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Blended Cognition

The Robotic Challenge

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Preface

Introduction: Blended Cognition

Two views on natural and artificial cognition seem to be locked in a contest today: the naturalistic, bottom-up and embodied/enactive/extended/morphological approach to cognitive systems vs. formal, top-down, and highly symbolic/statistical approaches. Facing these traditional battles, we suggest an ambitious hypothesis: these two views are not only biased, but are also theoretically overrated—there is a coherent middle way.

Embodiment contains, in its own structure, a syntax that expresses specific methods of semantics; while pure symbolic systems are not able to generate meta-discourses. Eventually both views converge at the same problem: how to deal with the multiplicity of strategies in cognition, and the choice between these strategies. The main idea of the present volume is to ask experts from different fields (e.g., engineering, logic, anthropology, computer sciences, and psychology) questions on how to design machines that are able to decide on combining multiple heuristics, or to explain how humans are able to make these decisions. This ability appears to be fundamental for many cognitive skills in humans.

This volume is a serious attempt to face both challenges: to study the pros and contras of morphology and symbolic processing without considering how both are deeply intertwined in decision-making. The structure (physical or formal) in which a reasoning process is performed shapes the individual's own reasoning, and this is never completely perfect (e.g., because of lack of data, inaccurate data, wrong data integration, misleading reasoning formalization, and changing conditions), but can be, at least, designed to satisfy minimal requirements. The natural way of integrating different heuristics and reasoning strategies is a good example of how adaptability provides some benefits, while it produces some 'biases'. For example, at a certain point in decision-making procedures, we need to choose between the accuracy and the speed of the answer. And even this process can vary depending on whether we are considering the performance of individual tasks or, rather, whether we are looking at social-network joint collaborative work, which can be either not directly supervised, as happens with swarm intelligence, or supervised and coordinated, as happens in human hierarchical collaborative actions. Humans do not act as rational agents, and think in different ways according their individual conditions: such as whether they are alone, sad, as members of a crowd, or excited. This vast range of ways of combining even imprecise or unconventional reasoning styles is of the greatest interest for the future of artificial intelligence (AI) and the design of artificial general intelligence (AGI).

This book introduces a new concept to cognitive sciences research: *blended cognition*, a concept that will contribute to the design of more realistic and efficient robots. After the extensive introduction of recent ideas into the field, such as extended, embodied, enactive, grounded, or morphological cognition (among several others), it may seem unnecessary to introduce a new category. But the truth is the opposite: we need a new conceptual space from which we can be able to understand real complex cognitive systems, such as human ones. Looking at the daily decision-making procedures undertaken by human beings, we can observe an unprincipled mixture of methods, as well as many intuition-driven actions. What can be affirmed is that humans blend and combine several kinds of heuristics, consciously or not, at symbolic or sensorimotor levels. This blending can occur in parallel or procedurally (one step at a time, completely sequential, or using turns/changes/dead ends).

Let us introduce the idea with an example: a young researcher who buys a cup of coffee. She has a headache and decides to walk to the coffee machine, she looks into her pockets (in fact, she feels with her fingers), grasping some coins while she is looking at the number code of the milk coffee. Then she inserts the coins into the machine, selects the desired option, and waits in front of the machine, thinking about what she has in the fridge for dinner. A characteristic smell makes her aware of the fact that the coffee is ready. She takes the cup, which is too hot to handle and must be changed from hand to hand every few seconds, and moves toward the office, but her phone rings; it is her best friend, who has a serious problem. She looks for a place to put down the hot coffee cup and meanwhile she downloads some files, checks them, and then decides to forward some to her friend. After that she carefully picks up the coffee and comes to the office. In this example some basic sensorimotor processes have been required to allow her movements; among them are object identification and selection (tactile as well as visual and auditory), action planning, object grasping, context evaluation, parallel actions, and mental calculations; some of the movements have followed automated processes (e.g., walking, looking at the pathway, pain arousal, and object identification and avoidance), while some of the movements have required several decisions (holding the cup alternatively in each hand until the required task was performed could lead to skin damage, and she decides to put the cup on a stable surface), as well as cognitive heuristics (how to solve the friend's problem while pending duties are also waiting for her at her desk and the headache needs resolution). She has undertaken all these processes, and more not described here, without falling to the ground, collapsing, or feeling blocked (some possible situations also experienced by stressed humans). Our analysis is that she has blended several heuristics and strategies in order to satisfy the demands of the actions she must solve.

Humans combine several heuristics and even think in meta-heuristic procedures in order to achieve their necessities. *Induction, common sense, analogy, syllogistic procedures, abduction, Bayesian statistics, classic logical reasoning, frequentist statistics, imitation, likelihoodism, amodal thinking, non-monotonic logics, deduction, algorithmic rules, moral codes, attribute substitution, fuzzy logics, swarm reactions, the availability heuristic, the representativeness heuristic, and the anchoring heuristic*—among a very long list of possible strategies or heuristics—are used indistinctively, being combined into a flowchart of possibilities while an action is required to be solved by the experiencer. The uses of these possible strategies or heuristics will, seemingly, vary according to the external and internal context of the human. From sensorimotor to symbolic, from intuitive to highly formalized, and from conscious to unconscious processes, performed sequentially or in parallel, humans select from among a long list of options in order to solve complex tasks. This process is what we call *blended cognition.*

The design of modern robotics and AI cannot be placed under the umbrella of a single and over-simplistic research field: good old-fashioned AI (GOFAI) is not worse or better at all possible scenarios than embodied or morphological approaches. It is true that the symbolic framework requires a bodily revolution, exemplified by the new ideas provided by embodied, enactive, grounded, or extended cognition. And that, after the alternate dominion of one of both sides (the mental and the corporal), it is time to be pragmatic and try to design new strategies to implement multi-heuristic procedures.

We will need to define a subsumption architecture and layer-managing system that makes possible this jump and combination between possible heuristics. At the same time, a discretization of possible flows of actions will be required. This process forces us to think about a grid of procedures, mechanisms, heuristics, and codes that are combined at different places according to the necessities and skills of the agent.

Blended cognition is, thus, the study of how an intelligent system can use or even partially combine several methods to decide among possible action outputs or data evaluation and storage. Here, there is a combination of possible data and task demands: semantics-body-mind**.** By 'semantics' we mean the value of information at a specific moment for the agent; by 'body' we mean the bodily requirements and possibilities (DOF (Degrees of Freedom), for example, flexibility and impact absorption) that the agent exhibits; and by 'mind' we refer to the heuristics mechanisms designed to give answers to the data flows. The importance of blended cognition is that there is no pre-established and rigid hierarchy of control among these possible main layers, or among their sub-layers. There are optimized functional strategies of agreement and combination, but the key point here is the *flexibility* and *adaptability* of the system.

Thanks to the collaboration of experts from a very broad range of academic fields, we have been able to create this book about blended informational processes. After the introduction by the editors, Professor Jordi Vallverdú explains the conceptual nature of the concept of *blended cognition*, following a naturalistic approach to multi-heuristic reasoning that can be applied to AI. Chapter 10 is a fundamental anthropological view of the naturalistic analysis of activity-based AI. Written by Corentin Chanet and David Eubelen, this chapter connects anthropological knowledge with possible ways of modeling AI. In Chap. 5, Gabriele Ferretti and Eris Chinellato propose an embodied model for neurorobotics. After this embodied approach, Chap. 6 suggests a specific way of implementing a bioinspired model using neurosimulation and emotional mechanisms; from an engineering perspective, Max Talanov, Alexey Leukhin, Fail Gafarov, and Jordi Vallverdú suggest a complex computational model that is very close to physical implementation via memristors. From the psychological research, Kay-Yut Chen and Daniel S. Levine explore the heuristics of numerical choice, adding more evidence in Chap. 9 about multiple reasoning strategies used by humans. Chapter 2 explores, with Professor Lorenzo Magnani, the possible connections between abduction and blended cognition, a field to be explored in more detail in the future. Chapter 7, by Qiang Zhang, Stef van der Struijk, and Toyoaki Nishida, analyzes the challenges of cognitive robotics, taking into account this multi-tasking problem and the presence of several heuristics. Robert Earl Patterson and Robert G. Eggleston, from the United States Air Force, make a sound contribution in Chap. 8, exploring the ways of blending the cognitions of humans and autonomous machines. In Chap. 3, Professor Douglas Walton constructs a deep analysis of the formal mechanisms present in practical reasoning in the deliberations of intelligent autonomous systems. Chapter 11, written by Professor Pei Wang, constitutes a fundamental logical analysis of the logics of everyday reasoning, something that is of the utmost interest for robots, which must operate in complex and diverse ‘trivial’ (for humans) contexts. Finally, Chap. 4 is a theoretical exploration, by Vassilis Galanos, of possible theoretical aspects of increasing intelligence automation to consider in the near future.

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Contents