Functional Research in Neuroscience Robert Henman June 2013

Part I: The Functional Specialty of Research

The first of the projected E-seminars[1] organized by Professor Philip McShane was on functional research.[2] It succeeded in illustrating the gap between the description in the chapter on research in *Method* and the need for an introductory account of the activity. What is at stake is an emergent new differentiation of consciousness. Functional research is to be a type of luminously-controlled restraint and thoroughness that is found occasionally in eccentrics, like the professor buried in the archives content to rummage round endlessly for a piece of a lost text, or like what is found presently in the field of physics, where expert observers are, or have to be, content with looking for anomalies in experimental setups.

But both the eccentric professor and the community of research physicists have an *a priori*, a context. There is the professor's background of a deep appreciation of literature or there is, in the mind of the research physicist, what is called *The Standard Model*. The focus is such that data in its possible suggestiveness is tackled in a thorough fashion, helped by the functional restraint: there is, so to speak, nowhere else to go, or like the eccentric professor, there is no desire to go anywhere else.

In the seminar on functional research the convenient and familiar illustration to Lonergan readers was that of Fr. Boyer pointing out a text of Aquinas to Lonergan and claiming that it was worth looking into.[3] This raises the issue of a possible division of labour, if Boyer had passed on in an orderly fashion all the relevant texts. Think too of the accumulated and ordered anomalies that a good research team might come up with. But all this thinking and imagining cannot replace the data on functional research provided, for its understanding, by the venture of actually doing it. So, here, I venture to do functional research that is significant for both Lonergan studies and for neuroscience. My first and central effort is towards manifesting the differentiation of functional research. Let me illustrate immediately the strategy in a way that echoes Boyer's suggestion to Lonergan. I simply point to a text, presented on the next page here. It is a page taken from current literature.[4] I am not invoking a standard model. Like Boyer, I speak from a vague taken-for-granted shared implicit standard model. Imagine now that you take the place of Lonergan, and pick-up of a hint of the worthwhile venture.

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[1] See http://www.sgeme.org/BlogEngine/archive.aspx for the 104 articles written for the seminar.

[2] The story of the E-seminar is contained in the FuSe series on the website www.philipmcshane.ca. In particular, functional research is the topic of Philip McShane's FuSes 0-9; these essays will also appear in the *Journal of Macrodynamic Analysis* 8 (2013) at http://journals.library.mun.ca/ojs/index.php/jmda .

[3] "Boyer reached for his copy of Thomas Aquinas' Prima secundae, pointed to an article that he himself had difficulty in interpreting, and suggested that Lonergan make a study of that article in itself, of its loca parallela, and of its historical sources", *Grace and Freedom*, (2000) CWL 1,University of Toronto Press. page xviii.

[4] *Neural Correlates of Thinking*, (2009) Editors, E. Kraft, B. Gulyas & E. Poppel, Springer, Germany, page 6.

You tackle the text and gradually find your way to make explicit an answer to the problem in the context of the inadequate standard model of the scholastic tradition. You end up, like Lonergan, with a thesis. You now pause over the notion of making explicit the answer. What is it to make fully explicit the answer?

Despite the difficult and controversial topic of providing an accurate definition, thinking is a core cognitive capacity and has traditionally been conceptualized into reasoning, problem solving and decision making (Holyoak and Morrison 2005). These are closely interconnected fields, although historically they have represented distinct perspectives on thinking. Reasoning, which in a broad description is drawing inferences from given information, can be subdivided into many special instances including relational reasoning, causal reasoning, conditional reasoning, analogical reasoning, and deductive and inductive reasoning. Problem solving has been defined as a goal-driven process of overcoming obstacles that obstruct the path to a solution (Simon 1999).

Thinking is a polymorphous term, as has been emphasized by Bennett and Hacker (2003), who argued that for this very reason the term may not be amenable to fruitful scientific investigation. However, it is owing to this polymorphous nature that it may be used as a relevant conceptual term referring to all facets of higher cognitive processing. Additionally, thinking would also incorporate into its traditional nomenclature terms such as "intuition", "insight", "spontaneous thought processes" and "free floating thoughts." One could consider a group of thinking operations (decision making, reasoning, problem solving) as explicit domains and another group (intuition, insight, spontaneous thought) as implicit domains in a taxonomy of thinking processes.

Two theories about reasoning have dominated the cognitive literature: mental model and mental logic (Braine and O'Brien 1998). Mental model is a semantic theory claiming that the central concept by which we perform reasoning operations relates to spatially organized mental models (Johnson-Laird 1983). Mental model would have predicted primarily right-hemisphere regions, especially parietal and occipital regions. In contrast mental logic claims that deductive reasoning is based on the application of formal deductive rules according to formal syntactic operations. Thus, one would expect that left-sided prefrontal and temporal regions would be implicated in formal, rule-based operations. Over the last few years alternative and more integrative concepts have been formulated by dual-mechanism theories. These theories are presented in different versions, for instance intuitive versus deliberate (Tversky and Kahneman 1986), associative versus rule-based, formal and heuristic processes (Newell and Simon 1972). These dual-mechanism concepts come closest to what one might consider as a general theory of thinking. Most of them would predict the presence of broadly distributed neural systems (Barbey and Barsalou 2006). However, despite all these approaches, a coherent theory of thinking is lacking, as is a proper taxonomy for all the different flavours of its components. All in all, given the lack of data and knowledge about neuroscientific investigation into thinking on the one hand, and the missing coherent theory and taxonomy on the other hand, a book exclusively dedicated to the present state of the art of neuroimaging techniques for gaining insight into the process and organization of thinking seems warranted.

This is also justified by the impression that central domains of thinking have neither participated in nor benefited that much from the interaction of cognitive science…

Let us follow the parallel. Lonergan tackled a problem within a muddled vague standard model starting from Boyer's selected text. I suggest a text, as above, and invite a tackling of the problem. Lonergan got as far as a published thesis, but did that make explicit the answer? Not according to the thinking represented by the quotation from the last chapter of *Method*. Indeed, not according to the perspective Lonergan developed on metaphysics in *Insight*, where implementation became of the essence of the task of metaphysics. Within that perspective the answer is explicit when it hits the streets. Lonergan's solution, as expressed in his thesis and more fully in *Grace and Freedom*, so far from hitting the streets, has not hit the theological community. Indeed, his contribution from that thesis that is central to our own illustration from neuroscience has not as yet hit the Lonergan community, "sixty-three articles in a row and all though treat of the will".[5]

The problem that the mature functional collaboration of later centuries is to meet effectively is the problem of bringing the solution all the way to the lives of people. This is the extraordinary vision and optimism embedded in Lonergan's achievement. What it is going to demand is a thoroughness that is luminous and humble, "eliminating totalitarian ambitions"[6] while contributing effectively to total global progress.

But the beginnings of our reach for that effective vision are going to be potentially adequate. Here my focus is on beginnings in the first specialty, but it seems to me - and part one aims at making that clearer - that those beginnings are central to our taking Lonergan seriously. I mentioned above the "sixty-three articles in a row", and it is worth pausing over that mention as illustrating the types of entry point that we need to get moving. Functional research has to be undertaken right across the works of Lonergan if we are to have a lift-off from a half-century of Lonerganism. Let me add here, to the phrase, "sixty-three articles in a row" two other phrases of Lonergan, from *Insight*, "pseudometaphysical mythmaking",[7] and "there have to be invented appropriate symbolic images of the relevant chemical and physical processes."[8] These three are a sample of a multitude of phrases of doctrinal poises in Lonergan of which we must honestly say, "this deserves recycling".[9] As it happens, the three phrases noted here dominate Part Two of this essay.

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[5] Bernard Lonergan, (2000) *Grace and Freedom: Operative Grace in the Thought of St. Thomas Aquinas*, CWL1, University of Toronto Press. Page 94. The reference is to Thomas' *Prima Secundae*, qq. 6-17.

[6] "An Interview with Bernard Lonergan" edited by Philip McShane, *A Second Collection*, (1974) edited by William Ryan & Bernard Tyrrell, page 213.

[7] Bernard Lonergan, Insight*: A Study of Human Understanding, (1992) CWL 3, University of Toronto Press, page* 528.

[8] *Ibid*, 489.

[9] The theme of the 2011 Halifax Lonergan Conference suggested by Phil McShane.

But the first challenge to us here and now regards the phrase, "this deserves recycling". The phrase itself deserves recycling, and that strange notion taken to a further level helps us to see what we are up against if we are to rise slowly to a luminous collaborative structure, what McShane calls "A Tower of Able". He regularly writes symbols like (discernment)^3.[10] Here I am talking about the recycling of the recycling of the meant-phrase about recycling. My talking, and McShane's symbolization, point to a very remote luminosity in that not yet realized science of functional collaboration. Each member of each specialty is to be self-luminous about the entire human enterprise in history, a sharing destined to be luminous. It is useful here to quote a short piece headed by Lonergan with the title, *The Genetic Circle*.

"That circle – the systematic exigence, the critical exigence, and the methodical exigence – is also a genetic process. One lives first of all in the world of community and then learns a bit of science and then reflects, is driven towards interiority to understand precisely what one is doing in science and how it stands to one's operations in the world of community. And that genetic process does not occur once. It occurs over and over again. One gets a certain grasp of science and is led onto certain points in the world of interiority. One finds that one has not got hold of everything, gets hold of something more, and so on. It is a process of spiraling upwards to an ever fuller view."[11]

I am not interested here in the complex manner in which Lonergan builds the various exigencies into his functional view. What I am interested in is us taking in the bit that hits us here and now as our seeding community "learns a bit of science and then reflects, is driven towards interiority …. ".[12]

The power of the new science is that it is geared to do that effectively. But again, we cannot grasp that scientifically until it gets seriously underway. So, for instance, when it has reached the level of omnidisciplinary operation the movement from the first to the second specialty is to involve a convergence, and so on up.[13] But note – here I am returning to the subject indicated by the McShane symbolism, (turn)^3 - the "is geared to" and "is to involve" are to have a new meaning in culture and science, a new meaning from becoming self-luminous about the fact that one "learns a bit of science and then reflects, is driven towards interiority …. ". The new science is to involve a new culture of presence that, e.g., was deeply absent when Lonergan made his appeal about reading in the Epilogue of *Verbum*.[14] But to give the meaning and the appeal new force I would note the discomfort of us noticing now that, just now, we did not read or hear "is geared to" or "is involved in" with that newness. Are we genuinely "driven towards interiority"

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[10] See, on this, McShane's Website book, *The Redress of Poise*, in the conclusion of chapter I, "The Value of Lonergan's Economics for Lonergan Students" at http://www.philipmcshane.ca/books.html

[11] Bernard Lonergan, (2010) *Early Works on Theological Method*, CWL 22, University of Toronto Press, page 140.

[12] Ibid. page 140.

[13] This convergence is discussed and mapped by McShane in *Cantower* 8, Slopes: An Encounter". See page 13.

[14] Bernard Lonergan, *Verbum: Word and Idea in Aquinas*, (1970), edited by David Burrell, University of Notre Dame Press, page 216.

by our present bit of science, indeed an optimistic drive towards an effective blossoming of humanity?

Such a simple puzzling brings us to confront the "Existential Gap"[15] in which we live and in which our present discussion occurs. The gap blocks out in us a psychological presence essential to being in history. In simpler terms it leaves us out of the Standard Model that McShane envisages as the mindset, of functional collaboration, a mindset which he expresses symbolically as "FS + UV + GS",[16] and of which he talks in terms of a "Leaning Tower of Able." In the simplest of terms, we may ask ourselves and each other about our present stance, our present interest, and find honestly that we are not psychically leaning towards being an effective ethos of progress, an ethos "that is too universal to be bribed, to impalpable to be forced, too effective to be ignored."[17]

So we arrive back, hopefully, at a fresh meaning of the phrase, "this is worth recycling". It does not matter what functional specialty we wish to join. And we may join none.

I presented above a simple page out of the literature of present neurochemical psychology. Is it worth recycling with ever widening circles, circles of inner exigencies, reaching effectively and glocally in "a process of spiraling upwards to an ever fuller view,"[18] a view that is relentlessly pragmatic? Is the 'worth' question clearly dynamic in us, so that "it ever rises above past achievement. As genetic process, it develops generic potential to its specific perfection. As dialectic, it overcomes evil both by meeting it with good and by using it to reinforce the good. But good will wills the order of the universe, and so it wills it with that order's dynamic joy and zeal."[19]

Above I recalled Lonergans' appeal for humble creative reading, and now it is worthwhile – that issue of worth again – recalling his comment on the failure of Catholic good will, a powerful paragraph which ends with "arriving on the scene a little breathlessly and a little late."[20] But now I wish to twist again to an arrival on the scene, the scene that is our reading of that single page of text included above, arriving, thus, freshly at the seen. We have seen the words in that text about "left-sided prefrontal and temporal regions", about "broadly distributed neural systems." Whose systems and regions are we talking about, reading about, if not our own? The page is, one might say, simply a nudge about the frontispiece of *Insight* that Lonergan took from Aristotle.[21]

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[15] Bernard Lonergan, *Phenomenology and Logic*, (2001) CWL 18 edited by Philip McShane, University of Toronto Press, see the index under *Existential Gap*.
[16] See FuSe 10.
[17] *Insight*, page 263. Following that statement he begins his sketching of the characteristics of Cosmopolis.
[18] *CWL* 22: *Early Works on Theological Method*, 140
[19] *Insight*, 722, conclusion.
[20] *Ibid*. 755.
[21] Aristotle, *De anima,* III, 7, 431b 2. "Thus, it is the forms which the faculty of thought thinks in mental images."

This gives us all a peculiar nudge about our reading of *Insight* and our self-discovery. In what sense were we discovering, or missing the discovery, of our cranial systems? "To say it all with the greatest brevity: one has not only to read *Insight* but also to discover oneself in oneself."[22]

The discomforting thing is that when we are reading Aristotle regarding image we are indeed reading about our "left-sided prefrontal and temporal regions", about "broadly distributed neural systems." And *Insight* invites us to push on towards "complete explanation."[23] The disturbing fact is that "organic, psychic, and intellectual developments are not three independent processes. They are interlocked with the intellectual providing a higher integration of the psychic and the psychic providing a higher integration of the organic."[24] So, "there results the problem of formulating the heuristic structure of the investigation of this triply compounded development."[25]

The fact is that what seems a topic that is innovative, grounding a massively significant invasion of the field of neuroscience, is actually a basic topic of self-understanding. Like many of the topics that emerged in McShane's E-seminar on functional research, the question of "worth recycling" in this case is merely pointing to a flaw in the reading of Lonergan since the beginning, a flaw however, which grounds a terrible corrupt nominalist Lonerganism that talks in non-explanatory ways of the elements of meaning as if they were characteristics of a simple-minded disembodied Platonic entity.

However, I am here merely illustrating the general problem that we are exposing to ourselves, about ourselves, in this conference. But the illustrating puts the effort of my functional research in a new context. The research has much larger scope than the lifting of neuroscience to a proper attention to its data. It also is a reach to lift Lonergan studies to a possibility of a fresh honest beginning.

So let us begin as we are, assuming that you share, at some level, the standard model I am using, the one imaged in the diagram of Appendix A here and of *CWL* 18. This diagram needs to be understood within the context of the fuller heuristic provided by W_3.[26] My research clearly brings up the question of the model that is, implicitly or explicitly, dominant in present neuroscientific research. I will only say here that it is a Scotist model that has, in fact, no seriously empirical or systematic grounding, and in particular the insight-experience has no systematic place.[27] In the conclusion to this essay I offer pointers to a reversal of the Scotist

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[22] *Method in Theology*, 260.
[23] Both the canons of explanation, from chapters 3 and 17 of *Insight*, are relevant in this context.
[24] *Insight*, op. cit., 494.
[25] *Ibid*., 494-5.
[26] Note that **W_3** points to another lacuna in present Lonergan studies. The pointing is through the symbolic use of the semicolon, " ; " which draws attention to the need to come to grips with a modern version of Aristotle's hylemorphism.
[27] Here it is best just to quote note 1 of *Method in Theology*, 336: "On conceptualism, see my *Verbum: Word and Idea in Aquinas*, London: Darton, Longman and Todd, and Notre Dame: University of Notre Dame Press, 1967, Index, *s.v.*, p. 228. That key issue is whether concepts result from understanding or understanding results from concepts."

influence. Future specialties and specialty work will bring forth a fuller analysis of this faulty model, as well as a fuller presentation of the elements of meaning that makes diagrammatically evident the place of insight in the four levels of logic that are involved in human thinking.[28]

The research below points to spatial correlations between cranial zones and elements of meaning that reveal an error in methodology due to the dominant influence of reductionism.

Part II: The Mind's Operations and Corresponding Cranial Regions

Methods of Research in Neuroscience and Neuropsychology

First, it will be helpful to list and distinguish briefly the different methods used to obtain this data.[29] Secondly, an attempt will be made to lineup the brain regions of activity corresponding with mental acts.[30] There are various types of data provided by the different methods of *mind mapping*. There are six methods of gathering data that are commonly used in brain chemistry research: 1) Electroencephalography technique (EEG), 2) MRI scans, 3) fMRI scans, 4) Near-infrared spectroscopy (NIRS), 5) Positron Emission Tomography (PET), and 6) Magnetoencephalography (MEG). I will begin with a grouping of the six methods which reveal a common characteristic.

These six methods of research and experimentation are used by neuroscientists, neurocognitive scientists and neuropsychologists. The neuroscientist is attempting to determine the function of the various brain regions, how they function individually and how the various regions function often in unison. There are more than 82 known sub regions within the 9 major regions of the brain and the interaction between these sub-zones corresponding to the acts and operations of consciousness is still largely unmapped and even less understood as to their function and interfunctioning. (See Appendix B) There are also interactions between both hemispheres of the brain and between the human brain and the reptilian and mammalian brains which are the evolutionary precursors still part of the present human brain.

The neurocognitive scientist is attempting to form a theory of thinking. The neuropsychologist is attempting to determine the relationship between the functioning of the brain and human behavior as well as searching for the breakdowns that are responsible for diseases such as

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[28] Each level of insight leap normally occurs with a full formulation. So, in answering the what-question there is a leap to a conclusion, and later the logical sequence is or can be worked out. Similarly with the leap to the answer to an is-question, whether in common sense, history or science; the case of the other levels, what-to-do and is-to-do, is best illustrated by recipes and successful cooking. Our text page and text (see note 4 above) point to the need for these refinements.

[29] Charles Nelson & Christopher Monk; "The Use of Event-Related Potentials in the Study of Cognitive Development", p. 133 in *Developmental Cognitive Neuroscience* "…this method would seem to represent an ideal tool with which to explore a variety of aspects of brain-cognitive relations."

[30] John Eccles, (1997) *The Understanding of the Brain*, McGraw-Hill, page 197. "Brain actions give experiences and these experiences can result in thoughts that lead to a disposition to do something and so to the operation of free will-of thought taking expression in action."

schizophrenia, autism and Down's syndrome. All of these sciences attempt also to determine whether such brain functions or malfunctions are genetically determined, environmental or some combination of both. A fourth science of intentionality analysis[31] is added for this discussion to aid in the development and collaboration of all three neurosciences. Intentionality analysis outlines the acts of cognition in the order that they occur in any act of human knowing. (See Appendix A)

The six methods of experimentation listed above are designed to obtain data that reveal corresponding activity between the brain and the operations of the mind. Correspondence is established empirically by measuring the simultaneous occurrence[32] of the mental act and the brain activity. Verification of these simultaneous events is achieved by the repetition of the experiments.[33] The data from the first 4 methods consist of graphs and images that signal the occurrence of chemical-electrical changes during brain activity. PET and MEG research are designed to record changes in chemistry and magnetic fields occurring in the brain.[34]

What follows is a listing of the data from various findings to date in neuroscience, neuropsychology and neurocognitive science. Researchers in these three neurosciences presently respect the present stage of their work as in its infancy in terms of the relationships between biology, psychology, and cognition.[35] *The integration of different imaging technologies is only in its infancy. Scientists have yet to fully explore interrelationships among different neurodiagnostic procedures.*[36]

This part of the paper will draw upon the findings of present neuroscience, neurocognitive science and neuropsychology and correlate these findings with the data on the operations of the human mind. This work, of listing these correlates, provides the data that has the potential for a reorientation of neuroscience as well as expressing the differentiation of consciousness that is functional research. I add at this time that without a prior theory of the mind's operations neuroscientists and neuropsychologists are trapped in a broad conceptualism that restricts development in their own fields. That problematic can be resolved through the work of cyclic collaboration within the context of the functional specialties.

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[31] Bernard Lonergan, (1992) *Insight: A Study of Human Understanding*, CWL 3, University of Toronto Press, Toronto, Canada. See this text for a detailed analysis of the intentional acts of the mind.

[32] The time lapse of the electro-chemical synaptic event following the mental operation has been determined to be approximately 100 ms..

[33] Electrode type experiments have been ongoing for over 50 years. MRI and fMRI canning techniques are more recent over the past two decades.

[34] PET is designed to measure oxygen and glucose changes and MEG records changes in magnetic fields.

[35] Susan Carey, "Bridging the Gap between Cognition and Developmental Neuroscience", p. 417 in *Developmental Cognitive Neuroscience* (2001) edited by Charles Nelson & Monica Luciana, MIT Press, MA. Carey expresses the need for interdisciplinary research in order to work out more fully the mind/brain operations and relations.

[36] Zillmer, E.A., Spiers, Mary. (2001) *Principles of Neuropsychology*, Wadsworth, Belmont, CA, page 222.

Sense Data and Brain Activity

Diagram Fig. 1 below depicts the various sensory experiences and the corresponding brain regions. The following is a listing of the correlations between the corresponding parts of the brain to the different senses.

Sense	Brain Region
Vision	Occipital and Parietal lobes & Cerebellum
Hearing	Temporal lobe
Touch	Outer band of Cerebrum cortex
Taste	Frontal lobe
Smell	Frontal lobe

As depicted in the list and shown in the diagram more than one brain region reveals synaptic activity during particular sense experience such as vision and touch. Vision activates regions related to spatiality, coordination, shape and color. Touch activates different outer regions of the cerebrum cortex depending on which part of the body is experiencing touching.

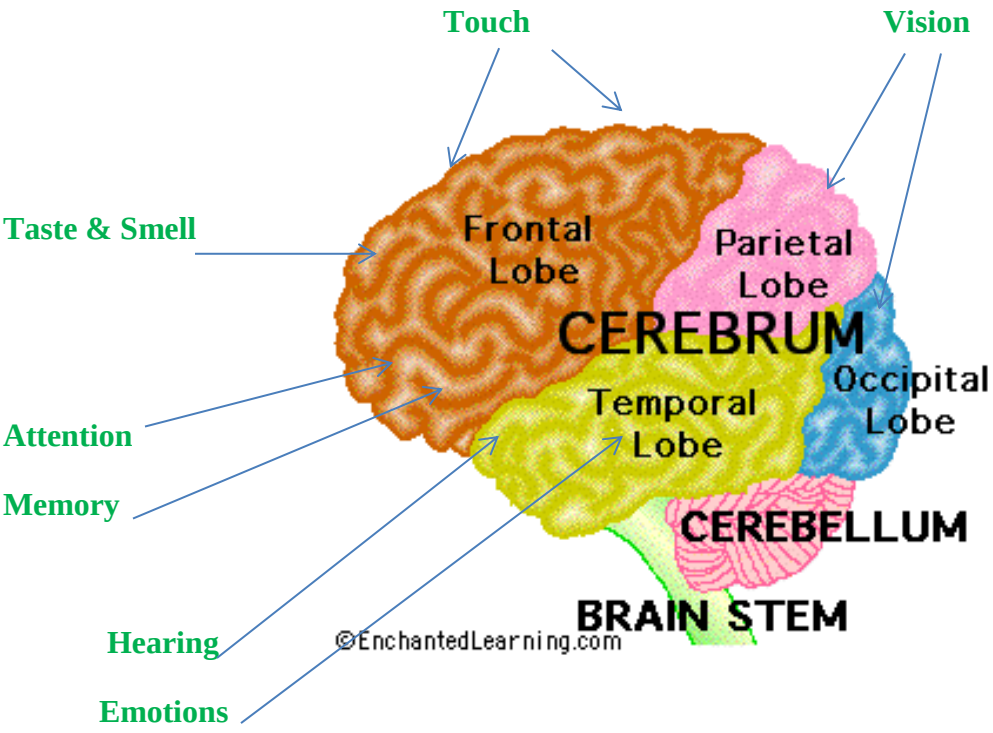

Fig. 1

Emotions and Feelings

Research has shown that emotions reveal synaptic activity in the limbic system which is made up of the Amygdala, the Caudate nucleus, the Hippocampus, the Hypothalamus, the Putamen and the Thalamus. Each region of the Limbic system performs different functions and the frontal lobes also show activity during the experience of emotions.[37]

Attention to Data or Experience: A First Activity of Consciousness

When a person focusses attention on some experience, such as visual or auditory, synaptic activity[38] increases in the frontal lobe areas.[39] The event-related potential (ERP) is believed to be primarily derived from pyramidal cells in the cerebral cortex and hippocampus.[40] The electrodes measured an increase in the brain's electrical activity during attention/memory experiments and when sufficient neurons are activated the current can be detected and measured against a baseline recording during a non-stimulus period or rest. Researchers provided visual and auditory experiences with different variables of intensity and time while recording the synaptic activity. This particular cortical electrode research establishes the regions of the brain in which the ERP occurs and the form of synaptic activity that is the brain pattern corresponding to the conscious element of attending.

Memory

Memory was tested by recording the activity when repeat experiences were provided as well as new experiences. When a test subject is utilizing their memory, synaptic activity occurs, and that activity was consistently different in a series of tests of research subjects of different age range.

Memory is believed to be the activity of drawing on storage of information which is believed to be stored in sodium compounds. Research methods have revealed that when memory is functioning, the basil forebrain structures which consist of the nucleus Basalis of Meynert, the Medial Septal nucleus, the nucleus of the diagonal band of Broca, and the Substantia Innominate are all active in coordination.[41] These areas are subcortical parts of the telencephalon surrounding the inferior tip of the frontal horn and interconnected with the limbic system. The temporal lobe, putamen, hippocampus, amygdala and the caudate nucleus are also activated during particular memory tasks. Again, we witness mental activity that has corresponding

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[37]Carter. page 40, 129 & 162. See also Candice Pert, (1997) *Molecules of Emotion: The Science behind Mind-Body Medicine*, Touchstone, Simon & Schuster, pages 133-135.

[38] Synaptic activity is the process of polarization of a cell in which ion channels occur to allow an electro-chemical transmission pass to an adjacent cell. The receiving cell absorbs the electro-chemical transmission and a transformation occurs in that receiving cell. The electrodes record this activity 100 ms after it occurs.

[39] Charles Nelson & Christopher Monk; (2001) "The Use of Event-Related Potentials in the Study of Cognitive Development", pp. 125-136. Chapter 9 in *Developmental Cognitive Neuroscience*.

[40]. Ibid. page 125.

[41] Kolb, B., Whished, I., (2003) *Fundamentals of Human Neuropsychology*, Worth Pub., University of Let bridge, 5th Edition, pages 468 – 474.

activity in brain chemistry. You have a relationship here between brain chemistry and mental activity.

Knowing and Planning

Knowing is comprised of the cognitive acts that seek to correctly understand a situation or any data pertinent to a situation. So, the cognitive acts of attention to the relevant data, relevant questions, insights, judgments that formulate the insights, and finally verification of those formulations are in play when the mind is in the process of knowing. Planning takes place when the mind reflects on knowledge achieved and asks: What is to be done? That question is followed by an insight, a grasp of possible options and eventually a choosing of a particular option. Rita Carter draws on research in neuroscience that has established that the caudate nucleus of the frontal lobes is where thinking, assessing and planning have corresponding brain activity.[42] Intentional analysis brings to this research the various distinctions of the mental acts which Carter et al do not include within the terms thinking, assessing and planning. (Carter, page 298-299) The following listing outlines the order of the various mental acts and their corresponding region of brain activity.

1. Wonder (**What** question): Prefrontal Cortex. Regions differ depending on whether or not the question draws on former knowledge. If the question does not draw on former knowledge the prefrontal cortex does not show any activity. A sub-zone of the prefrontal cortex does reveal activity for questions not requiring former knowledge and draws on general cognitive abilities. (page 233-239 Carter) It may be that the distinction of former knowledge is between drawing on former insights, recalled data or recalled facts.
2. Insight (Understanding): Multiple zones in the Medial Prefrontal Cortex[43]
3. Judgment (A Formulated insight): Multiple interactive zones of the Prefrontal Cortex and frontal lobes
4. Is question (Seeking verification of formulation): Various zones within the Prefrontal Cortex and frontal lobes
5. What-to-do question focused on developing options: Zones within the Prefrontal Cortex and frontal lobes
6. Creativity: The lower part of the Prefrontal cortex: the Ventromedial or subgenual cortex. (P. 321 Carter)

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[42] Carter, op. cit., page 92.

[43] Johnson, Mark., (2010) *Developmental Cognitive Neuroscience*, Wiley, Hoboken, UK, page 142-43. During early childhood broader regions of the brain are activated during thinking. Upon reaching adulthood less regions are activated during thinking. It would seem that regional specialization develops over time requiring less brain regions. See also E. Kraft, B. Gulyas & E. Poppel, Editors of *Neural Correlates of Thinking***,** Pages 253-267 see *Neural Correlates of Insight Phenomena*, by Jing Luo, Gunther Knoblich & Chongde Lin, page 258. Different types of insight activate different brain regions depending on whether the insight is brought on due to external, internal or restructuring hints. The common element is that insight activates many regions and usually more than other cognitive acts. The various regions activated manifest an integrative function of various brain regions just prior to and during the occurrence of an insight.

7. Formulating options: Frontal lobe zones
8. Insight into options: Multiple zones of the Prefrontal Cortex and frontal lobes
9. Choosing an option: Dorsolateral region of the Prefrontal Cortex
10. Decision to implement an option: Dorsolateral region of the Prefrontal Cortex and the Orbito-frontal cortex.
11. Act-Implementing the decision: Back of the frontal lobes: SMA: Supplementary Motor Area.

Will

The *will* is expressed in acts which are listed below as **Acts of the Will**. I begin with a description and account of the will found in the works of Thomas Aquinas.[44] From Aquinas we have the following.

But a thing is in our power by the will, and we learn art by the intellect. Therefore the will moves the intellect. A thing is said to move in two ways: Firstly, as an end; for instance, when we say that the end moves the agent. In this way the intellect moves the will, because the good understood is the object of the will, and moves it as an end. Secondly, a thing is said to move as an agent, as what alters moves what is altered, and whatever impels moves whatever is impelled. In this way the will moves the intellect,…

The will is then a motion expressed in mental operations which have corresponding activity in various regions of the prefrontal cortex. It is often described as the opposite of depression. The chemical changes initiated by depression are centered in the *locus coeruleus*.[45] The hypothalamic neurons stimulate a secretion of corticotropin-releasing hormone when stress occurs. This stimulation is regulated by norepinephrine neurons in the locus coeruleus. Depression alters this stimulation and a characteristic of depression is the absence or weakening of the desire to know and act. It would seem that the will no longer moves the intellect when this state is occurring. This is not to imply that regions inactive during depression are activated when the acts of will are occurring. It is probable that when the acts of will are occurring that corresponding cranial activity is widespread and interactive but is inhibited when other areas are inactive due to depression. Because current neuroscientific literature has little to say on the acts of the will little is known about the regions activated during the exercising of the acts of the will.[46]

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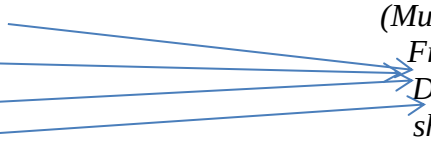
[44] Thomas Aquinas, The Summa Theologica, Part I-IIa, qq. 6 – 17.

[45] Bryan Kolb & Ian Whished, (2003) *Fundamentals of Human Neuropsychology*, 5th Edition, Worth Pub., pages 727-728 for a discussion of the chemistry of depression.

[46] Carter, pp. 331-334. Most authors make scant reference to the terms “free will”. It is too often juxtaposed with depression. Any inference of cranial zones active during acts of the will lack an empirical base at this juncture of the research.

The following list of terms and corresponding brain-activated regions outlines the process of the will from Initial to Final Serenity taken from Aquinas' analysis of the will.[47] The acts of the will are intellectual in nature but not explanatory in their reach. Therefore they may activate similar regions as do the cognitive operations listed on pages 11 and 12 but not necessarily.

Acts of the Will	**Cranial Regions**
1. Initial Serenity	Inactive frontal lobes
2. End	Prefrontal Cortex zones
3. Value-judgment	*(Multiple sub-zones of the*
4. Intention	*Frontal & Prefrontal lobes.*
5. Deliberation	*During Serenity these zones*
6. Consent	*show little activity.)*
7. Decisive plan	Prefrontal Cortex and the Orbito- frontal cortex
8. Choice	Dorsolateral region of the Prefrontal Cortex
9. Command	Prefrontal cortex zones
10. Application	Supplementary Motor Area
11. Achievement judgment	Prefrontal cortex zones
12. Final serenity	Inactive frontal lobe



Language

Different parts of the left hemisphere are involved in language. Spoken language activates the Wernicke's area, Broca's area is activated when speech is generated, and the angular gyrus is activated during the expression of meaning. These three areas are connected within the brain[48] enabling all these three aspects of language to operate as a unity when expressing a spoken word or phrase. Different regions are activated depending on the stage that the movement from desiring to speak, to formulating what is to be spoken to actually speaking. These regions do function in coordination with each other at different stages of speech. Within the context of the listing of the elements of meaning above and the inner reach to express meaning language would generate corresponding cranial activity in the prefrontal cortex since language is a reaching, a desire to express and *how* to do that is a process of early language development that becomes a spontaneous expression of meaning in childhood.[49]

The various operations of the mind activate more than one region of the brain and in most cases more than one area of a particular region. During some operations areas in both the left and right hemispheres are activated and when lesions are present in one region other regions not usually

[47] Thomas Aquinas, *Summa Theologia* (1970) Blackfrairs, Cambridge. Volume 17, *Psychology of Human Acts*, 1a2ae. Questions 6 – 17. Translation by Thomas Gilby, O.P..
[48] Carter; page 226 & 255.
[49] Philip McShane, (1998) *A Brief History of Tongue: From Big Bang to Colored Wholes*, Axial Press, Halifax, Canada. This text offers an account of the emergence of language and the mental operations involved.

activated for a particular operation will take over in an attempt to compensate for the non-functioning zone.

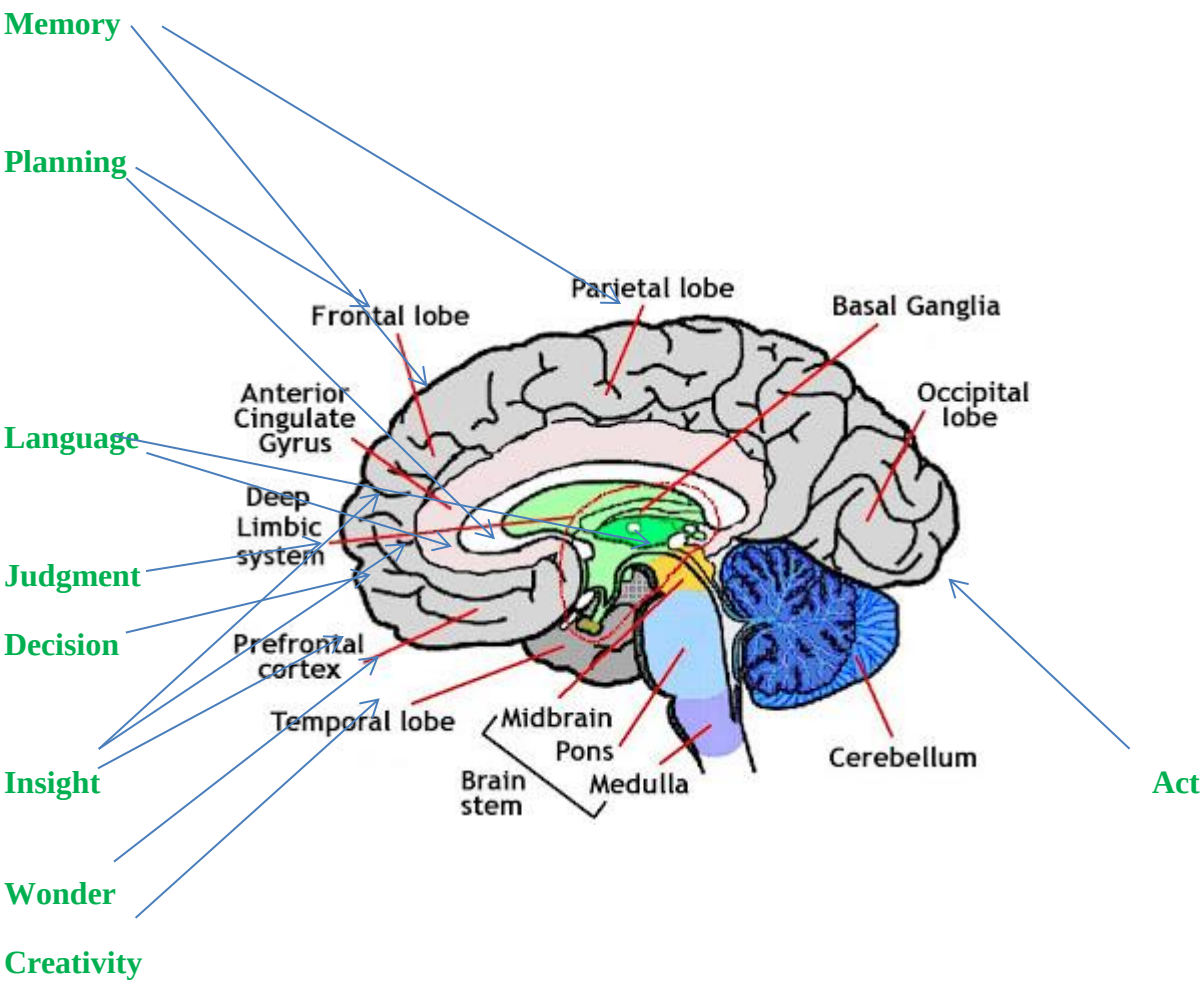


Fig. 2

There is a second grouping of data that is generated by the neuroscientist. The neuroscientist has objectives and outcomes. He or she wants to map the various regions of the brain that correspond with human experiences, such as sense experience and thinking. With those objectives and outcomes in mind the researcher is **curious** about the human brain. The researcher then works out experiments that he or she believes will assist in reaching their outcomes. The data generated in the mind of the researcher are **what type** questions, **what-to-do type** questions followed by **insights, judgments and decisions**. These are mental operations that are data for neuroscientific study in that their performance affects the intelligence and reasonableness of their outcomes.

A third grouping of data is the mental operations that I generated in myself while searching the literature and organizing the data found. Just as the neuroscientist's understanding of his or her own operations affects the outcome of their work, so does my understanding of my own operations affect the outcome of my work. We now have three groups of data that are relevant to functional research. The inclusion of all relevant data provides the possibility of future

development in the science and the possibility of moving towards an implementation of generalized empirical method into a particular science. The full implementation requires the recycling of this data through the functional specialties and that recycling may occur many times and widen in its inclusions as the recycling continues for its relevancy will flow over into other levels of performance as relations are discovered and systematized.

Conclusion

At the end of the introduction to this essay I stated that I would comment on the reductionism that is dominant in the present methodology functioning within neuroscientific work. It is *believed* by neuroscientists that eventually through the refinement of scanning and imaging techniques for the mapping of the brain and its chemical activity they will arrive at a theory of mind.[50] There are also doubts as to whether or not this can be achieved in this manner. In the Introduction to **Neural Correlates of Thinking**, the editors, Kraft, Gulyas and Poppel highlight this problematic and Gulyas raises the same question in his article *Functional Neuroimaging and the Logic of Conscious and Unconscious Mental Processes*. He asks; "Are these techniques helping us reveal the neurobiological underpinnings of cognitive processes?"[51] What follows are samples of comments by neuroscientists regarding their doubts about their methodology.

What about thinking? A major theme in this book is the quest to understand thinking. The question that most reading this chapter will want to know the answer to is: "What can fMRI, or more generally, neuroimaging, contribute to our pursuit of an understanding of thinking?" Does it really help to be able to look into the brain? To borrow an analogy, can one really truly understand how computers work by opening up a computer chassis and probing the components with a heat gun? Can identifying the when, where, and how much in the brain provide enough information so that we can begin, from this information, to derive principles of thinking? Even if we had a perfect picture at infinite spatial and temporal resolution of what was actually happening in the brain during thought, would we even then begin to understand thinking? Does it really matter what the limits of fMRI are with regard to answering questions about thinking?

It seems apparent that to truly understand the brain, a much wider context (physical and evolutionary factors) needs to be considered. Thinking itself might someday be deconstructed into simple algorithms that can be carried out within different media other than brains. Perhaps a simple model of interacting layers of neuronal networks may emerge as being able to explain thought (Hawkins and Blakeslee 2004). It is my feeling that because thinking is a subjective process, it tends to be shrouded in mystery and potentially elevated to a status, either correctly or incorrectly, that defies understanding.

At the end of the day, we might be able to then say that x network, on x spatial scale, is directly related to say, theory of mind, willed action, and humor. So fMRI reveals the functions of specific processing modules. Does this really tell us anything that will help our understanding of

[50] *Neural Correlates of Thinking,* Edited by E. Kraft, B. Gulyas & E. Poppel, (2009) Springer, Heidelberg, Germany, page 10.
[51] Ibid.; page 142.

thinking? Do we need to know what modules overlap in function or how large they are or where they are located in the brain?
Does this information really matter? What spatial scale in the brain is the most critical for the understanding of thinking? While all of our tools are able to probe many different spatial scales, there are also many which have not been investigated yet. Does this matter?[52]

Horace Barlow and Rita Carter add emphases to this quandary.

…reductionism is limited because its drive is to look for explanations at lower levels in the organizational tree. …Can we learn about the mind in the same way that we might seek to understand a machine-by taking it apart and examining its parts? Neurophysiologist Horace Barlow believes this approach can bring about important insights but can never tell the full story.[53]

With the help of them, (imaging techniques) can we exploit the differences between conscious and unconscious brain processes?[54]

It still remains unclear whether it is justified to assume that neural assemblies are actually the basic units of cognition.[55]

…a coherent theory of thinking is lacking…a book exclusively dedicated to…gaining insight into the process…seems warranted.[56]

The connection between neuroanatomy, neurochemistry, and neurodevelopment, and the behavioural research in cognition are rather tenuous.[57]

As always, an understanding of the mind must guide the search for its neural underpinnings.[58]

Richard Moodey offers an interesting insight into the relationship between researcher and human subjects in the following.

When working with human subjects, the neuroscientist has to ask people about their experiences in order to get information that he cannot know immediately, and relate this to his observations as an "outsider.' His outsider observations are aided by ever more sophisticated apparatus, but the connections with the phenomenological accounts of the research subjects are what give fuller meaning to the external observations.[59]

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[52] "Functional MRI Limitations and Aspirations" by Peter Bandettini, page 31-32, *Neural Correlates of Thinking,* op. cit.,
[53] Carter, page 43.
[54] *Neural Correlates of Thinking*, op. cit., page 142.
[55] Ibid., page 75.
[56] Ibid., page 6.
[57] "Bridging the Gap between Cognition and Developmental Neuroscience: The Example of Number Representation" by Susan Carey in *Developmental Cognitive Neuroscience*, (2001) op. cit., page 415.
[58] Susan Carey, ibid., page 429.
[59] lonergan_l@googlegroups.com [mailto:lonergan_l@googlegroups.com] Moodey, Richard W.

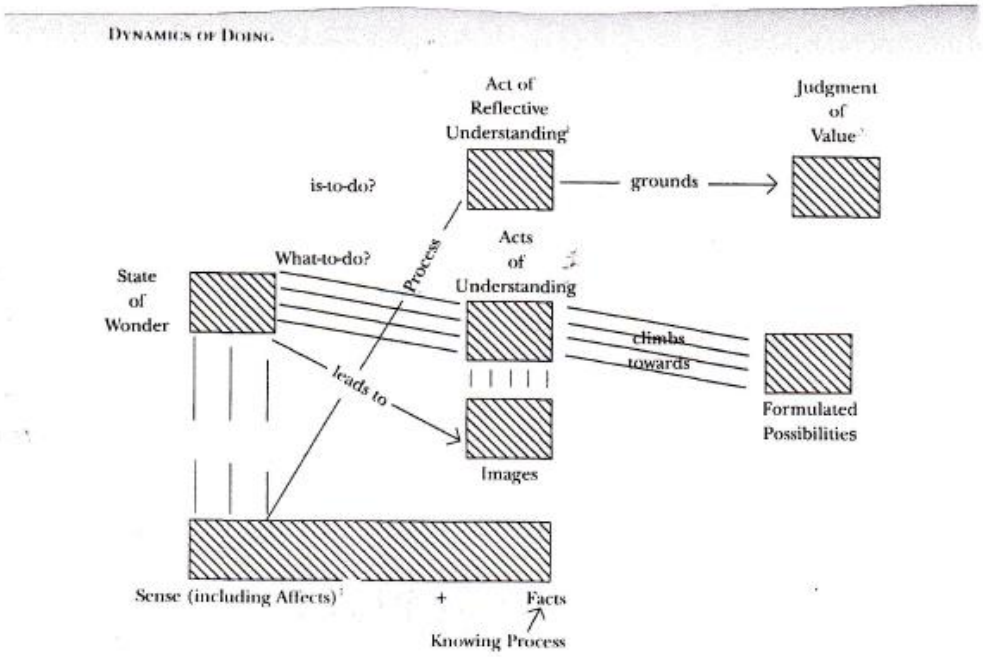
Moodey's point describes the current relations operative between the human subject and the researcher. What would fill out the researcher's account? The problematic that obfuscates the settling of the issue stated in the above quotations is expressed summarily by Lonergan in the following quotation.

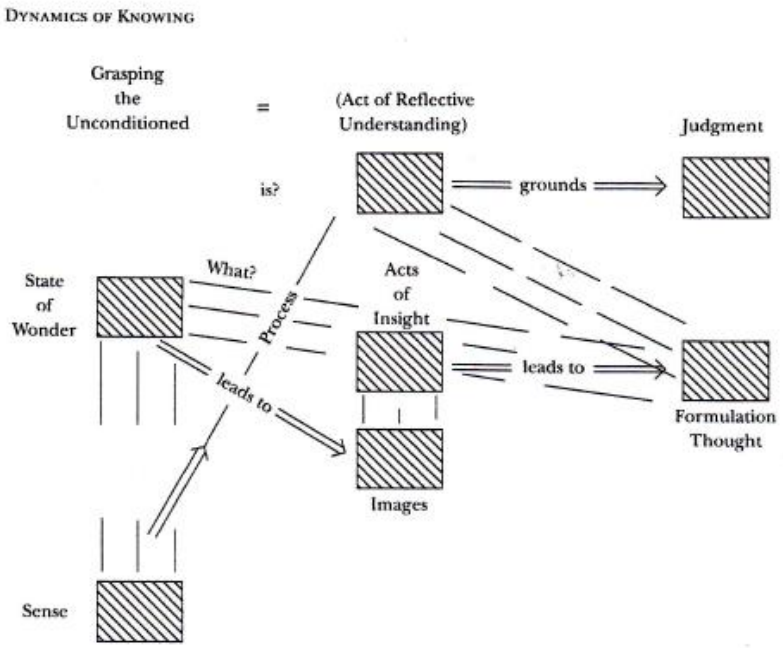
In this fashion, intelligence is reduced to a pattern of sensations; sensation is reduced to a neural pattern; neural patterns are reduced to chemical processes; and chemical processes to subatomic movements. The force of this reductionism, however, is proportionate to the tendency to conceive the real as a subdivision of the 'already out there now'. When that tendency is rejected, reductionism vanishes.[60]

There are further questions and doubts raised in the literature about the process and method of present scanning and mapping of the brain techniques as to whether or not the outcome desired can be achieved in this manner. While these concerns and doubts are raised by some it appears they are ignored, at least in much of the literature, by those focused on experimentation through scanning techniques. It raises the question as to why a large group are dedicated unquestioningly to the process of scanning and a smaller number who are raising questions, have little, if any influence on the overall presuppositions inherent in the fields of neuroscience, neurocognitive science and neuropsychology? This problematic is something to be worked out in the specialty dialectic. In as much as the quotation from Lonergan expresses the procedure and error of reductionism and a possible solution for some individual, how is that solution to be implemented in the larger context, of a science and a global culture? I pointed out in the introduction to this essay that "future specialties and specialty work will bring forth a fuller analysis of this faulty model…".[61]

[60] *Insight*, page 282-283.
[61] Page 7 of the introduction.

Appendix A


Dynamics of Doing
Act of Reflective Understanding
Judgment of Value
is-to-do?
grounds
What-to-do?
Process
Acts of Understanding
State of Wonder
climbs towards
leads to
Formulated Possibilities
Images
Sense (including Affects)
+
Facts
Knowing Process


Dynamics of Knowing
Grasping the Unconditioned
=
(Act of Reflective Understanding)
Judgment
is?
grounds
What?
Process
Acts of Insight
State of Wonder
leads to
leads to
Formulation Thought
Images
Sense

Appendix B

Frontal lobe	**Superolateral**	**Prefrontal**	• Superior frontal gyrus
			• Middle frontal gyrus
			• Inferior frontal gyrus:
			• Pars orbitalis
			• Broca's area
			  ○ Pars opercularis
			  ○ Pars triangularis
			• Superior frontal sulcus
			• Inferior frontal sulcus

		Precentral	• Precentral gyrus • Precentral sulcus
	Medial/inferior	**Prefrontal**	• Superior frontal gyrus • Medial frontal gyrus • Paraterminal gyrus/Paraolfactory area • Straight gyrus • Orbital gyri/Orbitofrontal cortex • Ventromedial prefrontal cortex • Subcallosal area • Olfactory sulcus • Orbital sulci

		Precentral	• Paracentral lobule • Paracentral sulcus
	Both		• Primary motor cortex • Premotor cortex • Supplementary motor area • Frontal eye fields

Parietal lobe	**Superolateral**		• Superior parietal lobule
			• Inferior parietal lobule
			  ○ -Supramarginal gyrus
			  ○ -Angular gyrus
			• Parietal operculum
			• Intraparietal sulcus

	Medial/inferior		• Paracentral lobule • Precuneus Marginal sulcus
	Both		• Postcentral gyrus/primary somatosensory cortex • Secondary somatosensory cortex • Posterior parietal cortex ○
Occipital lobe	**Superolateral**		• Occipital pole of cerebrum • Lateral occipital gyrus

		• Lunate sulcus • Transverse occipital sulcus
	Medial/inferior	• Primary visual cortex • Cuneus • Lingual gyrus • Calcarine fissure
Temporal lobe	**Superolateral**	• Transverse temporal gyrus/Primary auditory cortex • Superior temporal gyrus ○ Wernicke's area • Middle temporal gyrus -**Amygdala** • Inferior temporal gyrus • Superior temporal sulcus • Inferior temporal sulcus
	Medial/inferior	• Fusiform gyrus • Medial temporal lobe • Inferior temporal sulcus
Interlobar sulci/fissures	**Superolateral**	• Central (frontal+parietal) • Lateral (frontal+parietal+temporal) • Parieto-occipital • Preoccipital notch

	Medial/inferior	• Medial longitudinal • Cingulate (frontal+cingulate) • Collateral (temporal+occipital) • Callosal sulcus

Limbic lobe	**Parahippocampal gyrus**	• *anterior*
		  ○ Entorhinal cortex
		  ○ Perirhinal cortex
		• Posterior parahippocampal gyrus
		• Prepyriform area

	Cingulate cortex/gyrus	• Subgenual area • Anterior cingulate • Posterior cingulate • Isthmus of cingulate gyrus: Retrosplenial cortex ○
	Hippocampal formation	• Hippocampal sulcus • Fimbria of hippocampus • Dentate gyrus • Rhinal sulcus
	Other	• Supracallosal gyrus • Uncus
Insular lobe		• Long gyrus of insula • Short gyri of insula

	• Circular sulcus of insula
General	• Operculum • Poles of cerebral hemispheres