On Nonfoundational Reasoning

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Abstract

The goal of the paper is to describe the role and structure of nonfoundational reasoning, i.e. a kind of argumentation that meets the revisability, the feedback, the background stability and the disputability conditions. I begin by observing that any nonfoundational reasoning has two components: the deductive and the hermeneutic. Next, against the background of Gadamer's insightful, although somewhat vague, observations I attempt to uncover aspects of the hermeneutic component. I then proceed to reconstruct nonfoundational argumentation with the help of formal theory of belief revision, defeasible logic, and logical conception of coherence. Finally,

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I argue that nonfoundational reasoning is the backbone of both scientific endeavours and philosophical inquiry.

Keywords
nonfoundational reasoning, foundationalism, hermeneutics, belief revision, coherence, defeasible logic

1. What is nonfoundationalism?

The search for the foundations of knowledge has always been the Holy Grail of philosophers. Descartes famously begins *Meditations* with the following passage:

> Several years have now elapsed since I first became aware that I had accepted, even from my youth, many false opinions for true, and that consequently what I afterward based on such principles was highly doubtful; and from that time I was convinced of the necessity of undertaking once in my life to rid myself of all the opinions I had adopted, and of commencing anew the work of building from the foundation, if I desired to establish a firm and abiding superstructure in the sciences.[2]

He proceeds by employing his method of methodical doubt, and arrives at *ego cogito ego sum* as the only certain proposi-

[2] R. Descartes, *Meditations on First Philosophy*, transl. by J. Veitch, http://www.wright.edu/~charles.taylor/descartes/mede.html.

tion, one that may serve as the point of departure to reconstruct – albeit not deductively – the entire body of human knowledge.

The history of philosophy teaches us, however, that Descartes' grand project was destined to fail; that there is no such thing as the foundations of knowledge; that the belief in such foundations often leads to dogmatism, which is one of the great enemies in our pursuit of truth; and that our attempts to acquire knowledge are always imperfect and fallible. Perhaps the most famous metaphors which serve to underline these facts would be Neurath's image of the sailors rebuilding a ship on the open sea, and Quine's view of knowledge as a web of beliefs. Neurath says:

> There is no way to establish fully secured, neat protocol statements as starting points of the sciences. There is no *tabula rasa*. We are like sailors who have to rebuild their ship on the open sea, without ever being able to dismantle it in dry-dock and reconstruct it from its best components.(…) Imprecise 'verbal clusters' are somehow always part of the ship. If imprecision is diminished at one place, it may well re-appear at another place to a stronger degree.[3]

Quine echoes Neurath when he argues in "Two Dogmas of Empiricism" that our knowledge resembles a web, and any change

[3] O. Neurath, *Philosophical Papers 1913–1946*, D. Reidel, Dordrecht 1983, p. 92.

in one of its nodes may require changes in others; even logic and mathematics are just nodes in the web of knowledge, and hence they are not immune to revisions. Moreover, if this is the case, "our statements about the external world face the tribunal of sense experience not individually but only as a corporate body."[4]

The rejection of foundationalism leads to the following questions: what does nonfoundational reasoning look like? Can it be reconstructed logically? What are the criteria employed when one reasons nonfoundationally? In order to answer these questions, let us consider the following passage from Michael Heller's essay "Against Foundationalism", in which he observes that each philosophical argument has two components: the deductive and the hermeneutic:

> I believe that all arguments in philosophy, but also in the sciences, can be arranged in a sequence, such that at its – say – left end there are arguments without the hermeneutic component, while at the right – arguments without the deductive component. (…) Rationalistic arguments are relatively closer to the left-hand side of the sequence; visionary arguments are relatively close to the right-hand side. Crucially, any philosophical argument, which pertains to a non-trivial philosophical claim, is never devoid of the hermeneutic component.[5]

[4] W.V.O. Quine, *From a Logical Point of View*, Harvard University Press, Cambridge, Mass. 1980, p. 41.
[5] M. Heller, *Przeciw fundacjonizmowi*, [in:] M. Heller, *Filozofia i wszechświat*, Universitas, Kraków 2006, p. 93.

He also adds that:

> in a typical situation there exists a kind of feedback between the vision and the logical argumentation. Even if the chain of arguments is inspired by a vision, rational argumentation may influence it, giving rise to its revisions and, in a critical situation – even to its rejection.[6]

Such a view of philosophical argumentation leads firmly to the rejection of foundationalism: if argumentation is a constant interplay of the hermeneutic vision and deduction, there exist no indefeasible, 'clear and distinct' premises, or there exists no unshakable foundation for our philosophical constructions. Argumentation in philosophy takes on a different form:

> When one begins to solve a problem, (...), one accepts certain *hypotheses* (...). It is important to note that these are hypotheses, not certainties (...), and maybe even working hypotheses. By using them one arrives at a solution of a problem (…). The results of the analysis may either strengthen one's initial hypotheses, or lead to their modifications. Such a procedure may be repeated multiple times, resulting in the self-adjustment of the system.[7]

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[6] *Ibidem*, p. 94.

[7] M. Heller, *Nauki przyrodnicze a filozofia przyrody*, [in:] M. Heller, *Filozofia i wszechświat*, Universitas, Kraków 2006, p. 32.

Heller's insightful remarks may be summarized – and given more precise form – in the following way. Any philosophical argumentation must meet four conditions:

(a) the revisability condition: at least some of the premises of any philosophical argumentation are hypotheses – these can be rejected or modified;
(b) the feedback condition: the modification or rejection of premises (hypotheses) must be based on the evaluation of their logical consequences;
(c) the background stability condition: the argumentation background (some previously accepted theories other than the evaluated hypotheses) is relatively stable in relation to the hypotheses; it should be easier to modify or reject the hypotheses than the background;
(d) the disputability condition: any philosophical argumentation is open to formulating competing, even contradictory, hypotheses.

Heller rightly observes that arguments that meet the above stated conditions cannot be accounted for within classical logic. He urges us therefore to look for a 'non-linear logic', or such a logic that would encapsulate the structure of nonfoundational thinking.[8]

[8] The classical relation of logical consequence is a non-linear function. In addition, there exist formal systems called nonlinear logics. However, Heller speaks of something different – a logic of epistemological non-foundationalism – and hence I used the term 'non-linear logic' in quotation marks.

Although I cannot offer such a full-blooded logic here, I would like to suggest that non-foundational arguments can be explicated with the use of some non-classical but still well-known formal tools and, in particular, the formal theory of belief revision and the formal theory of coherence. However, I would like to begin the analysis by considering the 'hermeneutic component of reasoning' referred to by Heller.

2. The hermeneutic component

In order to understand the hermeneutic dimension of argumentation, it is necessary to consider the philosophy of Hans Georg Gadamer, or so I argue. Although Gadamer speaks of understanding and interpretation, and not of arguing, his conclusions are applicable, *mutatis mutandis*, to the characterization of any kind of reasoning. Gadamer and his followers claimed that the process of understanding cannot be accounted for with the use of standard logical tools; he went even further by claiming that understanding has little to do with logic. However, he speaks of the *structure* of understanding, and wherever there is a structure it must be – at least in principle – formally reconstructable: if not in classical logic, then with the use of nonstandard formal techniques. Moreover, I believe that some of the observations of the proponents of hermeneutics are indeed insightful, but it is difficult to appreciate and analyze them as they are usually expressed in vague and awkward language which is characterized by a high level of 'Gads' (Gadamer's students referred to less clear fragments of his works with this phrase).[9]

I posit that is it relatively easy to present a satisfactory – although not the only possible – formalization of the hermeneutic process of understanding, though it requires a non-dogmatic approach to the Gadamerian conceptual scheme. Gadamer claims that within the process of understanding "the constitution of sense or meaning (*Sinn)*" takes place.[10] The problem is, what does 'sense' or 'meaning' stand for here, since Gadamer speaks of their 'consistency' or 'coherence', and 'consistency of sense (meaning)' sounds awkward.

This problem may be dealt with when one follows an insightful directive formulated by Karl Popper, who insists on distinguishing subjective, personal and psychological activities and processes, from the

> (more or less successful) *outcomes* of these activities, from their result: the 'final state' (for the time being) of understanding, the *interpretation*. (…) [When a subjective] state of understanding [is] finally reached, so a psychological process which leads up to it must be analysed in terms of the third-world objects [i.e., abstract objects] in which it is anchored. In fact, it can be analysed *only* in these terms.[11]

9 J. Grondin, *Hans-Georg Gadamer. Biografia*, Wydawnictwo Uniwersytetu Wrocławskiego, Wrocław 2007, p. 291.
10 H.-G. Gadamer, *Truth and Method*, Continuum, London 2004, p. 164.
11 K.R. Popper, *Objective Knowledge*, Clarendon Press, Oxford 1972, p. 163–164.

Popper suggests that – instead of speaking of 'capturing the meaning' or other subjective processes connected with interpretation or understanding – one should rather analyze the *outcomes* of those processes. Thus, in what follows, I will read what Gadamer says about 'sense' or 'meaning' as if he were speaking of 'propositions' or 'sentences'.

The two key hermeneutic concepts that describe the structure of understanding are: pre-understanding or pre-judgment (*Vorverstandnis*, *Vorurteil*) and the hermeneutic circle. It is possible, or so I argue, to capture those concepts in a precise way with the use of some formal tools. Of course, it is only a paraphrase of the original conception, but arguably an admissible one.

Gadamer nowhere defined the concept of pre-understanding and he speaks of pre-judgments as a transcendental condition of understanding. He criticizes the Enlightenment tradition, claiming that by rejecting pre-judgments as not based on the authority of reason, the only admissible authority, it itself embraces a prejudice. One cannot however, Gadamer continues, imagine understanding without a pre-understanding. Gadamerian pre-understanding has at least two dimensions. Firstly, everyone who engages in the interpretation (understanding) of a text is a participant in a certain culture (tradition), and so understanding and interpretation are always relative to a tradition. Secondly, pre-understanding also has an individual 'flavor': one that interprets or 'poses a question to a text', always anticipates an answer, initially ascribes some meaning to the text.[12]

[12] Cf. H.-G. Gadamer, *op. cit.*, pp. 277–304.

These theses are far from clear and dangerously close to nonsense. What does it mean that one 'poses a question to a text'? What is 'the anticipation of meaning'? In what way – apart from the obvious, that context influences interpretation – does tradition play the role of a 'transcendental condition of understanding'? It is tempting to conclude that, while Gadamer may be trying to verbalize something important, the result is vague and imprecise and brings rather more confusion than insight.

However, I believe that it is possible to express the intuitions that stand behind Gadamer's obscure phrase in a more precise way. To do so, I suggest distinguishing between four kinds of pre-understanding. First, the thesis that 'tradition' is a transcendental condition of understanding may be seen as an attempt to say that whoever interprets something must use an interpreted language. Thus, she must have at her disposal a vocabulary, syntactic rules (rules for constructing compound expressions), rules of inference and a function which maps constants to individuals belonging to the domain of language, one-place predicates to sets of such individuals, etc. Second, participation in the same tradition requires a shared set of presuppositions. Usually, it is assumed that a sentence *A* is a presupposition of a sentence *B* iff *B* may be ascribed truth or falsehood only if *A* is true. Third, two persons participate in the same tradition if they have the same or similar background knowledge, where the term usually refers to all those statements that – within the process of solving a problem – are assumed to be true or unproblematic. Here, I shall understand background knowledge in a similar way, as consisting of all those sentences that – at least *prima facie* – are taken to be true or justified. Fourth, it seems that the best way to explicate the individual dimension of pre-understanding is to treat prejudgements as initial hypotheses, i.e. sentences capturing the sense (meaning) of the interpreted text, which one formulates at the beginning of the process of interpretation, and aims at confirming or rejecting them in due course.

Given the above, if one is to interpret a text then one is in the following position: she has at her disposal an interpreted language (L), a set of presuppositions (P), background knowledge (K) and a set of initial hypotheses (H). How does the *process* of interpretation look like? Gadamer describes it by recourse to the concept of a hermeneutic circle. He says, for instance:

> But the process of construal is itself already governed by an expectation of meaning that follows from the context of what has gone before. It is of course necessary for this expectation to be adjusted if the text calls for it. This means, then, that the expectation changes and that the text unifies its meaning around another expectation. Thus the movement of understanding is constantly from the whole to the part and back to the whole. Our task is to expand the unity of the understood meaning centrifugally. The harmony of all the details with the whole is the criterion of correct understanding. The failure to achieve this harmony means that understanding has failed.[13]

[13] *Ibidem*, p. 291.

And elsewhere he adds:

> every revision of the foreprojection is capable of projecting before itself a new projection of meaning; rival projects can emerge side by side until it becomes clearer what the unity of meaning is; interpretation begins with fore-conceptions that are replaced by more suitable ones. This constant process of new projection constitutes the movement of understanding and interpretation.[14]

According to my interpretation, Gadamer simply suggests that the structure of interpretation has a non-foundational character. In opposition to the 'linear' character of the classical logic, where from given premises one draws logically valid conclusions, non-foundational reasoning, although it begins with some premises, does not treat them as non-revisable.

3. The structure of nonfoundational argumentation

Given Heller's characterization of nonfoundational thinking, as well as Gadamer's insights regarding the hermeneutic dimension of understanding, we are now in a position to describe the structure of nonfoundational argumentation. The idea is simple: with a given language *L* and the background knowledge *K* one puts forward certain hypotheses *H1, H2, H3, …,* each aiming at solving a problem at hand. We shall say – simplifying conside-

[14] *Ibidem*, p. 263.

rably – that a problem is defined by a pair of contradictory sentences {*p, ~p*}, and that to solve a problem means to determine which of the sentences, *p* or ~*p*, is true. Thus, a hypothesis *H* solves a problem when it (together with some other previously accepted sentences) implies *p* or ~p. Importantly, any newly introduced hypothesis *H* together with the background knowledge *K* may yield contradiction. In such cases, one needs to revise or reject some parts of the background knowledge, and this procedure is well modeled in formal theories of belief revision.[15] In other words, the set *K***H1*, i.e., *K* revised by *H1*, may not include every sentence, which was originally in *K* (I simplify here, disregarding the fact that there usually are many ways of revising *K* by *H1*, and so the set *K***H1* is in fact chosen from among the possible ways of modifying *K* in order to accommodate *H1*). To put it succinctly: revisions such as *K*H1, K*H2, K*H3* often result in the modifications to the background knowledge.

Whether such modifications are acceptable depends on whether an introduced hypothesis (*H1*, *H2, H3*) indeed solves a problem that has previously remained unsolved. However, this is not the only criterion for assessing the quality of a hypothesis. The other such criterion is coherence: we shall say that the better the hypothesis (solving some problem) is, the more coherence it generates in our system of beliefs. Coherence is

[15] Cf. P. Gardenfors, H. Rott, *Belief Revision*, [in:] D.M. Gabbay, Ch. Hogger, J.A. Robinson (eds.), *Handbook of Logic in Artificial Intelligence and Logic Programming*, *vol. IV: Epistemic and Temporal Logic*, Oxford University Press, Oxford 1995, pp. 35–132.

determined by taking into account: (a) the number of nontrivial inferential connections in our belief set (so in *K*H1, K*H2, K*H3* respectively); and (b) the degree of its unification.[16] There exist nontrivial inferential connections between sentences belonging to a given set if they can serve together as premises in logically valid schemes of inference. In turn, a given set of sentences is unified if it cannot be divided into two subsets without a substantial loss of information.

Thus, the question is which from among the considered hypotheses *H1, H2,* and *H3* (all of which solve the problem at hand), should be given priority? The answer lies in the interplay between two factors: the extent of modifications a hypothesis causes within our background knowledge (the fewer changes the better), and the degree of coherence it brings about in our belief set (the higher degree the better). There is no simple formula to settle this interplay, it is rather a matter of decision on a case by case basis. However, it is reasonable to assume that if two hypotheses, *H1* and *H2*, bring about a similar level of coherence, and when *H1* causes substantial modifications in the background knowledge, while *H2* changes it only slightly, it is *H2* that should be preferred. Similarly, when both hypotheses produce similar modifications in the background knowledge, but one of them brings about more coherence, it should be preferred. It must also be added that there may be situations in which *all*

[16] Cf. L. Bonjour, *The Structure of Empirical Knowledge*, Harvard University Press, Cambridge, Mass. 1985.

of the considered hypotheses cause such substantial changes to the background knowledge that they cannot be accepted, even if they solve the problem at hand and bring about much coherence.

As I have already stressed, the situation depicted above, i.e. one which takes into account only the background knowledge and the hypotheses, is a simplification. However, it may easily be extended to give a more fine-grained description of nonfoundational argumentation. For instance, one can utilize the concept of presuppositions, which enables to capture two important aspects of non-foundational thinking. Firstly, one can speak of the presuppositions P of the background knowledge K; in particular, the set P may contain the so-called existential and lexical presuppositions. Existential presuppositions posit the existence of a certain entity or a state of affairs (e.g., when I say that "John has a new car" it presupposes that John exists); lexical presuppositions, on the other hand, are sentences which must be true in order for some concepts to be applicable (the lexical presuppositions of the sentence "John is not a bachelor" include "John is a male"). The introduction of the set of presuppositions P enables one to describe a situation in which a hypothesis leads to the modification not only of some fragment of our background knowledge, but also of our existential commitments and our conceptual scheme (when it causes the rejection of an existential or a lexical presupposition, respectively).

Secondly, the utilization of the concept of a presupposition enables one to account for a situation in which one determines that a given problem is ill-stated. This requires a modification in the way we understand the process of solving problems. We shall say that a hypothesis *H* solves a given problem defined by the set {*p, ~p*} if *H* (possibly together with some other sentences belonging to the background knowledge) deductively implies *p* or *~p*, or it deductively implies *~s*, where *s* is a presupposition of *p*. In the latter case – where *s*, a presupposition of *p*, turns out false – one can say that the solution to the problem defined by the pair {*p, ~p*} is that the problem is ill-stated, i.e. neither *p* nor *~p* can be ascribed truth-values.

The introduction of presuppositions into our formal account of nonfoundational argumentation requires two additional comments. The first is that while our background knowledge should be more stable (i.e., more immune to revisions) than our hypotheses, our presuppositions should be more stable than our background knowledge. Thus, when one chooses from among a number of hypotheses of which all solve the problem at hand and bring about much coherence into one's belief set, the hypothesis should be preferred which causes fewer modifications within one's system of presuppositions. Still, it must be stressed that taking advantage of the mechanism of presuppositions requires changes in the logic underlying nonfoundational reasoning.[17]

The above described procedure meets all the conditions of nonfoundational argumentation that I identified at the beginning of this essay. Firstly, neither the hypotheses one considers,

[17] Cf. B. van Frassen, *Presupposition, implication and self-reference*, „The Journal of Philosophy" 1968, 65(5), pp. 136–152.

nor one's background knowledge, are immune to revisions, and so the revision condition is fulfilled. Secondly, the quality of hypotheses hangs together with the changes they bring about in our belief system, and they are modified or rejected if the changes are unacceptable (so, the feedback condition is met). Thirdly, the background stability condition is fulfilled since although background knowledge is not immune to revisions, from among the hypotheses that solve the problem and bring about a similar level of coherence the one should be preferred that saves most of the original background knowledge. Moreover, in cases when all the hypotheses cause substantial modifications of the background knowledge, they may all be rejected. Fourthly, as the above described formal framework enables one to work simultaneously with several hypotheses, the disputability condition is met (it must be stressed, however, that this requires a special underlying logic, e.g., the so-called defeasible logic).

4. Nonfoundational reasoning in philosophy and science

Numerous philosophical conceptions which have been defended throughout history were foundational or isolationist. They include not only Descartes' grand project, described at the beginning of this essay, but also the philosophy of Immanuel Kant, various post-Kantian philosophies in the 20th century (e.g., Husserl's phenomenology), as well as various incarnations of Thomism.

For example: the defenders of the contemporary versions of Thomism underscore the *autonomy* of philosophical thinking:

> The autonomy of Thomism boils down to the fact that its point of departure, as well as justification criteria, are independent of the truth of revelation as well as the findings of the natural sciences. The results of those disciplines can only (and often do) constitute the source of inspiration for new philosophical questions and determine new issues for metaphysical reflection. The maximalism (of Thomism) is connected to the fact that the goal of philosophizing is to uncover the fist and ultimate causes of the entire reality, including the cause of all causes – the Absolute, which makes the world intelligible and frees philosophical explanation from absurdity.[18]

Thus, the representatives of Thomism repeatedly stress that the autonomy of philosophy hangs together with its specific object and method: while the sciences consider only the so-called proximate causes of things, philosophy is capable of uncovering the ultimate causes of reality. Because of that, no empirical finding can falsify – or serve as a means for the rejection of – a philosophical theory. One should rather speak of two separate *planes of reflection*, philosophical and scientific, and if there is any relationship between them, it is the philosophical method that represents a higher, more profound mode of cognition.

[18] A. Maryniarczyk, *Tomizm*, [in:] *Powszechna encyklopedia filozofii*, http://www.ptta.pl/pef/.

This is an example of foundationalism in philosophy. Thomists believe that there exists only one true view of reality, captured by the Aristotelian-Thomistic conceptual scheme and penetrable by the Aristotelian-Thomistic method. All the three dimensions of this foundationalism – ontological, conceptual and methodological – prevent the findings of the sciences from having any bearing on philosophical discourse: the sciences investigate only the manifestations of substances, utilize a method which cannot account for beings *qua* beings, and hence take advantage of a conceptual scheme which is not translatable into the metaphysical conceptual scheme and is inferior to it. The problem is that this kind of foundationalism in philosophy leads to daring consequences, when the relationship between philosophy and science is considered. As Michael Heller puts it:

> Today, after 300 years of the dynamic development [of the natural sciences], the employment of the strategy [of isolation] leads to two different kinds of danger. Firstly, some deep questions of obvious philosophical character (Did life originate from inanimate matter with no external factor at play? Is human brain only a perfect calculator?) may be rejected as no genuine philosophical issues (as they cannot be formulated within a given philosophical system). Secondly, artificial and highly confusing problems arise when one tries to speak of nature using a language which is inadequate for this purpose (i.e., a language of a certain philosophical system).[19]

[19] M. Heller, *Nauki przyrodnicze a filozofia przyrody*, *op. cit.*, p. 28.

What Heller stresses here is that the faith in a philosophical system – in unshakable ontological or conceptual foundations – may easily lead to dispensing with real problems and devoting time and effort to pseudo-problems. A closed, isolated philosophical system, one that provides answers to any questions, but only such that can be formulated within its conceptual framework, generates neither truth nor understanding, and hence becomes a caricature of what philosophical reflection should be.

This 'negative argument' against foundationalism in philosophy, underscoring the fatal consequences of adopting unshakable ontological foundations and caging oneself in a conceptual scheme fixed for eternity, is only one of a number of ways to defend nonfoundationalism in philosophical thinking. Another would be to stress human fallibility and indicate that the rational strategy in dealing with any problem should be to consider several possible solutions at once, and to treat those solutions as only temporary hypotheses than firm premises. This, boldly speaking, is the basis of Karl Popper's epistemology.

I believe that nonfoundationalism is also characteristic of argumentation in the sciences, which is clearly visible when one considers the accounts of scientific discovery provided by such philosophers as Popper, Lakatos, Kuhn or Feyerabend (there are, of course, differences between their stances, but the basic structure of scientific argumentation they all describe is arguably a nonfoundational one). Let us have a look at one particular example, beginning with an idealization: although it is commonly accepted in the philosophy of science that there exist no theory-free observations and experiments, and that our theories play important heuristic and interpretation roles in our observational and experimental activities, let us assume that there are 'pure' scientific facts (results of observations and outcomes of experiments). What does a scientific explanation of such facts consist in? I posit that there are three different criteria at work here: empirical adequacy, convergence and coherence. An empirically adequate theory must connect facts in such a way that it may serve as a means of prediction (even if not an infallible one). For instance, neuroscientists claim that the human mathematical cognition is partly based on the workings of the so-called Object Tracking System (OTS). It is a system that enables the tracking of multiple individuals (up to 3 or 4), and based on the principles of cohesion (moving objects are recognized as bounded wholes), continuity (objects move on unobstructed paths) and contact (objects do not interact at a distance).[20] The existence of the OTS system is confirmed by a number of tests, including visual short-term memory tasks, multiple-objects tracking tasks, or enumeration tasks. The last kind of tests confirms the human ability of *subitizing*, i.e. of an instant and highly accurate determination of a number of object in small collections (3-4), even presented very briefly.[21] Further, it is speculated that the posterior parietal and occipital regions of the brain play a crucial role

[20] M. Piazza, *Neurocognitive Start-Up Tools for Symbolic Number Representations*, [in:] S. Dehaene, E. Brannon (eds.), *Space, Time and Number in the Brain*, Academic Press, London 2011, p. 270.
[21] *Ibidem*, p. 271.

in the performance of such tasks, which suggests that these regions are the location of OTS.[22] Now, as the current theories posit that OTS is capable of discriminating up to 4 objects, they would be *empirically inadequate* if it turned out that infants are capable of tracking 10 or 15 object at once.

Still, there may exist various competing theories explaining the same set of facts. For instance, there is a controversy regarding how children move from using the numbers 1-4 (an ability which is likely based on the OTS mechanism), which seems to be an innate skill, to mastering arithmetic. One proposal was put forward by Piazza.[23] She observes that the Approximate Number System (ANS) – a mechanism for representing the approximate number of items in sets – may be used to represent not only large numbers, but also small ones. ANS works according to the famous Weber's Law: the threshold of discrimination between two stimuli increases linearly with stimulus intensity. In the case of ANS, Weber's fraction, or the smallest variation to a quantity that can be readily perceived, changes over human development. For newborns it is 1:3, for 6-month-old babies it is 1:2, for 1-year-old children it is 2:3, for 4-year-olds it is 3:4, for 7-year-olds it is 4:5, while for 20-year-olds it is 7:8. It means that a newborn can discriminate between 1 and 3, or 2 and 6, or 10 and 30, but not 1 and 2, 2 and 5, or 10 and 27. Four-year-old children can tell that there is a difference in numerosity between

[22] *Ibidem*, p. 270.
[23] *Ibidem*, p. 275–276.

sets consisting of 6 and 8 or 12 and 16 elements, but not 7 and 8 or 12 and 15. An adults' ANS system is even more 'sensitive': they can discriminate (without counting) between sets consisting of 14 and 16 elements or 70 and 80 elements, but not 70 and 78 elements.[24] Now, Piazza observes that ANS rather quickly becomes very precise as regards small numerosities. Given the progression in the sensitivity of ANS, in order to distinguish between 2, 3, and larger numbers a ratio of 3:4 is needed. This happens at around three years of age, and coincides with the period when children become 'three-knowers'. In other words, Piazza believes that no interplay between OTS and ANS is needed to 'break the number four barrier' – the increasing precision of the ANS system is sufficient to account for this ability.

Another hypothesis which addresses this problem is defended by Spelke. She observes that "children appear to overcome the limits of the core number system when they begin to use number words in natural language expressions and counting."[25] Children learn the first ten counting words by the age of 2, but initially use them without the intended meaning. At three they know that 'one' means one; at four they associate '2', '3' and '4' with the corresponding numerosities. Then, there is a kind of 'jump' – children learn the next numbers quite quickly. This, according to Spelke, requires two things: (a) to understand

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24 *Ibidem*, p. 268–269.

25 E.S. Spelke, *Natural Number and Natural Geometry*, [in:] S. Dehaene, E. Brannon (eds.), *Space, Time and Number in the Brain*, Academic Press, London 2011, p. 304.

that every word in the counting list designates a set of individuals with a unique cardinal value; and (b) to grasp the idea that each cardinal value can be constructed through progressive addition of 1.[26] How is this possible? "For most children, the language of number words and verbal counting appears to provide the critical system of symbols for combining the two core systems (i.e., ANS and OTS), and some evidence suggests that language may be necessary for this construction."[27]

Thus, we have two competing explanations of the same set of facts: that human innate skills cannot account for simple arithmetic, and that something in individual development must facilitate – or even enable – 'breaking the number 4 barrier'. Piazza believes that the increasing sensitivity of ANS is sufficient to explain how it happens, while Spelke claims that it is the development of language skills that plays the pivotal role here. How should one decide which of those is acceptable? One of the possibilities is to use to the criterion of convergence. Let us state some additional facts. First, both children and adults in remote cultures, whose languages have no words for numbers, when dealing with numbers larger than three recognize their equivalence only approximately. Second, deaf persons living in numerate cultures but not exposed to deaf community use a gestural system called homesign; they use fingers to communicate numbers, but only with approximate accuracy. Third, educated adults who suffer language

[26] *Ibidem*, p. 305.
[27] *Ibidem*.

impairments have problems with exact, but not approximate numerical reasoning. Fourth, when doing exact (but not approximate!) tasks, adults spend more time with numbers that are difficult to pronounce, even if they are presented in Arabic notation. Fifth, bilingual adults who are taught some new mathematical facts in one of their languages have difficulties in the smooth production of exact number facts in the other language.[28] All of these facts support Spelke's hypothesis – but not Piazza's – because it is Spelke's claim that language is essential to acquiring arithmetic skills which is empirically adequate for a larger set of facts. In other words, Spelke's hypothesis *converges* on more experimental and observational data than Piazza's.

Another criterion that may be used to pick from among competing – and empirically adequate – hypotheses is coherence. Spelke's claim that language is essential in the development of arithmetic skills seems highly coherent with Lakoff's theory of embodied mind, while Piazza's hypothesis is not. This may be seen as an argument from coherence in favor of Spelke's hypothesis. At the same time, there may be other theories – e.g., some incarnations of the modular mind paradigm – which would favor Piazza's stance. The point is that the criterion of coherence constitutes an important justification standard in neuroscientific discourse.

Thus, even in the idealized picture of neuroscientific practice we have assumed, one that posits the existence of pure,

[28] *Ibidem*, p. 307.

theory-free facts, there are *competing explanations* of the same sets of facts, and the criteria for choosing from among them include convergence and coherence. Of course, the situation becomes even more complicated when we drop our idealizing assumption and admit that our theories – and, in particular, some of our entire paradigms, such as embodiment or modular paradigm – provide both heuristic and interpretation frameworks for neuroscientific practice. But the conclusion remains the same: neuroscientific thinking, at its core, *is non-foundational*. Neuroscientific hypotheses – as well as background knowledge – are revisable, and the revisions are caused not only by empirical inadequacy of our theories, but also by the consequences we draw from our new hypotheses. The background knowledge in neuroscience is usually quite stable (as illustrated by the persistence of entire paradigms, such as the embodied or modular one). Finally, neuroscientific argumentation fulfills the disputability condition: one usually formulates and chooses from among a number of hypotheses explaining the given phenomenon.

*   *   *

In this essay I have tried to illustrate two things: that argumentation in philosophy and science is nonfoundational, and that nonfoundational reasoning – one that meets the revisability, feedback, background stability and disputability conditions – may be accounted for logically. Of course, there may exist other informal and formal explications of nonfoundational reasoning which are perhaps better than the one presented here. In particular, the present proposal is quite heterogeneous, as it glues together several different formal mechanisms (belief revision, the theory of logical coherence, and defeasible logic). It is possible that a more coherent formal framework could do the same job. I leave this problem for further research.

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