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Can brain scanning and imaging techniques contribute to a theory of thinking?

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In this article I analyse current efforts in cognitive neuroscience to explore the organic and cognitive processes involved in problem-solving. This analysis highlights a problem with assuming that cognitive processes can be wholly explained once one has explained organic processes. Reflection on scientific performance suggests how this problem can be evaded. This reflection on performance can also provide a paradigm for future neuroscientific research leading to a more detailed account of how brain locales and activities can be correlated with conscious cognitive acts.

Keywords: philosophic reflection, cognition, reductionism, cognitive neuroscience research

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INTRODUCTION

This article is a brief analysis of both the current methodology practiced in neurocognitive research and a problem inherent in that methodology. The analysis investigates the problem by: 1) adverting to the distinction between self-observation and reflection on the performance of test subjects, 2) identifying a problematic assumption within the practice of neuroscientific research and 3) providing pointers on possible lines of progress highlighting problems possibly entailed by the mentioned assumption.

There are different techniques presently used in neuroscientific research (Iliescu and Dannemiller, 2001, p.133). The following are six conventional ways of gathering data in the neurosciences: 1) electroencephalography technique (EEG), 2) MRI scans, 3) fMRI scans, 4) near-infrared spectroscopy (NIRS), 5) positron emission tomography (PET), and 6) magnetoencephalography (MEG).

Neuroscientists are attempting to "map" the brain and to determine the functions of different areas of the brain and the interactions among them. By doing so neurocognitive scientists are attempting to develop a theory of thinking. In turn, neuropsychologists are studying relationships between the functioning of the brain and human behavior (Henman, 2000), as well as searching for the breakdowns responsible for diseases such as schizophrenia, autism and Down's syndrome. The six techniques listed above gather data that reveal activity between brain locales that correspond to conscious operations and cognitive experiences. Correspondence is established empirically by measuring the simultaneous or sequential occurrences of mental acts and the brain activities. Verification of these correlated events is achieved by the repetition of the experiments. There are differing types of data generated by the different techniques of *mind mapping*, but the data are similar because they are technically produced images or scans of cerebral activity. The data from the first four techniques consists of graphs and images that signal the occurrence of electro-chemical changes during mental and conscious activity. PET and MEG research are designed to record changes in chemistry and magnetic fields occurring in the brain while test subjects perform designated tasks.

Tests are developed to evoke specific mental operations (paying attention, puzzling, memory, reasoning, decision-making, planning, speaking) and conscious states such as emotions and moods. One purpose in pursuing more specific and detailed descriptions of cerebral activity is to determine the causes of certain brain disorders linked to genetic mutations. It is hoped that such studies may lead to the prevention of some disorders as well as a better understanding of the genetic development of the human brain (Nelson, 2001 p. 149).

CURRENT NEUROSCIENCE EXPERIMENTATION

A common approach in neurocognitive research is to focus first on a particular mental operation or human experience of which the researcher wishes to find the cerebral correlate. As an example, let us say that we are searching for the cerebral correlates of conscious acts of problem-solving. The presupposition is that, if a researcher can locate the region or regions of the brain that manifest synaptic activity while a test subject is problem-solving, this information will aid in understanding both problem-solving and the links between what neurosciences uncover and what cognitive psychologists are studying. To these ends, researchers design experiments for test subjects in order to obtain the data of graphs and scans signifying the cerebral correlates of problem-solving. In clinical research, cognitive acts in participants are frequently stimulated through problem-solving. For example, Figure 1 below is a puzzle which could be utilized to locate the cerebral correlates of the different cognitive operations occurring when a person is problem-solving.

In fact, I have been using this puzzle (Figure 1) in my classes on cognitional theory and ethical decision-making for over 25 years. The problem to solve is why some letters are on top while others are on the bottom. I add a second question to the exercise. The students are asked to reflect on their conscious operations in trying to solve this puzzle. This is a leisurely exercise in which the students are not to help one another and are to relax with the process. The diagram provides the first set of data or clues. They attend to the diagram, the image. Now, a non-standard part of the problem is to notice that attending is also a datum. Of course, I do not mean that the experience of 'attending' is data that can be measured, but rather is data in the sense of being experience, being something that can be described and explained. Students are wondering and puzzling, revealing a second experience of data, in response to my question: What law or formula is in play that arranges the letters in the above format? And so, we can describe patterns of mental acts that occur: paying attention and puzzling.

Some of the students "get it" quite quickly; they experience an insight, a third mental operation that is a further datum. Others are somewhat slower in achieving insight, and some do not get it at all. I provide the following hint (Figure 2) for those who cannot get it. This also serves as verification for those who, at this point, think they have it and often assists others who have not achieved the insight.

Some students do not experience the insight without assistance, and eventually I ask one of the students who thinks she has it to explain why the letters are separated in the above manner. When I try to draw the students' attention to the second question (i.e., how are they operating in trying to solve this problem), it is very difficult for them to shift their attention away from the wanted solution and to focus on their mental operations. If they cannot attend adequately to their own acts of thinking, and this is often the case, I assist with further clues labelling and suggesting what their cognitional acts might be. The data needs to be generated first by their desire to solve the puzzle and then by their actual performance. Once all the students have understood the law that is functioning in the puzzle, I then focus directly on the second question.

How did you solve the puzzle?

What was going on in you as you were solving the puzzle?

Eventually a percentage, usually about half of the class, begins to notice and to acknowledge a distinction between the content and the cognitive acts.

Let me now focus on the term

Figure 1

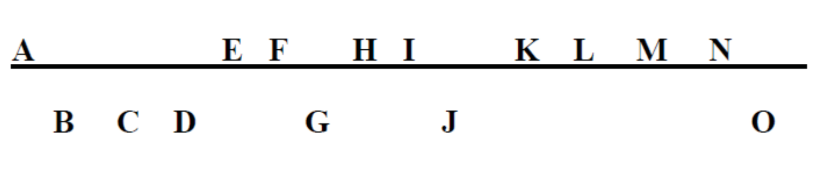
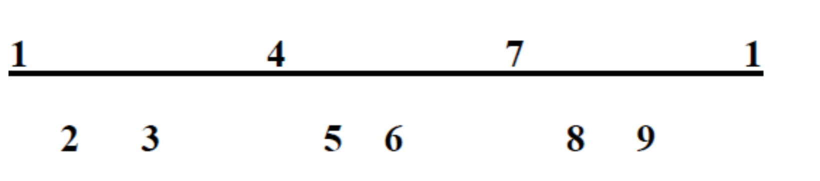


Figure 2



"problem-solving". From where do cognitive neuroscience researchers derive this terminology? What empirical data are researchers referring to when they use the term *problem-solving*? Are they referring to any empirical data when using the term *problem-solving*? We use terms such as paying attention, thinking, puzzling, explaining, understanding, knowing, judging, problem-solving, decision-making and planning in common-sense conversations, in philosophy and in science, but there may be no explicit empirical references cited. Neurocognitive scientists theorize that by locating the neural correlates of these "terms" they will achieve a better understanding of the meaning of these terms. Since the terms originate as first-person reports, scientists hope to shift the meaning of the terms into a third-person perspective, so that they can be studied less "subjectively". Hence, they are interested in locating observable data as potential correlates of these first-person reports. However, are the images and graphs that visually record synaptic activity occurring in the organism similar in any manner to the human subject's conscious experiences of attending, puzzling, explaining, understanding, judging, knowing, planning or decision-making? The data of mental acts and the images from brain scans are two distinct forms of data. They are related but distinct. Even though the listed terms signify, in a non-explanatory manner, mental operations, they are judged to be subjective reports, and we commonly use the terms as if we have some data-reference *in mind*. Do we? How can such terms be used in a scientific context or experiment if we have no specific empirical data-reference?

I suggest the following reflection on performance as a means to *resolve this problem*. What I am referring to here is implicit in normal procedure, but not often adverted to. I am, in fact, inviting attention by the researchers, on the processes of the researchers themselves. The researcher has a problem she *desires* to *resolve*. The researcher *desires* to *know* what the cerebral correlates for *problem-solving* are in the brain? The researcher's first task is to *design* an experiment that he or she *believes* will achieve the *intended* outcome. So, in *question* form: *What form of experiment is required?* The researcher *puzzles* and *reflects* on various possibilities, *reviews* other experiments by other researchers, until eventually an *insight* occurs (an ah ha experience). This or that particular experiment should provide the outcome that the researcher is *seeking*. But the researcher does not *know* at this stage. She may *search* more literature on similar studies or set up mock experiments in an attempt to *verify* her former *insight*. *Certainty* need not be the goal, but she may *feel sufficiently convinced* that the form of experiment she has *settled* on is *reasonable*. The only way to *verify* that this confidence is warranted is to run the experiment.

Let us retrace the steps of the researcher's problem-solving (Steps 1 to 9 from Benton et al., 2005, p. 67-71; Steps 10 to 21 from Lonergan, 2001, p. 322-323):

1. Desired outcome: Locate organic correlates of problem-solving. (Data)
2. A *What question*: What form of experiment will achieve this outcome?
3. *Insight* (Ideas, understanding of possible designs)
4. *Formulation* into a *Concept*, a formulated *Answer* to a *What* question
5. *Will it work?* Seeking verification of *insight*
6. *Indirect insight*
7. *Judgment*. Reasoning
8. *Planning*. How to set up and run the experiment?
9. Further *what* and *Is* questions
10. Set up and run the experiment. Doing
11. *Yes*, it worked. Verification
12. Outcomes achieved
13. *What-to-do* with the outcomes?
14. Further *insights*
15. *Develop* options
16. *Choose* the *most reasonable* option. *Judgment*
17. *Decision* to implement option
18. *How* to implement the option
19. Further *insights* on how to implement option
20. *Planning* the implementation
21. *Implementing* the option.

The listing in sequence of the first seven acts of problem-solving corresponds to the cognitive acts that my students report experiencing, when solving the alphabet puzzle. The terms in italics refer to mental acts that researchers can notice in themselves when trying to solve a problem. In other words, these distinct mental acts function heuristically as a dynamic sequence or pattern of acts occurring in problem-solving. As such, they are the basic elements of a theory of thinking. Verification of these elements requires that researchers reflect on their own performance while solving a problem and ask this *question* while doing so: Do we experience these acts and in this order when we are solving a problem? There are three possible judgments: "Yes", "No" or "Maybe". Such judgments are mental acts and can be made explicit by attending to one's own performance during problem-solving. Even a judgment of No requires the same process as a Yes, and, even though both are *reasonable* responses to any **IS** question, in this particular case, **No** is nonsensical. The researcher has to go through the first seven steps in order to verify the order and number of her own mental acts and arrive at the judgment: "No, I do not perform these acts when I am problem-solving". Why is this negative response nonsensical? This answer requires reflection on cognitive performance. Doing so will reveal the same patterned acts of attending to whatever is puzzling, asking questions, surmising what answers might work, asking whether they in fact work, checking them out and arriving at judgments.

Concerns about the reliability of self-observation are not groundless. One reflects on one's performance, and such reflection is quite different depending on whether one is reflecting on one's emotions or on one's scientific procedures. Brentano concluded that experiencing emotions and thinking yield the same type of data (Brentano, 1874/2013). Even so, there is no conflict, and no lack of distinction. Anger is not a mental operation. It is an emotion or conscious state, but the data of distinct types of cognitive acts are better classified as operations, not states. It is generally held that emotions are affective rather than apprehensive. The mental operations are generated by the desire to understand, but emotions are often evoked by either the inability to understand or a refusal to understand (Lonergan, 1992, p. 219). Anger, it would seem, has its origins in the complex integral dynamic of the human chemical, psychic and intellectual makeup of a person in response to an experience (Lonergan, 1992, Chapter XV, section7). Brentano, one would assume, reflected on his own performance in order to arrive at his conclusion. Was he observing himself or reflecting on his own performance? If not, what procedure did he employ to obtain and verify his conclusions?

What does this brief description of cognitive acts offer the neuroscientist? In preliminary fashion, it sketches the elements for a theory of cognition that later uses of imaging and scanning techniques can differentiate and track. It assists the neuroscientist in refining his or her own tests so that test-subjects can be deliberately "walked through" the various mental acts and thus reveal with more specificity the brain locales and activities that are correlates of the distinct types of acts.

What I am suggesting here is something that will add to present progress. The addition will lead to a theory of cognition that includes attending to one's own performance, to the data of one's own mental acts, when engaged in problem-solving. First-person reports of these acts can be followed by research into how each type of act has correlates in neural activities at specific brain locales. The goal is greater understanding of these mental acts and their neurochemical antecedents, all the while recognizing that working out such correlations is not the same as identifying the acts with their correlates.

I have offered only a listing and minimal descriptions of mental acts. An explanatory account of their functions and relations to one another would require a much larger work. Efforts have been made to understand acts of insight and to work out a procedure for achieving insight into insight and insight into other cognitive acts (McShane, 1975, Ch. 3 and 4; Lonergan, 1992, Ch. 3 & 4). Steinberg and Davidson's *The Nature of Insight* (Steinberg and Davidson, 1995) presents the work of 25 psychologists developing a descriptive phenomenology of the act of insight and its relationship to problem-solving and thinking. The text is limited in its expression by a lack of distinction between description and explanation and by the supposition that concepts precede insights. However, in the Preface, Janet Metcalfe makes a statement at odds with this assumption:

> Qualitatively, then, this kind of model has the right feel for the emergence of concepts as a result of insight (Steinberg and Davidson, 1995, p. xiii)

This statement can be verified in one's own experience. Concepts are the result of insight, not the reverse (Lonergan, 1970, pp. 38, 42). Though the above quotation is not followed up with any explanation it challenges the supposition inherent in conceptual analysis which is dominant in present scientific procedure. The author was probably not aware of the paradigmatic shift she was advocating by making such a statement. And that shift is one of meaning. Steinberg's and Davidson's text does not do justice to the acts of intellect in the manner that Lonergan offers in his text *Insight* (Lonergan, 1992), but it does point beyond the reductionist tendencies (a residue of nineteenth-century positivism) often present in neurocognitive literature.

If a theory of cognition cannot be achieved solely through imaging and scanning techniques, what outcomes can these techniques produce? While a theory of cognition needs to account for the data produced by scanning and imaging research, must it not also include and account for the data produced by the researcher and that of the subject's performance? Both accounts are important if the research is to be thorough and the resulting theory comprehensive. Still, understanding the relationship of the brain to body chemistry, psychology, observable behaviour and mind remains an ongoing challenge.

A detailed account of the mental acts increases the specification of locales and events in the brain. Understanding more completely the relations between the various types of mental acts will help to influence the design of future experiments. A specific puzzle may be the reason why different combinations of brain locales are sometimes activated during the occurrence of the same type of mental act. In contrast to these varying combinations, scans may record different rates of synaptic activity in the same cerebral regions for the same type of mental act during different problem-solving experiments. This is not to suggest that the mental acts "cause" the synaptic activities or that the latter "cause" the former. A cause is an explanation, and a comprehensive explanation will treat correlates as dependent variables without relegating either to an epiphenomenal status (Lonergan, 1992, p. 316-318).

Neuroscientists have to work out the specific outcomes of cognitive neuroscience research. However, a more complete account would result from "framing" research projects including all the relevant data (both neurological and psychological). This contribution will arrive, eventually, at a comprehensive theory of thinking (Gulyás, 2009, p. 142).

There are doubts within the neuroscientific community, as to whether or not a theory of cognition can be achieved through the current techniques. In the Introduction to *Neural Correlates of Thinking*, the editors, Kraft, Gulyás and Poppel highlight this problematic, and Gulyás 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?" (Gulyás, 2009, p. 142). He does not ask what these "cognitive processes" are, but at least he accepts a distinction between the two. What follows are some comments by a few leading neuroscientists, regarding their doubts about their methodology (from Bandettini, 2009, p 31-32):

> 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 ex-

> plain 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 thinking, 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 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?

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 (Carter, 1998/2000, p. 43)

> With the help of [imaging techniques] can we exploit the differences between conscious and unconscious brain processes? (Gulyás, 2009, p. 142)

> It still remains unclear whether it is justified to assume that neural assemblies are actually the basic units of cognition (Öllinger, 2009, p. 75)

> …a coherent theory of thinking is lacking…a book exclusively dedicated to…gaining insight into the process…seems warranted (Kraft et al., 2009, p. 6)

> The connection between neuroanatomy, neurochemistry, and neurodevelopment, and the behavioural research in cognition are rather tenuous (Nelson et al, 2001, p. 415)

> As always, an understanding of the mind must guide the search for its neural underpinnings (Nelson et al, 2001, p. 429)

Richard Moodey (personal communication, email correspondence at: lonergan_l@googlegroups.com, 2013) offers an interesting insight into the relationship between researchers 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.

Moodey's point is that both first-person reports of test subjects and the third-person reports of researchers are legitimate sources of data. Will this more inclusive perspective make researchers' accounts more comprehensive? The problematic that obfuscates the settling of the issue stated in the previous quotations is expressed summarily by Lonergan:

> 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 (Lonergan, 1992, p. 282-283)

Part of the problem then, is how to unify results. The verifiable patterns of mental acts are conscious events, conscious in the sense of experienced. At the same time, neuroscience is uncovering verifiable patterns of aggregates of biochemical and cellular events. But, the conscious acts of attending, puzzling, understanding and judging "look" nothing like scanned images or graphs (McShane, 2013).

GENERALIZED EMPIRICAL METHOD

To reach a more complete and balanced account of mental acts, researchers can reflect on their own performance when they, for example, are problem-solving. For, performance, such as problem-solving, provides data about mental acts. To identify functional relations can be part of formulating a structured heuristic, a framework for studying thinking and knowing. The following quotation describes one procedure for developing a more balanced framework.

Generalized empirical method [hereafter GEM] operates on a combination of both the data of sense and the data of consciousness: it does not treat of objects without taking into account the corresponding operations of the subject: it does not treat of the subject's operations without taking into account the corresponding object (Lonergan, 1985, p. 141).

The procedure goes forward by first listing distinct types of operations, then by describing them, and eventually by grasping the functional relations among them. Without this procedure, the scanning and imaging techniques presently operative in the various neurosciences will probably overlook some of the first-person data and so not achieve a comprehensive theory of cognition. GEM can provide more complete and balanced accounts of mental acts to be correlated with cerebral locales and events during experimentation. For example, the detailed listing of cognitive acts can serve as a guide for tracking components in problem-solving. It will also provide researchers with a standard model of performance of her or his research procedure. It is a standard model of performance in research not unlike the standard model of the periodic table. The intelligibility of the periodic table has provided a foundation for progressive development in pharmacology, industry and medicine for the past 144 years. The standard model of the mental operations of the human mind is paradigmatic in that it is the source of the very nature of a paradigm that results from reflection on performance. Margaret Masterman supports this in her comment on Kuhn:

> *Kuhn's form of thinking,…reflects the complexity of the material. … because he has taken a close look at what mathematicians really do…"* (Masterman, 1970, p. 60)

Kuhn, even though he advocates reflection on the performance of the mathematician, does not expose the operations of the mathematician's mental operations (McShane, 1980, p. 5f.).

A standard model of mental operations results from reflecting on the very operations that one is engaged in while trying to develop such a model. The practice of GEM and a self-appropriation of one's own mental acts are steps toward systematic control over research, evaluations and recommendations as well as over any ontogenetic account of the development of the cerebral organism (McShane, 1980, p. 49 f.).

Only by performance and reflection on that performance can one come to notice the distinctions and differentiations involved in problem-solving. Generalized empirical method calls into question the traditional definition of human subjectivity. How does a researcher know if he or she is working with the correct data, asking the right question(s), getting the correct insight(s), and formulating that insight(s) into a correct judgment(s)? The researcher does so by gathering all the relevant data, asking all the relevant questions and answering them (McShane, 1975, chapter 4). In other words, objectivity is achieved through authentic subjectivity (Lonergan, 1992, chapter 13; McShane, 1976, p120-126). There is an objective element to each mental act. In other words, how does the researcher know when she is asking the right question? In short, because intelligence seeks to be intelligent and that drive is the human desire to understand correctly. In the final judgment of yes or no, one achieves a greater degree of objectivity. When one verifies an insight, one is not verifying data, one is verifying an **insight into data** and such an act looks nothing like the "seen" data (McShane, 2013). Such distinct operations ground GEM and scientific research in general. The larger issue is whether science is an effort to understand data, all data. As long as science refuses to attempt to understand the data of human consciousness and first-person reports relevant to them, scientific research will remain truncated in its development.

> *The neglected subject does not know himself. The truncated subject not only does not know himself but also is unaware of his ignorance and so, in one way or another, concludes that what he does not know does not exist* (Lonergan, 1968, p. 8)

CONCLUSION

There are further questions and doubts raised in the literature about the process and method of the present scanning and mapping techniques of the brain. While these concerns and doubts are raised by some of the leading researchers, it seems that their theories are ignored in much of the literature. In particular, there is the present restriction to experimentation through scanning and imaging techniques. A more complete method, though, will lift these excellent results into a balanced account that includes detailed description of conscious events. In other words, a Generalized Empirical Method (GEM). Such doubts and concerns are indicative of an observation, by the authors referenced above, in order to distinguish between two forms of data. Scanning and imaging techniques contribute to our understanding of the human brain and its relationship to human genetics, psychology, mental acts and intellectual development. An explanatory account of the mental acts of the researcher occurring when performing experimental research can broaden the perspective of the researcher. Might this could be of help to cognitive neuroscience in order to achieve what it has been seeking for some time, namely, an understanding of the brain in its relationship to the data of mental operations?

My response to the question expressed in the title of this essay is obviously "No." A theory of mental operations cannot be provided through scanning and imaging techniques but such techniques can and do assist in understanding the underlying biological aspects of cerebral activity. I envisage, then, a shift from reductionist tendencies to a more balanced methodology. And this shift would also provide the beginnings of a new heuristics for phylogenetic and ontogenetic development of the cerebral organism and its relationship to a theory of thinking (Lonergan, 1992, p. 489, McShane, 1975, p. 106).

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