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Tendencies in Logic, and Some Modest Advice to Young Logicians

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ABSTRACT

This brief note raises the question of why there is no advice in the literature for young logicians, while there is for mathematicians, musicians, and others. Trying to take advantage of what exists in other areas, some tendencies in logic, and reasons to follow – or not to follow-- trends are discussed.

Keywords: Contemporary logic, advice to logicians, main trends in logic

1. Why There Is No Advice to Logicians?

In **The Princeton Companion to Mathematics**[1]**,** three experienced mathematicians, among them the Fields medallist Timothy Gowers, offer, as editors, 1034 pages of great ideas and techniques of modern mathematics, beautiful theorems and fascinating theories (some logic included). The book ends with a charming piece of "Advice to a Young Mathematician"[2] in which five mathematicians deliver their advice to the young generation entering the battlefield of mathematical research. One of those five, Sir Michael Atiyah, with whom I had a long talk at Rio de Janeiro in 2018, some months before he died – was astonishingly lucid and full of life, his passing being a sad surprise to everyone – gives a most sweet and comfortable consolation to the ones starting the career. "The first year or two of research are the most difficult", he says. "One struggles unsuccessfully with small problems, and one has serious doubts about one's ability to prove anything interesting". So it is not only you and me that have suffered: "I went through such a period in my second year of research, and Jean-Pierre Serre, perhaps the outstanding mathematician of my generation, told me that he too had contemplated giving up at one stage".

We can only thank the universe that Jean-Pierre Serre and Michael Atiyah did not give up; the world would have lost a lot. Recipient of the Fields Medal in 1954 and of the Abel Prize in 2003 for his contributions to algebraic topology, algebraic geometry, and algebraic number theory, Serre had been an inspiration for Atiyah, who himself was awarded the Fields Medal in 1966 and the Abel Prize in 2004 for his work in developing the K-theory and proving the Atiyah Singer theorem. In his contribution to "Advice to a Young Mathematician", Atiyah makes clear that the driving force in research is curiosity, an advice he followed until his death. In September 2018, nearly four months before his passing (on January 11th, 2019), Atiyah announced to have found a simple proof of the Riemann hypothesis, one of the most important and challenging problems in mathematics. The mathematical community remained skeptic, afraid of any mistakes, yet hoping for success. Skepticism won, Sir Michael Atiyah was not right – but he was very brave to have had the heart to announce a simple proof for such a deep theorem in his nineties, risking his reputation on a tremendous problem.

Motivation, the role of finding proofs, the importance of style of writing, and the relevance of acquiring independence, are also further ingredients of his advice to young mathematicians. And a very important recommendation, hard to be taken seriously by beginners: "If you are not in a desperate hurry to publish, put your paper aside for a few weeks and work on something else. Then return to your paper and read it with a fresh mind. It will read differently, and you may see how to improve it."

In 1860, in the last period of his life, Robert Schumann, one of the greatest composers of the Romantic era, published a booklet[3] with a list of pedagogical maxims as guiding ideas for

1 T. Gowers, J. Barrow-Green, and I. Leader, **The Princeton Companion to Mathematics**, 2008.
2 T. Gowers, J. Barrow-Green, and I. Leader, **The Princeton Companion to Mathematics**, Chpt. VIII.6, 2008.
3 R. Schumann, **Advice to Young Musicians**, J. Schuberth & Co, Musikalische Haus- und Lebens- Regeln, Translated by Henry Hugo Pierson, 1860.

young musicians. His intention was to show that music has to serve a greater purpose. Some of his advice, that fit perfectly well the activities of young logicians, are the following:

- "When you play, never mind who listens to you."
- "Play always as if in the presence of a master."
- "Never help to circulate bad compositions; on the contrary, help to suppress them with earnestness."
- "Let your intimate friends be chosen from those who are better informed than yourself."
- "Do not judge a composition from the first time of hearing; that which pleases you at the first moment, is not always the best. Masters need to be studied. Many things will not become clear to you until you have reached a more advanced age."

If we replace 'playing' with 'writing' or 'speaking', and 'composition' with 'ideas' or 'theories', most of Schumann's seventy prescriptions will work very well for logicians, and anyway for philosophers and scientists in general.

There are a few timid pieces of advice for philosophers, and even for computer scientists: Donald Knuth, for instance, urges young people not to overly listen to their elders[4]: "So follow your own instincts, it seems to me, is better than follow the herd."

Sir Peter Brian Medawar, a British biologist born in Petropolis, Brazil (1915– 1987), who received the 1960 Nobel Prize for Medicine in 1960, has confessed in his own advice to young scientists[5] that he also felt embittered wit ideas that didn't work out, and urges them to have the courage to throw away ideas that start showing evidence of error: "Twice in my life I have spent two weary and scientifically profitless years seeking evidence to corroborate dearly loved hypotheses that later proved to be groundless; times such as these are hard for scientists, days of leaden gray skies bringing with them a miserable sense of oppression and inadequacy. It is my recollection of these bad times that accounts for the earnestness of my advice to young scientists, that they should have more than one string to their bow and should be willing to take no for an answer if the evidence points that way."

Medawar lost his Brazilian citizenship for not having served in the Brazilian military service, so he had to opt for English citizenship to continue his studies in England. His father, owner of a well-established company in Rio de Janeiro, reportedly appealed to the Air Force Minister around 1941-1945, to no avail. Unfortunately, members of government usually do not listen to evidence – this is perhaps one of the basic warnings, if not advice, to young logicians: do not expect your field of study to be popular among those who hold the power. I never found, however, any attempt to provide advice for young logicians. Why? Perhaps,

4 D. Knuth, "Confusability", **Personal blog**, 2008.

5 P. Medawar, **Advice to a Young Scientist**, Harper Row, 1979.

because they do not need it. If logic, as Hintikka and Sandu put it in , **"What Is Logic?"**[6], is to be identified as the study of inferences and inferential relations whose practical use is to help us to reason well, to draw good inferences, logicians will themselves get good inferences from advice in other areas, and will adapt them to their case. After all, analogy is a fundamental tool in reasoning, and logicians should know how to use it in their favour. This brings us to the second point of this essay.

2. Tendencies In Logic, and Reasons (Not) To Follow Trends

Jakko Hintikka is famous, among other things, for his criticism of first-order logic: it should be replaced, argues Hintikka, by independence-friendly first-order logic (IF-logic), a system of logic essentially equivalent to second-order logic, able to represent branching quantification. Independently, on his insistence about IF-logic, what is relevant for young logicians is to be convinced that Hintikka thinks that reasoning is more central than logic, as in his **"Is Logic The Key to All Good Reasoning?"**[7]: "Philosophers generally consider deductive reasoning as the paradigmatic type of inference. However, there is a widespread view among non-philosophers that might be called the Sherlock Holmes view. According to it, all good reasoning including ampliative reasoning, turns on 'deductions' and 'logic'." Hintikka has a more descriptive attitude about logic, with his 'Sherlock Holmes view' being connected to general human rationality. At this point, he disagrees with Gottlob Frege, who considered that the laws of logic are laws of thought in a universal sense, prescribing the way in which one ought to think. Ludwig Wittgenstein however, differently from Frege, warned against the misunderstandings of the logic of language, his writings (early and late) tried to show what this logic should be.

So what is logic? When learned logicians and philosophers keep writing papers on the topic, some of them bearing this same title, and give no definite answers, as "**What Is Logic?"**(**The Journal of the Philosophy)**[8] and **"What Is Logic" (Philosophy of Logic)**[9], I do not see that young logicians should wait to answer this question before starting. Logic is what logicians do, and the best way to enter the research arena is to try to see why and how they do it. Johan van Benthem, in **"Where Is Logic Going, and Should It?"**[10]**,** agrees that the modern logic is about processes that transform and transmit information: reasoning, computation, questioning, announcing, or learning. I would add denying, negating, affirming relevantly, fuzzyfying, computing chances and probabilities, measuring evidence, revising beliefs, thinking non-monotonically, and many others. So this gives great and immediate value to the so-called 'non-classical logics' or 'non-standard logics', a bad name that should perhaps be changed to 'contemporary logics', while waiting for a better label. Calling the enormous amount of logical systems that treats probability, computation, learning, negating, etc., by the nickname 'non-classical logics', is like calling modern cars 'non-classical horse carts'.

6 J. Hintikka and G. Sandu, "What is logic?", **Philosophy of Logic**, 2007, 1339: XX-YY.
7 J. Hintikka. "Is logic the key to all good reasoning?", **Argumentation**, vol. 15, 2001, pp. 35-57.
8 I. Hacking, "What Is Logic?", **The Journal of Philosophy**, 76(6), 1979, pp. ,285-319.
9 J. Hintikka and G. Sandu, "What Is Logic?", **Philosophy of Logic**, 1339, 2007, XX-YY.
10 J. van Benthem, "Where Is Logic Going, and Should It?", **Topoi**, 25(12), 2006, pp. 117-122.

Artificial Intelligence, sometimes called Synthetic Intelligence, is partly dependent on probability, but greatly dependent on logic, since its task is to model information states in logical terms (according to an anonymous saying, as van Benthem recalls in **"Logic and Reasoning: Do The Facts Matter?"**[11], Artificial Intelligence is the 'continuation of philosophy by computational means').

An overly simplified catalog of the new logics where young logicians will find intriguing problems with astonishing applications is the following. This is mainly a list of topics that have changed since I was a young logician, and reflects my personal taste. It is by no means complete. I use the term 'logics' in plural to mean the systems or schemes, not the science.

1. Modal and Epistemic Logics

Before called "philosophical logics", nowadays much used in computer science, modal logics in general are the logics intended to express notions as necessity and possibility, as well as epistemic terms as knowledge and belief, normative and legal inferences, tenses and time, multimodalities, etc. Gentle introductions to such logics are **Modal Logic for Open Minds**[12] and **Modalities and Multimodalities**[13]**.** Modal logics present an abundance of problems, from philosophical to highly technical, and is one of the best gardens for harvesting problems.

2. Logics Around Negation and Its Significance

Those are logics that investigate the behaviour of negation. Paraconsistent logics are logics with a modified consequence relation such that the Law of Explosion does not hold, that is, it is not the case that any contradiction entails arbitrary absurdities. There is a large spectrum of paraconsistent logics, from weak to strong, many-valued to non-finite valued, modal, first-order, etc. There are considerable philosophical differences about paraconsistent logics, as exemplified by the opposite views between dialetheic logics (**Paraconsistency and Dialetheism**[14]) and the logics of formal inconsistency (**Logics of Formal Inconsistency**[15] and **Paraconsistent Logic: Consistency, Contradiction and Negation**[16]). The rules for negation in IF-logics are also not strictly classic, as they do not obey the law of the excluded middle. For a comparison between IF-logics and paraconsistent logics, see **Meeting Hintikka's Challenge to Paraconsistentism**[17].

11 J. van Benthem, "Logic and Reasoning: Do The Facts Matter?", **Studia Logica**, 88(1), 2008, pp. 67-84.

12 J. van Benthem, **Modal Logic for Open Minds**, Center for the Study of Language and Information, 2010.

13 W.A. Carnielli and C. Pizzi, **Modalities and Multimodalities**, Springer Verlag, 2008.

14 G. Priest, "Paraconsistency and dialetheism", ed. D. Gabbay, J. Woods, **Handbook of the History of Logic**, vol. 8, Amsterdam, North Holland, 2007, pp. 129-204.

15 W. A. Carnielli, M. E. Coniglio, and J. Marcos, "Logics of Formal Inconsistency", ed. D. Gabbay and F. Guenthner, Handbook of Philosophical Logic, volume 14, Springer-Verlag, Amsterdam, 2007, pp. 1-93.

16 W.A. Carnielli and M.E. Coniglio, "Paraconsistent Logic: Consistency, Contradiction and Negation", **Series Logic, Epistemology, and the Unity of Science**, Springer, 2016.

17 W.A. Carnielli, Meeting Hintikka's Challenge to Paraconsistentism, **Principia - An international Journal of Epistemology**, 13(1), 2009, pp. 283-297

3. Many-Valued Logics

Many-valued logics start from the idea that truth (and falsity) can be given in degrees, and use that idea in several applications. Such truth degrees or truth values can be finite or infinite, and it is a difficult philosophical problem to discuss the nature of such degrees. In **Paul Bernays and the Eve of Non-tandard Models in Logic**[18], I defended that the best way to understand the birth of many- valued logics is to see them as defining more ample 'logic rooms', which gives better ways to understand other systems of logic and to prove certain of their intrinsic properties. Then, if we decide for a moment to concentrate of their technical status, instead of insisting on their philosophical significance, many-valued logics turn into useful mathematical tools, with lots of connections to mathematical topics, such as group theory, finite fields, polynomial rings, etc. Many-valued logics are quite naturally connected to probability, and find several applications to problems in Artificial Intelligence and Machine Learning. Good references, perhaps not the easiest to understand, are **Many-Valued Logics**[19] and **A Treatise on Many-Valued Logics**[20].

4. Logics and Probability, and Probability Logic

The idea of combining logic and probability will seem to be very natural if one regards, as Leibniz did, and several contemporary authors do, probability as a kind of generalized logic, or even, as Karl Popper saw it, as logic and probability both being particular cases of a much more abstract theory. But then, taking this view seriously, one will naturally ask how different logics will give way to new probability theories.

This will shed new light on formal representations of belief, on Bayesian epistemology, and on novel applications in statistics. There is a huge literature on such topics; I can only wisely advise a couple of references with distinctive objectives, that somehow represent this view: **Against All Odds: When Logic Meets Probability** [21] and **Paraconsistent Probabilities: Consistency, Contradictions and Bayes' Theorem**[22].

5. Higher-order Logics and Type Theory

Higher-order logics are, in a certain sense, parallel to set theory with type restrictions. In 1940, Alonzo Church proposed a powerful, but simple and elegant, formulation of the simple type theory, known as Church's type theory, modifying an earlier proposal by Bertrand Russell in 1908 (his 'ramified theory of types', by which Russell wanted a logic that would avoid the set-theoretic paradoxes).

18 W.A. Carnielli, "Paul Bernays and The Eve of Non-standard Models in Logic". Ed. J-Y Beziau**, Universal Logic: An Anthology – From Paul Hertz to Dov Gabbay**, vol. 18, Birkhuse, 2012, pp. 33-41.

19 G. Malinowski, **Many-Valued Logics**, Clarendon Press, Oxford, 1993.

20 S. Gottwald, "A Treatise on Many-Valued Logics", Studies in Logic and Computational, vol. 9, **Baldock: Research Studies Press Ltd.**, 2001.

21 J. van Benthem, "Against All Odds: When Logic Meets Probability", ed. J.P. Katoen, R. Langerak, and A. Rensink, **Modeled, Tested, Trusted Essays Dedicated to Ed Brinksma on the Occasion of His 60th Birthday**, Springer, 2017, pp. 239-253.

22 J. Bueno-Soler and W.A. Carnielli, "Paraconsistent Probabilities: Consistency, Contradictions and Bayes' Theorem", **Entropy**, 18(1), 2016, pp. 170-325

Simple type theory is based on functions instead of relations, and incorporates the constructors of lambda-notation and lambda-conversion used to define and apply functions.

Type theory is a version of higher-order logic, a generalized extension of first-order logic that has had a profound influence on computer science due to its great expressive power. Areas like computer theorem proving (HOL, IMPS, Isabelle, etc.), programming languages (Lisp, Haskell, etc.) and computational logic are dependent on type theory.

Type theory and higher-order logics, in computer terms, induce a new way to express complex mathematical concepts: if you define well, the internal machinery of the system almost does the rest. I say 'almost', because simple type theory is incomplete, an immediate consequence of Gödel's Incompleteness Theorem, and most systems of type theory are undecidable, since they contain the undecidable First-Order Logic as a fragment.

I am not giving any list of problems for the next century; I will just mention some broad problems offering a lot of opportunity for research, and some conjectures where young logicians may try their hands – they are not necessarily hard problems, perhaps not even new, but to the best of my knowledge, have not been yet (completely) solved:

- Connecting modal logics and many-valued logics: Is it true, that every finite many-valued logics can be regarded as a modal logic with only finite models? My conjecture is that this is true based on some examples I have found, but have no general solution.
- Connecting type theory and combinations of logics: Can a general theory of combination of logics (in the sense of **Analysis and Synthesis of Logics**[23]) be established based entirely on type theory? The answer seems to be obviously true, but not done yet (not even remotely...)
- Connecting logics around negation: İs it possible to give a general notion of logics that define the standard properties of negation, such as paraconsistent logics in general, IF-logic, fuzzy logics, relevant logics, etc.? Possible in principle, but a courageous task that would require a deep knowledge of all forms of negation, as well as a deeper notion of a logical system. Even partial answers would be impressive.
- Connecting probability and logic: The standard concept of (mathematical) probability is criticized by many authors as insufficient for reasoning under uncertainty. Such standard formalizations of probability admittedly fail to resolve important questions about uncertainty and belief, as much as standard logic alone admittedly fails to resolve all questions about truth and truth preservation. So, new forms of logic, probability or their combinations are justifiable. Perhaps, probability theory does not extend logic, and both logic and probability, are extreme, but particular cases, of a more general theory of reasoning. I personally believe that the notions of evidence, argumentation, uncertainty, decision systems, etc., will gain

23 W.A. Carnielli, M.E. Coniglio, D. Gabbay, P. Gouveia, and C. Sernadas, **Analysis and Synthesis of Logics**, Springer, 2007.

much from a generalized form of probabilistic reasoning. While we do not have such a super-general theory, combining systems of modern (or contemporary) logic with new forms of probability measures are good starting points.

Mixing and combining questions related to the above topics can be a good strategy. As a final advice, I find nothing better than encouraging the reading of the great names – as Schumann recalls, 'there is no end of learning'.

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