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FOREWORD – COGNITIVE SCIENCE: A NEW SCIENCE WITH A CONSIDERABLE TRADITION

Abstract. We ask which ideas of cognitive science have their roots in traditional logic, grammar and rhetoric. We also emphasize the presence of cognitive science in the pages of *Studies in Logic, Grammar and Rhetoric* since its very beginning.

Keywords: grammar, logic, rhetoric, cognitive science.

1. The title *Studies in Logic, Grammar and Rhetoric* (SLGR) alludes to the *trivium* of Late Antiquity and the Middle Ages, a group of subjects which, together with the *quadrivium*, formed the *artes liberales*, or the seven liberal arts (the skills worthy of a free person). The title is intended to suggest continuity with the long tradition of European rationalism, which had its roots in Antiquity. According to this tradition, the three disciplines making up the *trivium*, concerned with transforming information according to particular criteria of rationality, constituted a necessary introduction to all science.

The presence of logic, with an emphasis on its formal (syntactic) aspect connoted by the term "grammar", was clear from the beginning of the journal's existence, and there never was a shortage of papers concerned with broadly construed grammar or linguistics. Rhetoric came a bit later, though not in the narrow sense of the art of public speaking, but in the wider Renaissance sense associated with the belief that the art of effective communication and argumentation is only possible when the speaker or writer has a comprehensive knowledge of society, politics, and the law.

2. The problems of cognitive science have always been present in SLGR. Thus, SLGR is also a journal in cognitive science, which is clear both from its title and from the material it publishes. The direct reference in the title

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of this volume to cognitive systems is meant to highlight that the traditional problems of human cognition are now being studied from the new perspective of contemporary cognitive science. Nowadays, logic, grammar, and rhetoric are all understood more broadly than in the past, and the classical *trivium* has been expanded to include other skills worthy of a free man. These new skills include the computational methods of artificial intelligence (AI). This is how SLGR is realizing its agenda of developing the rationalist tradition by drawing on its history, using the methods of contemporary cognitive science, and taking up current research problems.

One can distinguish four aspects of artificial intelligence (in its objective-functional sense): a) thinks like a human, b) thinks rationally, c) acts like a human, d) acts rationally. Rational thinking is thinking in accordance with the rules of logic, whereas rational action is action that leads to the best outcome or, in the case of uncertainty, to the best expected outcome. In order to construct a system that thinks and acts like a human, one must first find out how humans act and think. This is the job of cognitive science. Cognitive science seeks to answer questions about human cognition, or about the process by which humans acquire knowledge. Cognitive science integrates the results obtained within a variety of disciplines that investigate aspects of human cognition. It draws on philosophy – especially on logic (to discover the principles of reasoning) – but also epistemology, philosophy of mind, neurophilosophy, and the philosophy of science. Computer science provides knowledge about things like algorithms (what can be computed), while computer engineering tells us how to build an efficient computer. Cognitive linguistics studies the relation between language and thought (e.g., natural language processing, knowledge representation), whereas cognitive psychology analyzes cognitive processes such as perception, thought, memory, and consciousness. Cognitive biology studies the biological processes underlying cognition. One of its important branches, the evolutionary theory of cognitive systems, investigates various kinds of biologically evolved cognitive systems. Neuroscience asks how brains (neural networks) process information. Man is a social animal. Cognitive activity has a social dimension. This is why research in sociology and cognitive economics is also needed, especially in fields such as decision theory, game theory, and operations research. So cognitive science is a) a science of cognitive processes, which it b) conceives as problem solving c) in terms of information processing.

3. The notion of information processing has a sufficiently exact definition to serve as a basis for a clear and effective research program into cognition. This is because information processing is defined in terms of computation, a notion of unparallel precision that comes from the theory of Universal Turing Machines (UTMs). In current cognitive science, there are two rival views as to whether a) the class of what is Turing-computable is a proper subset of the class of what counts as information processing (this would be a sufficient, but not a necessary condition), or b) the two classes are identical (a sufficient and necessary condition). This controversy is decisive in determining the research program of cognitive science. Its significance becomes clear upon considering its relations with two major currents in AI research: solution a) supports *weak* AI because if not every instance of information processing is a Turing computation then there exist problem-solving processes that go beyond the capacities of a UTM (which undermines the radical version of AI); in such a case, being a computation is not a necessary condition of being an instance of information processing. Correspondingly, solution b) supports *strong* AI.

Another important problem associated with the controversy mentioned above is how to develop the language of cognitive science to give its theories as much explanatory power as possible. Is it better to take computation in its narrowest sense, as identical with information processing within the limits of a UTM, or to define computation more broadly, as a process of finding the value of any kind of function, including (paradoxically!) functions that are uncomputable? Another key question: should we classify all or some instances of analog information processing as computations? And, if so, how would that relate to the broad notion of computation, which covers processes of finding the values of uncomputable functions? Since an analog process has the structure of a continuum which encompasses uncomputable numbers, then there might exist analog computations that find the values of uncomputable functions. This would undermine the claim that the mind/brain is essentially a UTM, but as both views have eminent supporters, this is an open question.

Another important group of problems in cognitive science concerns the evolution of science. In this case, cognitive science has tools at its disposal that are unavailable to other sciences of cognition (with the exception of logic). In this case, mathematical logic, especially the discoveries made by Gödel and Turing, are absolutely crucial.

Consider mathematics. The undecidability of logic and arithmetic entails that, at any given time, mathematics is limited with respect to what kind of problems can be solved algorithmically, by a UTM. This, however, puts no limits on progress in finding new axioms and concepts by way of mathematical insight. Having found new axioms or new logical tools, such as higher order logics (Gödel's claim from 1936), we can axiomatize new areas of mathematics, which we can then formalize and, finally, algorithmize (i.e., express their formalism in a language interpretable by a UTM).

This process is aptly captured by the title of a volume of SLGR – *From Insight to Proof*, where, as one can gather from the volume's contents, the word "proof" refers to mechanized proofs, interpretable by a UTM. Thus, when it comes to discovering new truths, the progress of mathematics is not limited by the nature of mathematics or by the nature of the human mind. This translates into the possibilities of progress in all sciences that rely heavily on mathematics, for example theoretical physics and the branches of economics that use mathematical modeling and computer simulations.

4. The observation we made at the beginning, that many problems of cognitive science had become the focus of various disciplines even before the term "cognitive science" was coined or a research program formulated, can be illustrated by considering linguistics and economics. In linguistics, we have the field known as mathematical linguistics, where Chomsky's grammars and Ajdukiewicz's grammar bear a particularly close resemblance to theories in cognitive science. Despite differences in their content and range of applications, they both took up the problem of the computability of grammatical correctness, or (in terms of Ajdukiewicz's theory) syntactic coherence; they also proposed suitable algorithms as the problem's solution. Thus, mathematical linguistics might deservedly be called cognitive linguistics.

In linguistics, the cognitive approach flourished in a single field or line of inquiry; in economics, it was adopted by the whole discipline. Furthermore, as theoretical reflection and experience accumulate, the cognitive character of economics is becoming increasingly pronounced. The turning point was the appearance of the new theory of price pioneered by members of the Austrian school, especially Ludwig von Mises and Friedrich Hayek. In classical economics, it was believed that the price of a product should reflect the cost of the work and raw materials needed to manufacture it (which was a relic of the medieval idea of the *iustus pretium*). However, in the developed economies that emerged as a result of the industrial revolution, the increasing role of mechanization, managerial skills, scientific knowledge, etc., the idea of price as a simple function of two variables (work and raw materials) has lost its explanatory power.

Consider the following example: how is price to be affected by the license costs vis-à-vis the cost of labor, which depends not only on the time and effort needed to manufacture the product but also, to a significant extent, on the laborers' level of expectations (which is different in China than in Germany)? In traditional economics, this problem is intractable. It is tractable if we follow the Austrian recipe and track the quantitative indicators of how much people are willing to pay for a product. These indicators are many in kind and number, varying from demand statistics to the fluctuations of share prices on the stock exchange. Combined with risk assessment, they provide manufacturers, traders, bankers, consumers, etc. with a reliable strategy for calculating product prices. The cognitive approach has had similar successes with calculation problems in other domains as well – for example, in criticizing the socialist system of central planning on the grounds that it makes it difficult to adequately calculate the profitability of prices. This is how, right after the Russian Revolution, von Mises and Hayek were able to predict the eventual breakdown of socialism, which, admittedly, was a historic epistemic success for the cognitive approach. The cognitive approach has also succeeded in predicting and accounting for economic crises, which it explains in terms of speculation bubbles resulting from a lack of control in risk assessment, especially in the case of derivatives. Even on the cognitive approach, it is still an open question whether the free market is primarily the source of economic calculability (e.g, through generating the quantitative indicators mentioned above) or of economic incalculability (e.g., due to calculation errors made by the actors in the marketplace; the effects of irrational drives, say, on the stock exchange; and the presence of dishonest practices). The debate within the cognitive camp is between the advocates of Keynes and the supporters of Hayek. But the cognitive approach has one important advantage over its competition: unlike the other approaches, it has at its disposal the conceptual apparatus necessary to formulate the problem, a sine qua non for its solution. It is also clear that, in our attempts to solve the problem, we must take into account the role of economic insight. The situation here is similar to that in mathematics, where, on its cognitive construal (inspired by Gödel), we ask about the role of insight in the process of proving a mathematical proposition and discovering how the proof can be formalized and mechanized.

5. By establishing a series in cognitive science within SLGR, we signal the need for a more consistent approach to problems that have already been taken up in the pages of this journal from the beginning of its existence. Cognitive problems were the focus of the Department of Logic of what used to be the Białystok branch of the University of Warsaw, which founded this journal in 1980; the department was later transformed into the Chair of Logic, Informatics, and Philosophy of Science, and is now part of the University of Białystok.

The need for establishing a series in cognitive science has become all the more apparent as a result of the intensified research that has accompanied plans to offer a new BA Program in Cognitive Science and Communication at the University of Białystok; the program is scheduled to start in the academic year 2015/16. We intend the issues of SLGR devoted to cognitive science to become a forum for the exchange of ideas for researchers from Poland and abroad.