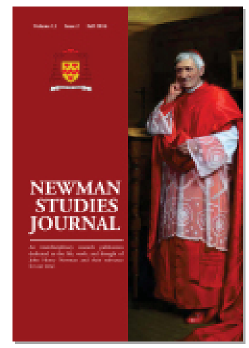
Cognitive Inhibition and the Conscious Assent to Truth: A Newmanian Perspective



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COGNITIVE INHIBITION AND THE CONSCIOUS ASSENT TO TRUTH: A NEWMANIAN PERSPECTIVE

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When must a specific cognitive habit be called upon to solve a problem? In the subject's learning process, "knowing-to" is connected with a conscious particular judgment of truth or "aha" moment enacting a new behavioral schema. This paper comments on recent experiments supporting the view that a shift from automatic to controlled forms of inhibition, involving conscious attention, is crucial for detecting errors and activating a new strategy in complex cognitive situations. The part that consciousness plays in this process agrees with its philosophical description as "judge of truth", and can thus be regarded as an essential precursor to the development of higher cognitive habits. In this regard, John Henry Newman's explanation of human assent to truth, for which our consciousness of self is always prior,[1] proves to be decisive.

Introduction

Why does a theoretical physicist decide to tackle a problem from the point of view of its mathematical symmetries instead of performing a calculation? The scientist chooses the strategy that is deemed to produce the most relevant information. However, all the strategies have not always been available. Mathematical discovery has happened in history thanks to the creativity of a good number of thinkers, whose new insights proved to be decisive for the developing of new branches of mathematical thinking. New ways of confronting well-posed problems may eventually become intellectual habits of generations to come, but such habits can only develop after the validity of new perspectives have been checked. What the history of Mathematics shows is somehow reproduced in mathematical learning. The creativity or 'aha' moment must be experienced by someone who learns new ways to attack mathematical problems and develops a new cognitive habit. For most people, this creative moment is unavoidably related to the confrontation with, and acquisition of, the truth or adequacy of the new way of thinking. The aim of this paper is twofold: (a) to show the neuroscientific support of this "confrontation with the truth" moment thanks to some inhibition mechanisms of the brain;[2] (b) to present John Henry

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[1] John Henry Newman, *An essay in aid of a grammar of assent* (London: Longmans, Green, and Co., 1903 [1870]), 61. Hereafter cited: Newman, *GA*.

[2] "Cognitive inhibition is the stopping or overriding of a mental process, in whole or in part, with or without intention": Colin M. MacLeod, "The concept of inhibition in cognition," in David S. Gorfein

Newman's perspective on the human being's assent to truth as a valid philosophical framework for the sake of understanding intentional inhibition. This deliberate inhibitory process is needed in order to free a new intellectual habit of tackling a problem. In short, intellectual habits need confrontation of the thinking subject with truth before they can develop.

Thinking mathematically covers many different brain tasks and, overall, little is known about how abstract mathematical thinking emerges from the perspective of neurosciences. For example, even if the distinction between primary topographic representations in the brain – as the one related to numerosity perception[3] – and abstracted representations of higher cognitive functions has been challenged, differences still remain – e.g. regarding lack of neuron response to symbolic number representations.[4] Judgments about counting and the use of small natural numbers rely on different processes in comparison with more complex mathematical abilities, as multiplication and division. However, neurosciences say little about the content of mathematical thinking and its validity regarding the actual knowledge of the world. Many scientists agree with Stewart and Golubitsky's claims that "the mathematical patterns that scientists observe in nature are not delusions: they're really there. The question is, to what extent are they fundamental to the way nature works; and to what extent are they just convenient descriptions that the human mind can grasp?"[5] "Are symmetries intrinsic patterns of nature, or artefacts of human perception? . . . [T]hose patterns that the brain is able to detect may not be arbitrary: it may have evolved to detect the patterns that are 'really' present."[6] "Many of the most striking phenomena associated with symmetric systems turn out to be model-independent, that is, due to the symmetry of the system, rather than to the detailed equations normally used to model it."[7] Even though such mathematical subtleties stem from abstraction, they nevertheless correspond to reality.

Creativity, Learning and Truth

The content of mathematical propositions is thus different from the neurological processes that are necessary for their formulation. Confrontation with the truth and its understanding – at least in Mathematics – poses serious challenges to

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and Colin M. MacLeod (eds.), *Inhibition in cognition* (Washington, DC: American Psychological Association, 2007), 3–23, 5. Along the paper, I shall mainly focus on intentional inhibition.

[3] Numerosity can be defined as the set size of a group of items.

[4] Ben M. Harvey, Barrie P. Klein, Natalia Petridou, and Serge O. Dumoulin, "Topographic representation of numerosity in the human parietal cortex," *Science* 341, 6150 (2013): 1123–26, 1126. doi:10.1126/science.1239052.

[5] Ian Stewart and Martin Golubitsky, *Fearful symmetry: is God a geometer?* (London: Penguin Books, 1993), 256. Hereafter cited: Stewart and Golubitsky, *Fearful symmetry*.

[6] Ibid., 259.

[7] Ibid., 263.

a pretended fully computational view of human cognition.[8] One of his most renowned critics is Roger Penrose, who claims:

> One might imagine that it would be possible to list all possible 'obvious' steps of reasoning once and for all, so that from then on everything could be reduced to computation – i.e. the mere mechanical manipulation of these obvious steps. What Gödel's argument shows is that this is not possible. There is no way of eliminating the need for *new* 'obvious' understandings. Thus, mathematical understanding cannot be reduced to blind computation.[9]

"[W]e indeed perform non-computational feats when we consciously understand".[10] We are not able to characterize all mathematical concepts in terms of computational rules. On the contrary, new computational rules can be defined only after a new understanding and conceptualization of a particular problem has been achieved and tested by mathematicians – think, e.g. about the introduction of non-Euclidean geometries. Invention in Mathematics cannot be modeled by a classical algorithm.[11]

Hence, statements such as "it is always an empirical question just what human ideas are like, mathematical or not";[12] "the only scientific account of the nature of mathematics is therefore an account, via cognitive science, of human mind-based mathematics"[13] are highly problematic. While one may investigate the origin of mathematical ideas from a cognitive perspective, there remains the question of their value and meaning. Cognitive science of mathematics does not address the question of mathematics itself. It deals with the neurological origin of mathematics (with underlying assumptions that they are not even aware of), but absolutely misses the point about the origin of the truth-content in mathematical propositions. Actually, research in pure mathematics contradicts this purely cognitive view. Some human beings study mathematics for the sake of truth.[14] The problem is not the origin of mathematical ideas (as Lakoff and Núñez emphasize), but the recognition of their

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[8] The computational theory of mind is still one of the paradigms of cognitive science, see Michael Rescorla, "The computational theory of mind," in Edward N. Zalta (ed.), *The Stanford Encyclopedia of Philosophy* (Winter 2015).
URL = <http://plato.stanford.edu/archives/win2015/entries/computational-mind/>.

[9] Roger Penrose, *Shadows of the mind* (Oxford: Oxford University Press, 1994), 56. Hereafter cited: Penrose, *Shadows*.

[10] Ibid., 61.

[11] Ignacio Sols, "La ciencia lo dijo. Relaciones entre ciencia, razón y fe," *Scientia et Fides* 1/1 (2013): 87–149, 140. doi:http://dx.doi.org/10.12775/SetF.2013.004.

[12] George Lakoff and Rafael E. Núñez, *Where mathematics comes from* (New York: Basic Books, 2000), xii.

[13] Ibid., 4.

[14] I will not enter the question about the external, objective truth of mathematics. I will only say this here: Even if symmetries, numbers, elementary particles, intermediate bosons or spacetime geometry do not exist until a human mind think on them (through some neural process), a human mind capable of thinking them must be something different from sheer physical nature. This is obviously related to the hard problem of consciousness. Cfr. David J. Chalmers, "Facing up to the problem of consciousness," *Journal of Consciousness Studies* 2/3 (1995): 200–19.

truth and thus their validity for the formation of, e.g. a new branch in Mathematics. Shifts of paradigm, a new set of axioms, and different kinds of generalizations need inhibition of some old-fashioned mathematical habits. Cognitive inhibition can spark off new thinking habits.

It is clear the relevance of this view for education. "Knowing-about" forms the heart of institutionalized education: students can learn and be tested on it. But success in examinations gives little indication of whether that knowledge can be used or called upon when required, which is the essence of "knowing-to."[15] When should a specific intellectual habit be called upon? "Knowing-to" has to do with the conscious use of cognitive habits. It implies a conscious judgment of the problem from a new conceptual perspective. When the true answer for the problem is found from such perspective, new habits can form with their corresponding "knowing-to"[16] – the reason why they can be called upon. Either in the case of a mathematical discovery or in the case of the understanding of a new mathematical problem by a student (a sort of discovery for her/him), we are in face of the question of assenting to the truth: a conscious judgment about the truth, which is different from the methods by which one attains it. As John Henry Newman explains in the second part of his *Grammar*, "[N]either apprehension nor inference interferes with the unconditional character of the assent, viewed in itself. The circumstances of an act, however necessary to it, do not enter into the act; assent is in its nature absolute and unconditional, though it cannot be given except under certain conditions."[17] In my opinion, such assent is instantiated by the educational "aha" moment, which must be carefully checked to avoid illusions and mistakes afterwards. The practice of reflection is a means to help students improve their "knowing-to" act in the moment. The triggering situation for the enactment of a behavioral schema must be conscious. Being explicit about one's own thinking improves mathematical teaching and learning.[18]

Neuroscientific support: The role of inhibition

Extensive neuroscientific work shows the specificity of some high order cognitive processes enacting inhibition. My claim is that those high order cognitive

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[15] John Mason and Mary Spence, "Beyond mere knowledge of mathematics: the importance of knowing-to act in the moment," *Educational Studies in Mathematics* 38 (1999): 135–61; Kien Lim and Annie Selden, "Mathematical habits of mind," in Susan L. Swars, David W. Stinson, and Shonda Lemons-Smith, *Proceedings of the 31st Annual Meeting of the North American Chapter of the International Group for the Psychology of Mathematics Education, vol. 5* (Atlanta, GA: Georgia State University, 2009), 1576–83, 1578. Hereafter cited: Lim and Selden, "Mathematical habits of mind."

[16] There is here an interesting parallelism between these different forms of knowing and Michael Polanyi's distinction between "focal" and "subsidiary" awareness. Focal awareness is necessarily conscious, while subsidiary awareness may have different degrees of consciousness": Michael Polanyi, *Personal knowledge. Towards a post-critical philosophy* (London: Routledge, 1962), 97. "The logical antecedents of an informal mental process . . . come to be known subsidiarily in the very act of their application; but they can become known focally only later, from an analysis of their application, and, once focally known, they can be applied by re-integration to guide subsidiarily improved performances of the process.": Ibid., 172. For this reason, my focus here is on the focal awareness of "knowing-to."

[17] Newman, *GA*, 157.

[18] Lim and Selden, "Mathematical habits of mind."

processes are the neural correlate of the "judgment and assent to truth" that become necessary in order to develop a new intellectual habit. Inhibitory control is an executive process involved in attention, self-regulation, and consciousness. Intelligence is closely tied to the ability to inhibit a misleading behavior, judgment, or strategy, and inhibition is precisely the cognitive mechanism that should allow one to redirect attention towards the logically relevant items.[19] For instance, as is well known in learning, emotional inhibition is necessary for abstraction in logic.

Houdé's group has experimentally shown that the biased (spatial) to logical shift in the way of solving a logical problem with geometrical objects of different colors and shapes stems specifically from the executive impact of matching-bias inhibition. It is not the effect of practice or instruction, but a specific consequence of the executive training in matching-bias inhibition. The relevant point here is that inhibition allows subjects to redirect attention to the logically correct shapes, a shift process in which the activated brain networks can change radically, from posterior to anterior, in the same subjects, carrying out the same task, depending on their ability to inhibit a misleading strategy.[20] This posterior-to-anterior reconfiguration brought about by inhibitory control might be the neural correlate of human abstraction, the ability to break away from perceptual biases during cognitive development. This phenomenon seems to be quite general irrespective of the subject's age. Several concurrent reasoning strategies might compete at any time, even during adulthood, in such a way that perceptual responses often override logical ones, and cognitive inhibition turns out to be the key that opens the door to deductive logic. Cognitive inhibition is therefore a key executive function in adult reasoning.[21] The acquisition of increasingly complex knowledge is based on the ability to resist (inhibit) heuristics and previously acquired knowledge. Whether this is in good accord with (neo) Piagetian postulates is controversial.[22] Nevertheless, my claim is that inhibition of the misleading strategy (habit) is performed by the conscious attention in determining the truth of the new statement. Inhibition of the wrong habit is the neural correlate of

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[19] Olivier Houdé, Laure Zago, Emmanuel Mellet, Sylvain Moutier, Arlette Pineau, Bernard Mazoyer, and Nathalie Tzourio-Mazoyer, "Shifting from the perceptual brain to the logical brain: the neural impact of cognitive inhibition training," *Journal of Cognitive Neuroscience* 12/5 (2000): 721–8. Hereafter cited: Houdé et al., "Shifting from the perceptual brain to the logical brain."

[20] Ibid.

[21] Houdé and Tzourio-Mazoyer, "Neural foundations of logical and mathematical cognition," *Nature Reviews. Neuroscience* 4 (June 2003): 1–9.

[22] For a favorable position, see Grégoire Borst, Nicolas Poirel, Arlette Pineau, Mathieu Cassotti, and Olivier Houdé, "Inhibitory control efficiency in a Piaget-like class-inclusion task in school-age children and adults: a developmental negative priming study," *Developmental Psychology* 49/7 (2013): 1366–74. doi:10.1037/a0029622; Amélie Lubin, Julie Vidal, Céline Lanoë, Olivier Houdé, and Grégoire Borst, "Inhibitory control is needed for the resolution of arithmetic word problems: a developmental negative priming study," *Journal of Educational Psychology* 105/3 (2013): 701–8. doi:10.1037/a0032625. Hereafter cited: Lubin et al., "Inhibitory control is needed for the resolution of arithmetic word problems." For an opposite view, see Alan Baddeley, "Theories, models, and controversies," *Annual Review of Psychology* 63 (2012): 1–29; Sandrine Rossi, Amélie Lubin, Céline Lanoë, and Arlette Pineau, "Une pédagogie du contrôle cognitif pour l'amélioration de l'attention à la consigne chez l'enfant de 4-5 ans," *Neuroéducation* 1/1 (2012): 29–54. Hereafter cited: Rossi et al., "Une pédagogie du contrôle cognitif."

noticing that something goes wrong and careful verification is needed. For understanding a deeper truth, it is necessary noticing where the nature of the previous mistakes lies.

The specificity of Houdé's training lies in the warning elements for inhibitory control. Sheer logical training did not enable subjects to shift from a matching bias to a logical strategy. On the contrary, in Houdé's experiment it is necessary to make the subjects aware of the possible mistake, when identifying the wrong answers. This belongs to the inhibition learning.[23] But this is a role of consciousness: understanding why something is wrong or true. Houdé's group helps the subject to be conscious of the implicit mistake she/he is making, and therefore, what she/he must do to avoid the trap. The important lesson here is: we can change the thinking strategy and the corresponding working areas of the brain only when we become aware of the mistake (inhibition bias training, induced inhibition) and consciously try to avoid it (active inhibition after training). The dynamics of inhibition and activation of strategies allows for the cognitive flexibility at the core of the cognitive architecture. It must be learned how to resist to dominant answers in order to correct mistakes.[24]

Automatic and deliberate inhibitory processes

Overall, how errors impact the processing of subsequent stimuli and in turn shape behavior remains unresolved in neuroscience. However, "the literature so far documents two main mechanisms of training-induced behavioral and brain plasticity of inhibitory control: the development of bottom-up, automatic forms of inhibition and the optimization of top-down, controlled forms of inhibition."[25] Actually, many results are generally interpreted in terms of a shift from a fast automatic to a slow controlled form of inhibitory control induced by the detection of errors, which could have been caused by an attentional modulation.[26] Some experiments on post error slowing in subjects support the view that outcome expectancy (not accuracy) is crucial for such effect. Post error slowing is caused by attentional orienting to unexpected events, and not by a strategic adjustment of cognitive nature.[27] Shifting to post error slowing is not always due to lack of accuracy. There seems to be a qualitative criterion to decide when accuracy is important, because the expectancy is

[23] Houdé et al., "Shifting from the perceptual brain to the logical brain."
[24] Rossi et al., "Une pédagogie du contrôle cognitif", 31.
[25] Lucas Spierer, Camille F. Chavan, and Aurelie L. Manuel, "Training-induced behavioral and brain plasticity in inhibitory control," *Frontiers in Human Neuroscience* 7 (August 2013): 427. doi:10.3389/fnhum.2013.00427. Hereafter cited: Spierer et al., "Training-induced behavioral and brain plasticity in inhibitory control."
[26] Aurelie L. Manuel, Fosco Bernasconi, Micah M. Murray, and Lucas Spierer, "Spatio-temporal brain dynamics mediating post-error behavioral adjustments," *Journal of Cognitive Neuroscience* 24/6 (2012): 1331–43. doi:10.1162/jocn_a_00150.
[27] W. Notebaert, F. Houtman, F. Van Opstal, W. Gevers, W. Fias, and T. Verguts, "Post-error slowing: an orienting account," *Cognition* 111 (2009): 275–79; Elena Núñez Castellar, Simone Kühn, Wim Fias, and Wim Notebaert, "Outcome expectancy and not accuracy determines posterror slowing: ERP support," *Cognitive, Affective & Behavioral Neuroscience* 10/2 (2010): 270–8. doi:10.3758/CABN.10.2.270.

not fulfilled. In short, the subject has expectancy. She/he looks for an *adaequatio* (adequacy) between mind and reality. And she/he needs consciousness for that, i.e. attentional reorientation.

There are intentional inhibitory mechanisms when one deliberately resists using a misleading cognitive strategy. For example, an additional way to improve children's understanding of 'inconsistent language" problems is to emphasize the need to inhibit the spontaneous automatic response (what have been previously learned) to activate a more reflexive strategy.[28] It is then customary to distinguish between automatic (bottom-up) and intentional (top-down) inhibitory control, with the possibility of different transitions between these two regimes. For instance, with training, automatic processes progressively replace top-down controlled processes to inhibit prepotent motor responses. However, when inhibitory control training is based on a task involving inconsistent mappings between stimulus and response, automatic processing would not develop. Rather, only top-down control mechanisms would be constantly solicited during the training phase, and thus ultimately modified by practice.[29] Moreover, the training for the transition from deliberate to automatic controlled forms of inhibition seems to be problem-specific,[30] and cannot be easily generalized. Inhibition may eventually become habitual, but always after a top-down confrontation with the truth or falseness of the response to a particular problem. Error commission allows shifting from fast automatic to slow top-down controlled forms of inhibition. These errors lead to the (re)engagement of controlled forms of inhibition.[31]

I therefore claim that intentional inhibitory control always exists when dealing with a new problem where creativity and checking of the truth is needed. Deliberate inhibition is necessary even though you have the proper knowledge. In other words, intentional inhibition is an effect of detecting error, assenting to truth, and shifting to the new cognitive strategy. So, awareness is necessary for shifting from fast to slow form of inhibitory control. The role of consciousness would have to do with deliberate inhibition of common (habitual) reasoning strategies. This would allow for the activation and recruiting of the brain areas involved in a new type of reasoning. Consciousness – attentively deciding that some habitual reasoning is not valid to tackle the problem at stake – would pave the way for using brain areas that perform new types of reasoning. The point is how, why and to which new strategy do I shift my new expectation value? In Clark's terminology,[32] to which "hyperprior" do I change when I am facing a new problem? The additional role of consciousness is thus to judge the validity of the reasoning for reaching truth or new perspectives about a

[28] Lubin et al., "Inhibitory control is needed for the resolution of arithmetic word problems."
[29] Spierer et al., "Training-induced behavioral and brain plasticity in inhibitory control."
[30] Lisa B. Thorell, Sofia Lindqvist, Sissela Bergman Nutley, Gunilla Bohlin, and Torkel Klingberg, "Training and transfer effects of executive functions in preschool children," *Developmental Science* 12/1 (2009): 106–13. doi:10.1111/j.1467-7687.2008.00745.x; Spierer et al., "Training-induced behavioral and brain plasticity in inhibitory control."
[31] Ibid.
[32] Andy Clark, "Whatever next? Predictive brains, situated agents, and the future of cognitive science," *Behavioral and Brain Sciences* (May 2013): 1–24. doi:10.1017/S0140525X12000477.

specific question.[33] When this judgment is done, a new intellectual habit is ready to be used. In this context, Newman's philosophical perspective becomes relevant.

The Newmanian perspective

In the second part of the *Grammar*, entitled "Assent and Inference", Newman explains the differences between two mental acts that are irreducible to one another. "Acts of Inference are both the antecedents of assent before assenting, and its usual concomitants after assenting."[34] As mentioned at the end of the second section: "[N]either apprehension nor inference interferes with the unconditional character of the assent, viewed in itself. The circumstances of an act, however necessary to it, do not enter into the act; assent is in its nature absolute and unconditional, though it cannot be given except under certain conditions."[35] In my view, it is precisely the distinctiveness of the act of assenting which manifests itself in the inhibition of old cognitive strategies when the subject is confronted with learning a new truth. The subject must overcome his/her internal prejudices that hinder "assent to the most incontrovertible proofs."[36]

However, especially in the case of truths, as the experiments of Houdé's group show, the need of longer times for attaining such truths should be expected because "[t]hough every step may be indisputable, it still requires a specially sustained attention and an effort of memory to have in the mind all at once all the steps of the proof, with their bearings on each other, and the antecedents which they severally involve; and these conditions of the inference may interfere with the promptness of our assent."[37] The important point to keep in mind is that assent is not necessarily a consequence of the process of inference: "When I assent to a doubtfulness, or to a probability, my assent, as such, is as complete as if I assented to a truth; it is not a certain degree of assent. And, in like manner, I may be certain of an uncertainty."[38] Because of that completeness or perfection, the subject's search for assent is guiding the whole process, eventually changing the cognitive strategy in order to attain certitude, "the perception of a truth with the perception that it is a truth."[39]

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[33] Of course, one could still maintain that minimizing-error strategies are selected because of selective advantages. But then one should not experience these new strategies as goal-directed activities or a conscious shift of thinking habits. In other words, selection does not explain my conscious dealing with error and truth in judgment. For this particular problem, selection remains as a would-be explanation remaining in itself unexplained: Carlos Blanco, "Truth in an evolutionary perspective," *Scientia et Fides* 2/1 (2014): 203–19. doi:10.12775/SetF.2014.012. Natural selection has nothing to do with truth in statements, but with mere development of physical laws in nature; but again, mere development does not whatsoever bring in itself comparison between input and expected signals in any subsystem. However, there seems to be a "subjective" meaning of physiological events to living beings: Stuart A. Kauffman, *Investigations* (Oxford: Oxford University Press, 2000).

[34] Newman, *GA*, 189.

[35] Ibid., 157.

[36] Ibid., 169.

[37] Ibid., 170.

[38] Ibid., 175.

[39] Ibid., 197.

Assent thus means the subject's acknowledgment of the truth – either of a doubt, of a probability or of a simple truth – for which the inhibition of the wrong cognitive strategy is a necessary condition: "[N]o one can be called certain of a proposition, whose mind does not spontaneously and promptly reject, on their first suggestion, as idle, as impertinent, as sophistical, any objections which are directed against its truth."[40] Assent is then incompatible with certain subjective attitudes revealing fear of error, as "irritation and impatience of contradiction, vehemence of assertion, determination to silence others, – these are the tokens of a mind which has not yet attained the tranquil enjoyment of certitude."[41]

According to Newman, there are some conditions in order to attain certitude as unconditional complex assent:

> [T]hat it follows on investigation and proof, that it is accompanied by a specific sense of intellectual satisfaction and repose, and that it is irreversible. If the assent is made without rational grounds, it is a rash judgment, a fancy, or a prejudice; if without the sense of finality, it is scarcely more than an inference; if without permanence, it is a mere conviction.[42]

Now, what is remarkable for the neuroscientific viewpoint is that "[a]s a conscientious deed is attended by a self-approval which nothing but itself can create, so certitude is united to a sentiment *sui generis* in which it lives and is manifested."[43] In other words, assent involves the whole subject in a specific manner, which cannot be accounted for by means of mere objective conditions. Therefore, Newman is undertaking the problem "of ascertaining how it comes to pass that a conditional act leads to an unconditional."[44] The problem of assent for neurosciences is the problem of the subject, because "science, working by itself, reaches truth in the abstract, and probability in the concrete; but what we aim at is truth in the concrete."[45]

The distinction between inference and assent makes room for a better understanding of the subject's personal involvement in the latter, since "from the nature of the case, and from the constitution of the human mind, certitude is the result of arguments which, taken in the letter, and not in their full implicit sense, are but probabilities . . ."[46] Sheer objectivity is thus not a *sufficient* condition for assent because "a proof, except in abstract demonstration, has always in it, more or less, an element of the personal, because 'prudence' is not a constituent part of our nature, but a personal endowment."[47] Moreover, when assenting to some conclusions, as Newman stresses, "we have arrived at these conclusions – not *ex opere operato*, by a scientific necessity independent of ourselves, – but by the action of our own minds,

[40] Ibid.
[41] Ibid., 201.
[42] Ibid., 258.
[43] Ibid., 204.
[44] Ibid., 259.
[45] Ibid., 279.
[46] Ibid., 293.
[47] Ibid., 317.

by our own individual perception of the truth in question, under a sense of duty to those conclusions and with an intellectual conscientiousness."[48]

Newman's perspective allows us to consider conscious inhibition as the beginning of a different way of judgment, so that a truth is attained by the subject with the help of new cognitive strategies. "Judgment then in all concrete matter is the architectonic faculty; and what may be called the Illative Sense, or right judgment in ratiocination, is one branch of it."[49] But "the sole and final judgment on the validity of an inference in concrete matter is committed to the personal action of the ratiocinative faculty . . ."[50] "It is the mind that reasons, and that controls its own reasonings, not any technical apparatus of words and propositions. This power of judging and concluding, when in its perfection, I call the Illative Sense . . ."[51] Due to such personal involvement in the ratiocinative faculty, driven by the final achievement of assent, one may explain why

> . . . in any inquiry about things in the concrete, men differ from each other, not so much in the soundness of their reasoning as in the principles which govern its exercise, that those principles are of a personal character, that where there is no common measure of minds, there is no common measure of arguments, and that the validity of proof is determined, not by any scientific test, but by the illative sense.[52]

To sum up, Newman's *Grammar* offers a relevant philosophical framework for neuroscience in which how a subject reaches the truth of a problem is different from his own assenting to truth. The act of assent is manifested by the inhibition of mistaken cognitive strategies, marked by post-error longer times, which shows that the whole subject is compromised in the search of truth. Eventually, the cognitive subject will use her/his illative sense according to a new cognitive habit (or strategy) in order to reach a new truth, preparing the ground for a new assent. It is in this particular sense that human assent can lead to a new cognitive strategy – understanding that there is more to any particular human knowledge that its ways of judging.

Some consequences of Newman's perspective

The judgment of truth to accept or reject a new strategy confronts us with the unavoidable role of consciousness in checking the validity of new ideas. This explains, in particular, why the judgment of truth of a specific mathematical generalization cannot initially be a mathematical habit, but something that is assented to. Mathematicians and theoretical scientists must beforehand decide the *relevant* strategy for tackling a problem, and then make use of an intellectual habit to solve it,

[48] Ibid., 318.
[49] Ibid., 342.
[50] Ibid., 345.
[51] Ibid., 353.
[52] Ibid., 413.

which might be new in the case of new theoretical discoveries. Consciousness, as something different from a brain state, is needed in order to establish the validity of a new theoretical perspective. Once this is reached, new mathematical habits may appear. In other words, consciousness mediates between the unconscious formation of new ideas and the development of new habits. Habits need the conscious check of the new idea's validity in order to be formed. Consciousness is the forerunner and the necessary condition for habits to appear. None of Lakoff and Núñez's work can consistently explain the specific content of human creativity.

In this context, the philosophical retrieval of the idea of *adaequatio* seems appropriate. When an intellectual discovery is done, there is consciousness of a new perspective being more adequate for a problem that was hitherto tackled differently. Thus, for example, mathematical discovery is a matter of higher unification of perspectives. This is something non-algorithmic, non-habitual, requiring a very high degree of consciousness of the problem at stake and the adequacy of the new perspective. This can be extended, *mutatis mutandis*, to empirical sciences needing theoretical descriptions. Science has mainly to do with truth. For that reason, it carefully checks what is not true – with the help of current-science habits – and disregards those new ideas that do not fulfill the requirements of truth (falsifiability criterion). The allowance of a new perspective implies an actual consciousness of (partial) truth: a judgment of truth and an *assent* to truth.

As mentioned in the previous section, assent to truth is something different from checking the validity of the conclusions in a step-by-step procedure[53] because it is *personal*. On one hand, "[o]ur consciousness of self is prior to all questions of trust or assent;"[54] on the other:

> . . . methodical processes of inference, useful as they are, as far as they go, are only instruments of the mind, and need, in order to their due exercise, that real ratiocination and present imagination which gives them a sense beyond their letter, and which, while acting through them, reaches to conclusions beyond and above them. Such a living *organon* is a personal gift, and not a mere method or calculus.[55]

When we correct a mistake and assent to the (possible) truth of a new perspective, we come to it not by a scientific necessity independent of ourselves, but by the action of our own minds, by our own individual perception of the truth in question, under a sense of duty to those conclusions and with an intellectual conscientiousness.

[53] "[T]he conclusiveness of a proposition is not synonymous with its truth. A proposition may be true, yet not admit of being concluded; – it may be a conclusion and yet not a truth. To contemplate it under one aspect, is not to contemplate it under another; and the two aspects may be consistent, from the very fact that they are two *aspects*." Ibid., 190.
[54] Ibid., 61.
[55] Ibid., 316.

> . . . [t]here is no ultimate test of truth besides the testimony born to truth by the mind itself, and . . . this phenomenon, perplexing as we may find it, is a normal and inevitable characteristic of the mental constitution of a being like man on a stage such as the world. His progress is a living growth, not a mechanism; and its instruments are mental acts . . .[56]

In short, scientific activity is primarily concerned with looking for the truth, as an *adaequatio* of the human intelligence with some specific reality. With the exception of some branches of cognitive neurosciences, science is not directly worried about the logical mechanism that may guide to truth. The former is a means for the latter. "[T]he sole and final judgment on the validity of an inference in concrete matter is committed to the personal action of the ratiocinative faculty . . ."[57]

Conclusions

With the help of a top-down inhibitory mechanism, the human person needs to assent to truth in order to trigger new habits and cognitive strategies. Assent to truth is a specifically conscious, spiritual activity, which cannot be explained away in physiological terms, since acknowledgment of adequacy is inescapable. What would it physiologically mean that the mismatch between input signal and expected signal must be corrected? The acknowledgment of identity (or adequacy) corresponds to rational human judgment based on conscious attention. From the viewpoint of neuroscience, the mechanism of deliberate inhibition is a top-down mechanism. It frees the possibility of thinking on the problems otherwise. Therefore, knowledge is not a matter of having built-in structures that are able to perform a specific cognitive task, but a matter of attentively selecting which cognitive strategy must be used. Conscious attention to the meaning and truth of the statements about the problem is ultimately responsible for triggering the top-down inhibitory mechanism and for enabling new cognitive habits.

The confrontation of some mathematical problems – as global geometrical visualization – already offers a hint about the non-computability of new solving strategies, [58] and is valid for a wider range of assenting-to-truth conscious experiences. Mathematical habits have to do with learning, and learning has to do with truth and value: an adequacy of the new mathematical ideas to the previous network of ideas which must be carefully checked and understood by the subject. Habits of mind are thinking that "one acquires so well, makes so natural, and incorporates so fully into one's repertoire, that they become well mental habits – one not only can draw upon then easily, but one is likely to do so."[59] For this to happen,

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[56] Ibid., 350.

[57] Ibid., 345.

[58] "An approach entirely based on a bottom-up organization would give very poor results. It is difficult that a good simulation of the geometrical motions or the topological restrictions of some objects could be achieved without *understanding* what is actually going on." Penrose, *Shadows*, 60.

[59] E. Paul Goldenberg, "'Habits of Mind' as an Organizer for the Curriculum," *Journal of Education* 178 (1996): 13–34; Joanna Mamona-Downs, Samuele Antonini, Fulvia Furinghetti, Francesca

attention is required in the form of a deliberate inhibitory mechanism. Once the subject has consciously given the meaning of truth or error to a definite input signal (in comparison with her/his expectancy signal), the transition from deliberate to automatic inhibition is available. Hence, new conscious perceptions of truth allows for new meanings and new intellectual habits (as mathematical habits).

According to an extended neuroscientific view, truth (even mathematical truth) is what exists due to adaptive struggle.[60] Is that enough to explain what happens when we begin to think in a different way thanks to a new intellectual habit? Is the rejection of an outdated intellectual habit (according to the Popper's falsifiability rule) a mere adaptive strategy? Why is consciousness so much involved in this process, as response times show? Why do I reject or accept *now* one particular strategy? This is especially important when dealing with an eventually *new* intellectual discovery. But even more dramatically one may ask: Why does a new habit of thinking – with its correlated different use of the brain – appear when one consciously learns and understands some mathematical truth? As Stewart and Golubitsky affirm, "the aim of science is not just the manufacture of new toys: it's the enrichment of the human spirit."[61] John Henry Newman's philosophical framework continues to offer a simpler way of understanding these transitions, not in terms of pure physical processes, but in terms of personal confrontation with and assent to the truth of new ideas.

Morselli, Elena Tosetto, Corine Castela, Martin Downs, et al., *Synopsis of the Activities of Working Group 14, Cerme-5, on the Theme of "Advanced Mathematical Thinking"* (CERME 5, 2007).

[60] Within such perspective, truth is the partial result of a process of random variation and natural selection (adaptive struggle) and, in that sense, "a posteriori". However, when we talk about human knowledge of the truth, despite its provisional nature, we are implicitly assuming for our thoughts the fulfilment of some consistency relations that are a priori and not the result of a physical process. For more on this issue, see footnote 33.

[61] Stewart, Golubitsky, *Fearful Symmetry*, 128.