitute for it. Where do better responses come from? They come from two unique aspects of Type 2 processing: the processes of *hypothetical reasoning* and *cognitive simulation*.

When we reason hypothetically, we create a temporary 'model of the world' and test out actions (or alternative causes) in that simulated world. In order to reason hypothetically we must possess a critical cognitive capability: the ability to distinguish our representations of the real world from representations of imaginary situations. For example, when considering an alternative goal state that is different from the one we currently hold, we must be able to represent our current goal and the alternative goal and to keep straight which is which. Likewise, we need to be able to differentiate the representation of an action about to be taken from representations of potential *alternative* actions that we are considering; but the latter must not infect the former while the mental simulation is being carried out.

Researchers have modeled this by positing a so-called 'secondary representation' that is a copy of the primary representation but is 'decoupled' from the world so that it can be manipulated; that is, it becomes a mechanism for simulation. Decoupling secondary representations from the world and maintaining the decoupling while performing a simulation is a Type 2 processing operation that is computationally-taxing. However, such decoupling must take place when an individual engages in a simulation of alternative worlds in order to solve a problem.

Following is an example of a situation that requires a decoupled simulation: Jack is looking at Anne but Anne is looking at George. Jack is married but George is not. Is a married person looking at an unmarried person?

**A)** Yes **B)** No **C)** Cannot be determined

The vast majority of people choose C, when in fact the correct answer is A. To answer correctly, both possibilities for Anne's marital status (married and unmarried) must be considered to determine whether a conclusion can be drawn. If Anne is married, then the answer is Yes because she would be looking at George who is unmarried. If Anne is not married, then the answer is still Yes because Jack, who is married, would be looking at Anne. Considering all the possibilities reveals that a married person is looking at an unmarried person whether Anne is married or not. However, the fact that the problem does not *reveal* whether Anne is married suggests to people that nothing can be determined.

In short, we often make the easiest (often incorrect) inference from the information given and do not proceed with the more difficult (but correct) inference that would follow from considering all of the possibilities – what we call 'fully-disjunctive reasoning'.

## Serial Associative Cognition

All hypothetical thinking involves Type 2 processing, but not all Type 2 processing involves hypothetical thinking. 'Serial associative cognition' represents this latter category. This term can be understood by considering a discussion of a four-card selection task, whereby the participant is told the following:

"Each of the squares below represents a card lying on a table. Each one of the cards has a letter on one side and a number on the other side. If a card has a vowel on its letter side, then it has an even number on its number side. As you can see, two of the cards are letter-side up, and two of the cards are number-side up. Your task is to decide which card or cards must be turned over in order to find out whether the rule is true or false. Indicate which cards must be turned over."

The participant chooses from four representations of cards labelled K, A, 8, 5 (corresponding to not-X, X, Y, and not-Y). The correct answer is to pick the A and the 5 (X and not-Y), but the most common answer is to pick the A and 8 (X and Y) – the so-called 'matching response'. The 'matching bias' evident in this task has led some investigators to infer that the analytic system is not actively engaged in this task. However, Type 2 processing does occur here: not full-blown cognitive simulation of alternative world models, but thinking of a shallower type, known as 'serial associative cognition'.

Serial associative cognition is locked into an associative mode that takes as its starting point a model of the world that is *given* to the subject. That is, people accept a stated rule as given, assume it

is true, and reason from this single focal model – systematically generating associations from it, but never constructing another model of the situation. The central characteristic of serial associative cognition, then, is that it displays a *focal bias*.

Focal bias hearkens back to the idea that humans are 'cognitive misers'. There are two aspects to such miserliness. First, a tendency to default to Type 1 processing whenever possible. However, defaulting to Type 1 processing is not always possible – particularly in novel situations. In such cases, Type 2 processing will be necessary, but a cognitive miser default operates even in this scenario: Rule two of the cognitive miser is that when Type 1 processing does not yield a solution, the miser will default to serial associative cognition with a focal bias.

The notion of focal bias conjoins similar ideas in the literature under the overarching theme that they have in common: that we will find any way we can to ease our cognitive load and process less information. As a result, the focal model that dominates is usually the most easily-constructed one. It accepts what is directly presented and models what is presented as 'true'; it ignores moderating factors – because taking account of those factors would necessitate modeling several alternative worlds, and this is what cognitive misers seek to avoid. As documented in the voluminous literature on 'belief bias' and 'my-side bias', the easiest models to represent are those closest to what a person already believes and has modeled previously. 'Framing effects', for instance, are a clear example of serial associative cognition with a focal bias. As Kahneman has noted, "the basic principle of framing is the passive acceptance of the formulation given."

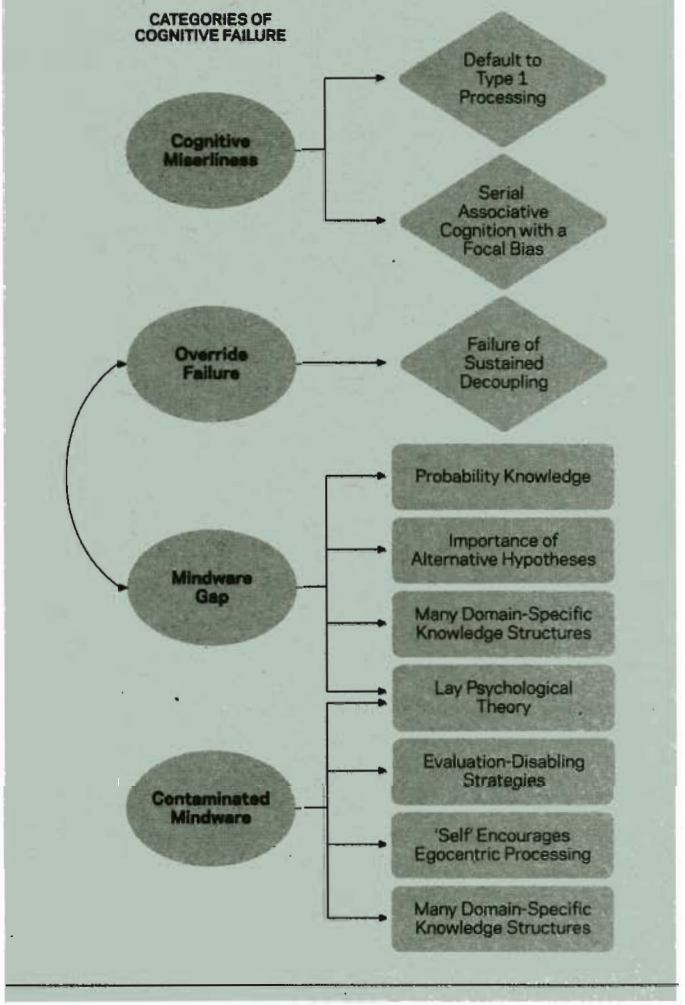
One aspect of Dual Process Theory that has been neglected is that the override process of Type 1 by Type 2 is not simply procedural: it also utilizes content. The knowledge bases that are brought to bear on Type 2 processing include not only an individual's knowledge structures but, importantly, her opinions, beliefs and personal goal structure. Likewise, Type 1 processing implicates not only encapsulated knowledge bases from evolutionary adaptations, but also information that has become available due to repetition and practice. Together, these two elements of an individual's knowledge base form her 'mindware' – the collected rules, procedures, and strategies that she can retrieve and put to work in solving problems.

Mindware problems can cause irrational thinking in two ways: via 'mindware gaps' and 'contaminated mindware'. When an override of Type 1 processing is necessary but the mindware necessary for a substitute response is not available, this represents a mindware gap. The second problem area draws attention to the fact that not all mindware is helpful – either to goal attainment or to epistemic accuracy. In fact, acquired mindware can be the direct cause of irrational actions that thwart our goals.

## A Taxonomy of Reasoning Problems

**Figure One** presents an initial attempt at a classification of common rational thinking problems. The characteristic presented first is 'defaulting to the response options primed by Type 1 processing'.

**A Preliminary Taxonomy of Thinking Errors** Figure One




This represents the shallowest kind of processing, because no Type 2 processing occurs at all. The second processing tendency of the cognitive miser is to engage in 'serial associative cognition with a focal bias,' and the third category is that of 'override failure'. Here, unlike in the first two cases, Type 2 cognitive decoupling is engaged; inhibitory Type 2 processes try to take the Type 1 processing 'offline', but they fail.

Next in Figure One are the two categories of cognitive failure that are related to mindware problems. Mindware gaps can occur in a variety of relevant domains such as probabilistic reasoning, causal reasoning, logic and scientific thinking. The two represented here are categories that have been implicated in research in the heuristics and biases tradition: missing knowledge about probability and probabilistic reasoning strategies; and ignoring alternative hypotheses during the evaluation process.

At the bottom of **Figure One** is the category of 'contaminated mindware'. First is a sub-category of contaminated mindware that is much discussed in the literature: mindware that contains evaluation-disabling properties. These include:

- the promise of punishment if the mindware is questioned;
- the promise of rewards for unquestioning faith in the mindware; or
- the thwarting of evaluation attempts by rendering the mindware unfalsifiable.

An important sub-category of contaminated mindware is a concept of 'self' that encourages egocentric thinking. The self is a mechanism that fosters one characteristic of focal bias: that we tend to build models of the world from a single 'my-side' perspective. My-side processing makes difficult such modern demands as unbiasedness and discouragement of racial and religious discrimination. The last subcategory of contaminated mindware is meant to represent what is actually a whole set of categories: mindware representing specific categories of information or culturally-conditioned beliefs. As with the mindware-gap category, this may entail a large number of misinformation-filled or contaminated mindware that supports irrational thought and behaviour.

In terms of their prevalence, following are the most common heuristics and biases to watch out for:

**1. Defaulting to the most-vivid stimulus**

This is a common way for cognitive misers to avoid Type 2 processing and is often used in situations with emotional salience. The classic **Volvo** versus **Saab** scenario provides an example. In this problem, a couple is deciding to buy one of two otherwise equal cars. Consumer surveys, statistics on repair records and polls of experts favour the Volvo over the Saab. However, a friend reports experiencing a severe mechanical problem with the Volvo he owns. The participant is asked to provide advice to the couple. Preference for the Volvo indicates a tendency to rely on the large-sample information in spite of salient personal testimony. A preference for the Saab indicates reliance on the personal testimony over the opinion of experts and the large-sample information.

**2. My-side processing**

Excessive my-side thinking is fostered by contaminated mindware: our notion of 'self' makes us egocentrically think that the world revolves around ourselves. But a form of focal bias may be contributing to this error as well – the bias to base processing on the mental model that is the easiest to construct. What easier model is there to construct than a model based on our own previous beliefs and experiences? Such a focal bias is different from the egocentric mindware of the self. The focal bias is not egocentric in the motivational sense that we want to build our self esteem or sense of self worth; it is simply concerned with conserving computational capacity and it does so in most cases by encouraging reliance on a model from a my-side perspective. Both motivationally-driven 'self' mindware and computationally-driven focal biases contribute to my-side processing, making it a multiply-determined bias.

**3. Belief Bias**

Consider the following:

Premise 1: All living things need water
Premise 2: Roses need water
Therefore, roses are living things
Task: judge the conclusion as either logically valid or invalid.

To the surprise of many people given this problem, the conclusion is invalid. Premise 1 says that all living things need water, not that all things that need water are living things. So, just because roses need water, it does not follow from Premise 1 that they are living things.

However, consider the following syllogism with exactly the same structure:

Premise 1: All insects need oxygen
Premise 2: Mice need oxygen
Therefore, Mice are insects
Task: judge the conclusion as either logically valid or invalid.

Here, it is not hard to see that the conclusion is invalid. In both problems, prior knowledge about the nature of the world (that roses are living things and that mice are not insects) is becoming implicated in a type of judgment that is supposed to be independent of content: judgments of logical validity. In the rose problem, prior knowledge was interfering, while in the mice problem, it was facilitative.

**4. Mindware Gaps**

Mindware gaps are common in the domain of probability knowledge and judgment, where many notable heuristics and biases cluster. For example, *conjunction effects* represent rational thinking errors that arise because of mindware gaps in the domain of probability. Consider another problem that is famous in the literature of Cognitive Psychology – the so-called 'Linda problem':

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. Please rank the following statements by their probability, using 1 for the most probable and 8 for the least probable.

a. Linda is a teacher in an elementary school
b. Linda works in a bookstore and takes Yoga classes
c. Linda is active in the feminist movement
d. Linda is a psychiatric social worker
e. Linda is a member of the League of Women Voters

**A Basic Taxonomy of Thinking Errors** Figure Two

| | THE COGNITIVE MISER | | OVERRIDE FAILURE | MINDWARE GAPS (MG) | | CONTAMINATED MINDWARE (CM) | | MG & CM |
|---|---|---|---|---|---|---|---|---|
| **TASKS, EFFECTS, AND PROCESSING STYLES** | Default to Type 1 Processing | Focal Bias | Failure of Sustained Decoupling | Probability Knowledge | Alternative Thinking | Evaluation Disabling Strategies | Self and Egocentric Processing | Lay Psychological Theory |
| Vividness effects | ✖ | | | | | | | |
| Affect substitution | ✖ | | | | | | | |
| Impulsively associative thinking | ✖ | | | | | | | |
| Framing effects | | ✖ | | | | | | |
| Denominator neglect | | | ✖ | | | | | |
| Belief bias | | | ✖ | | | | | |
| Self-control problems | | | ✖ | | | | | |
| Conjunction errors | | | | ✖ | | | | |
| Non-causal baserates | | | | ✖ | | | | |
| Bias blind spot | | | | | | | | ✖ |
| My-side processing | | ✖ | | | | | ✖ | |
| Affective forecasting errors | | ✖ | | | | | | ✖ |
| Confirmation bias | | ✖ | | | ✖ | ✖ | | |

f. Linda is a bank teller
g. Linda is an insurance salesperson
h. Linda is a bank teller and is active in the feminist movement

Most people make what is called a 'conjunction error' on this problem: because alternative h (Linda is a bank teller and is active in the feminist movement) is the conjunction of alternatives c and f, the probability of h cannot be higher than that of either c (Linda is active in the feminist movement) or f (Linda is a bank teller). All feminist bank tellers are also bank tellers, so h cannot be more probable than f – yet often over 80 per cent of people in studies rate alternative h as more probable than f.

## In closing

Our classification of cognitive biases is by no means exhaustive, but it does provide a framework for many of the major classes of thinking errors that make people less than rational.

An important finding from our research has been that most of the thinking errors we have discussed are very imperfectly correlated with intelligence – meaning that IQ tests fail to capture individual differences in rational thought. It is important to realize that the thinking errors made in all domains are more related to rationality than they are to intelligence. On the bright side, they are also the types of thinking errors that would be reduced if schools, businesses and government focused on the aspects of cognition that intelligence tests miss. ***R***



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