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The Language of Thought and the Existence of a Mental Logic: Experimental Investigations in the Laboratory and in the Field

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RESUMO

Este artigo descreve a hipótese da linguagem do pensamento que estabelece em primeiro lugar que para armazenar informações proposicionais na memória declarativa é necessário que exista um formato no qual representar esta informação. Visto que este formato precisa distinguir entre propriedades e as entidades que possuem estas propriedades, é necessário incluir uma estrutura predicado/argumento, isto é, precisa que seja incluído algum tipo de lógica mental. Iremos descrever uma proposta detalhada desta teoria da lógica mental que tem sido apresentada por Braine e O'Brien (1998), e uma ampla variedade de evidências empíricas corroborando esta teoria a partir de estudos de laboratório em crianças e adultos. Enfim, iremos discutir que a predição da existência de habilidades lógicas universais decorre do pressuposto que esta lógica mental tem sido o resultado do desenvolvimento bio-evolucionário da nossa espécie. Nesta perspectiva é descrita uma investigação sobre raciocínio lógico em populações indígenas não alfabetizadas que vivem na bacia amazônica brasileira. Nesta investigação aborda-se esta questão da existência de habilidades de raciocínio lógico independentemente do nível de alfabetização e escolarização da população investigada. Os dados mostram que habilidades inferenciais de tipos proposicional são disponíveis nesta população da mesma forma como são disponíveis em populações escolarizadas e alfabetizadas da Europa e da América do Norte.

Palavras-chaves: Lógica mental; Linguagem do pensamento; Desenvolvimento bio-evolucionário; Alfabetização; Escolarização.

The central idea we present in this article is that propositional thought takes place in a language of thought, and that this language of thought is profoundly logical. Our proposal begins with the observation that human memory includes a

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declarative part, that is, that there is a memory for linguistically expressible propositions. This is the sort of memory that is tested in schools, for example, when a student is presented a verbal question and is required to provide a verbal response. This sort of memory is distinct from other sorts that do not seem in any obvious way to rely on storage in a linguistic format and for which the stored information thus may not be expressible directly or easily in any linguistic way, for example, including memories of images, memories of melodies, memories of perceptions of smells or sounds, and so forth. Declarative memory is different, for example, from what was reported by Marcel Proust (1927) when a memory of an emotion from his childhood was elicited by the smell of a sweet desert. Thus, it is intuitively obvious that one should distinguish between propositional information of the sort recorded in a declarative memory and memories of other sorts that are stored in ways that are not based on linguistic representational formats. Our proposal presented here refers only to propositional information of a declarative sort, and we shall describe something of the format for representation of propositional information in a declarative memory and of the inferences that are drawn about such information in the language of thought.

Our next observation concerning declarative memory seems to us as fairly obvious: In order for propositional information to be recorded in a declarative memory, there must be a format in which such information can be represented. In representing declarative propositional information, one would need to distinguish, for example, between properties and the entities that have those properties, and to keep track of which properties go with which entities and which entities go with which properties. For example, the proposition *the third grader is wearing a red shirt* contains *wearing a red shirt* as a property that attaches to the entity *the third grader*, and one needs to know which concept is a property and which is an entity that has that property.

A representational system that could keep track of entities and properties in this way would be a predicate/argument structure, that is, it would share some basic features of a sort of a predicate-level logic system, and it would need as well other features typically found in systems of logic, if such a representational format were to provide the basis for a declarative membory for a species that could be considered intelligent. For example, one would want to be able to distinguish between those propositions that are true and those that are false, which typically is done in representational systems of logic with negation (e.g., *the third graders are not wearing red shirts,* or*, it is not true that the third graders are wearing red shirts*). One also would want to distinguish between those propositions that are asserted and those that are hypothesized or supposed (e.g., *the boy wearing a red shirt is in the car* vs. *if the boy is wearing a red shirt he is in the car* or *the boy is wearing a red shirt if he is in the car*); further, for such suppositional propositions, one would need a way to mark clearly which clause conveys the supposition and which conveys the consequences of that supposition. One also would want to keep track of which properties are conjoined and which properties are alternatives, as well as which entities are conjoined or are alternatives. Understanding a proposition such as *either the third grade or the fourth grade children went to the park*, for example, requires that one can distinguish that *going to the park* is a property and that *third grade children* and *fourth grade children* are alternative entities to which that property attaches, and the proposition that *the third graders either are swimming or are eating ice cream* presents *third graders* as the entities to which the alternative properties of *going swimming* and *eating ice cream* are attached. Storage of such information in a declarative memory thus requires not only a representational format that has sufficient capacity to represent entities and properties separately and to keep track of which properties go with which entities, but also to represent alternatives, conjunctions, suppositions, and negations.

The existence of such a logical representational format would be necessary prior to recording of any propositional information, that is, a child could not begin to record propositional information in memory unless some sort of format of this type existed prior to the recording of such information. In a Kantian sense, such a structure would be an *a priori* condition for the representation of propositional information. Such an a priori structure would be, we assume, the result of human bio-evolutionary history, and thus would be innate in ontogenesis and would become apparent in concert with language development during development. Indeed, we have argued elsewhere (Braine & O'Brien, 1998, Chapter 4) that such a structure could provide much of the basis for the acquisition of a native language as well as the basis for propositional thought.

Although our argument for the existence of such a language-of-thought structure is similar to Fodor's argument in favor of an innate language of thought (Fodor, 1975), our proposal differs from Fodor's in that whereas Fodor viewed just about everything in the language of thought as innate, we separate the structural—or syntactic—part of the language of thought from its content predicates. Although we propose a part of a language of thought that allows for the separation of properties and entities to which these properties attach through an innate predicate/argument structure, we do not suggest, and see no reason to do so, that the concepts being represented (e.g., the concepts associated with the clauses *wearing a red shirt*, *being a third grader*, and so forth) are innate. Thus we are suggesting that there is an innate syntax of thought that includes a predicate/argument structure, a set of propositional operators, some referring devises such as indexicals and pronominals, some quantifiers, and some ways of keeping track of quantificational scope. Given that formal theories of logic, linguistics, artificial intelligence, and so forth have provided a large set of candidate structures for us to consider, constructing a plausibly testable cognitive theory that contains such structures requires making some choices about what to include and what to exclude as ways of modeling this psychological structure.

Before we describe some of the details of the model we have developed, let us describe how we conceive of our proposed model as operating. Imagine someone encountering as linguistic input, for example, the proposition that *the third graders are wearing red shirts*. A listener would translate the sentence from the natural language in which the proposition is received, such as English or Portuguese or Cantonese or Tukano, for example, into the language of thought, where the concepts and relations among them that are expressed in the received sentence of the natural language are understood. It is in the language of thought that the received words have meaning in terms of concepts that presumably reside in semantic and episodic memories. The innate syntax of thought would enable recording both entities and properties, thus keeping track of them, and interpretation of input in terms of some acquired content predicates would allow the meanings of *third graders* and *wearing red shirts* to be understood. Our proposal that a natural language does not by itself provide the meanings and relations needed to understand linguistic input is consistent, of course, with standard notions in modern linguistics that differentiate between surface inputs and deep structures, and also is consistent with semantic theories in psychology that differentiate between a lexicon and a conceptual memory in which concepts reside and to which the lexical items refer. Indeed, the ability to translate between two natural languages, such as between English and Portuguese, presupposes a common language of thought into which one natural language is translated and from which a translation is provided into the second natural language. One can say that such a translation is accurate if both natural languages refer to the same propositional concepts in the language of thought. Further, a language of thought provides an explanation for choices that are made concerning which concept is the appropriate reference when homophones are received, for example, in deciding whether the word *bank* in English refers to the side of a river or to the place one deposits one's pay check.

We use the expression *language of thought* because we propose not only that items of declarative memory are recorded there, but also that inferences are made concerning the propositions that are recorded in such a declarative memory and are active in working memory; from this perspective, the propositional architecture is not merely a passive recipient of linguisitic input but also is an active processor of that input. Propositional information is useful to an intelligent organism, we believe, because such information allows for the drawing of inferences that go beyond mere storage of information. This notion is consistent with the notion that intelligence concerns the ability to go beyond the information given. Thus, a principal part of the work of the propositional system concerns making propositional inferences. Given that a basic part of propositional representation enables the distinction between true and false propositions, one would expect some inference-making procedures that ensure that inferences based on true propositions are themselves true, that is, that one does not pass from true premise assumptions to false inferences. In other words, such a system would include some procedures for making sound inferences and for checking the soundness of inferences made by other processes.

This proposal that the human propositional system includes both a representational part and an inferential part is consistent with our assumption that this system would have bio-evolutionary origins. Our hunter/gatherer ancestors would have benefited from an ability to record information about alternatives, for example, and knowing that there are two alternatives, it would be useful to be able to infer on the discovery that one of the two alternatives is false, that the other must be true. For example, imagine that a woman knows that her son either went to the river or to the lake, and subsequently she discovers that he did not go to the river. It would be useful for her to be able to infer that her son went to the lake. Someone without an ability to make such an inference might otherwise be doomed repeatedly to check both locations each time the need to find a colleague arose.

The assumption that the syntax of language of thought is part of human bio-evolutionary inheritance leads us to an expectation about its properties. Our hunter/gatherer ancestors would not have had any need to do many of the things that are of interest to professional logicians or to others who have highly developed and specialized logical reasoning skills. There is no reason, for example, to think that our hunter/gather ancestors would have needed to test the consistency of large sets of propositional assumptions; indeed, humans apparently are able to hold large sets of beliefs that are in contradiction simultaneously without noticing the contradictions. The ability to construct proofs of the consistency of premise sets—the sort of thing that has been of great importance to professional logicians concerned with metalogical proofs, or to investigators of artificial intelligence systems—thus is unlikely to be part of our bio-evolutionary inheritance, and construction of complex proofs in general seems unlikely to have been part of the cognitive needs imposed on our hunter/gatherer ancestors by their environment. Such skills probably are developed only with the emergence of professional classes, such as academics, lawyers, theologians, mathematicians, scientists, cognitive scientists, and the like, and with the rise of cities and literate civilizations. The sorts of skills that would have benefited a hunter/gatherer group are likely to represent alternatives, conjunctions, suppositions, negations, as so forth, and to draw inferences that can be drawn immediately from such representations with short and direct lines of reasoning. We doubt that bio-evolutionary motivations alone would have provided for lines of reasoning beyond the drawing of direct inferences, and the construction of complex lines of proof that require sophisticated reasoning strategies would exist only for literate societies and typically would be found among classes of professional thinkers. Other inferential forms that would be useful for our hunter/gatherer ancestors, we think, would be those that could draw immediate conclusions on the basis of quantifiers and their scopes. For example, it would be useful knowing that if all of Biberi's sons went fishing, and that Yupuri is one of Biberi's sons, one could to infer that Yupuri went fishing. Alternatively, it also would be useful to realize that one cannot infer whether Yupuri went fishing from the knowledge that some of Biberi's sons went fishing and that Yupuri was one of Biberi's sons. The need to make such inferences about instantiation would be the reason for the language of thought to have evolved universal and existential forms of quantification, we believe, and a person who did not draw such differential inferences about instantiation could not be said to understand the meaning of the words *all* and *some*.

The Inference Schemas and Reasoning Program of the Mental-Logic Model

The mental-logic theory that we propose consists of a representational format, a set of schemas that draw inferences based on the form of these representational formats, a reasoning program that applies these schemas to construct lines of reasoning, and a set of pragmatic principles. The inference schemas of the mental-logic model that we propose consist of two parts: a set of schemas that operate on sentential particles for conjunction, disjunction, negation, and supposition, such as with the English-language particles *and*, *or*, *not*, and *if*, and a set of schemas that provide additional representation of quantification expressible, for example, with English-language quantifier terms such as *all* and *some*. The sort of schemas that rely only on sentential particles can be referred to as sentential-logic schemas, and the sort that also include quantifiers can be referred to as predicate-logic schemas. The sentential-level and predicate-level schemas differ in that the representational format upon which the predicate-level schemas rely is more complex because of the demands associated with the representation of quantifiers and of quantificational scope. Because the predicate-level representational system is more complex and thus requires difficult choices in constructing a theoretical model, the sentential-level part of the theory was developed first, and more empirical evidence in support of this part of the theory exists than for the predicate-level part.

Table 1 shows the principal sentential-logic schemas of the mental-logic theory that were presented in greater detail in Braine and O'Brien (1998, Chapter 6), and Table 2 shows a representative sample of the predicate-logic schemas proposed in Braine and O'Brien (1998, Chapter 11). In both tables the schemas are accompanied by examples to illustrate the sorts of sentences that they can be used to represent. Inspection of Table 1 reveals three different sorts of schemas: core schemas, feeder schemas, incompatibility schemas, and supposition schemas. The division of schemas into these four groups stems from both conceptual and empirical reasons. Let us consider first the distinction between the core and the feeder schemas. The difference between the two sorts is defined by the way the two sorts are applied. Indeed, a schema can be applied only by the use of a reasoning program and the reasoning program consists of two parts: a direct-reasoning routine (the DRR), which is claimed to be universally available and is applied essentially effortlessly to construct direct and usually short lines of reasoning, and a set of more sophisticated reasoning strategies that are not claimed to be universally available and whose use requires effort.

The core schemas are applied by the DRR whenever propositions of the requisite sort for their application are available conjointly in working memory. For example, so long as propositions of the form *p or q* and *not-p* are held conjointly in working memory, the sentential-level Schema 3 of Table 1 is applied to infer *q*. The only general restriction on the use of the core schemas is that the premise propositions must be assumed true; none of the schemas are applicable in situations where the premise propositions might be false. (This restriction strikes us a sensible in that one would not want to draw inferences unless these inferences could inherit the truth of the propositions from which they are drawn. If the basis for the inferences in uncertain, the conclusions could not be inferred with certainty.) The feeder schemas, however, are more restricted in the conditions of their application, and they are applied only when their output feeds into the application of a core schema or allows the evaluation of a tentative conclusion. For example, imagine a situation where one knows that *if p then q* and *p and r*; in this case one can apply the sentential-level feeder Schema 9 of Table 1 to derive *p*, which then feeds into the application of Schema 7 of Table 1, which allows the inference of *q*.

The incompatibility schemas are used principally to make evaluations of tentative conclusions as false; when a line of reasoning derives a proposition that is incompatible with a tentative conclusion by either Schema 10 or 11 of Table 1, a "false" conclusion can be rendered. The supposition schemas govern the inferences that can be made following from a line of reasoning under a supposition. Schema 12 of Table 1, known as the conditional-proof schema, provides for a conclusion in a conditional form, that is, in the form of *if p then q*. The DRR provides some specifications for how and when this schema is applied. First is the case when a conditional conclusion is presented for evaluation. The DRR adds the antecedent of the conditional (i.e., the *p* of *if p then q*) to the premise assumptions and then proceeds to reason toward the consequent (i.e., toward *q*) as a conclusion to be

Table 1 – Inference schemas for the mental sentential logic

Core Schemas:

1. ~~p ≡ p
   E.g., It is false that there is no wine in the cellar
   ∴ There is wine in the cellar.

2. IF p_1 OR . . . OR p_n THEN q; p_i
   ∴ q
   E.g., If José's mother or his father come for dinner then he will bake a cake; His mother will come for dinner
   ∴ José will bake a cake

3. p_1 OR . . . OR p_n; ~p_i
   ∴ p_1 OR . . . OR p_{i-1} OR p_{i+1} OR . . . OR p_n
   E.g., Filipe works in Braga or in Porto; He does not work in Porto
   ∴ Filipe works in Braga

4. ~(p_1 & . . . & p_n); p_i
   ∴ ~(p1 & . . . & pi-1 & pi+1 & . . . & pn)
   E.g., It is false that both Maria and Sílvia went to Lisboa; Maria went to Lisboa
   ∴ Sílvia did not go to Lisboa

5. p_1 OR . . . OR p_n; IF p_1 THEN q; . . .; IF p_n THEN q
   ∴ q
   E.g., Jorge published a book or a journal article; If he published a book then he is starting another project;
   If he published a journal article then he is starting another project
   ∴ He is starting another project

6. p_1 OR . . . OR p_n; IF p_1 THEN q_1; . . .; IF p_n THEN q_n
   ∴ q_1 OR . . . OR q_n
   E.g., There is an apple in the bag or there is an onion; If there is an apple then the lunch belongs to Antônio;
   If there is an onion then the lunch belongs to Rosa
   ∴ The lunch belongs to Antônio or to Rosa

7. IF p THEN q; p
   ∴ q
   E.g., If Paulo got the job in Paris then he will get a salary increase; Paulo got the job in Paris
   ∴ He will get a salary increase

Principal Feeder Schemas:

8. p_1; p_2; . . . p_n

∴ p_1 AND p_2 AND . . . AND p_n

E.g., Eliane went to work; Vera lost her job
∴ Eliane went to work and Vera lost her job

9. p_1 & . . . & p_i & . . . & p_n
∴ p_i

E.g., There is a Fiat and a Ford in the driveway
∴ There is a Fiat in the driveway

Incompatibility Schemas:

10. p; ~p

∴ INCOMPATIBLE

E.g., There is a monkey in Teofilo's bedroom; There is not a monkey in Teofilo's bedroom
∴ INCOMPATIBLE

11. p_1 OR . . . OR p_n; ~p_1 AND . . . AND ~p_n
∴ INCOMPATIBLE

E.g., The lottery was won by Marcos or by Carol; The lottery was not won by Marcos and was not won by Carol
∴ INCOMPATIBLE

Supposition Schemas:

12. Given a chain of reasoning of the form
Suppose p
∴ q
One can conclude: IF p THEN q

13. Given a chain of reasoning of the form

Suppose p

– – – -

∴ INCOMPATIBLE

One can conclude: ~p

Note. Where there are subscripts, *i* indicates any one of the subscripted propositions. "~" is negation and can be expressed as "It is false (not the case) that . . .". Schema 12 states that when *q* can be derived with the aid of the supposition *p*, one can conclude IF *p* THEN *q*. Schema 13 says when a supposition leads to an incompatibility, the supposition is false.

Table 2 – Some Examples of Schemas for a Mental Predicate Logic

1a. S1[All X] OR S2[PRO-All X]; NEG S2[☐]; [☐] ⊆ [X] ∴ S1[☐]
E.g., The boys either went fishing or they went to a festival; Fernando and Henrique did not go fishing
∴ Fernando and Henrique went to a festival

1b. S1[All X] OR S2[PRO-All X] ∴ S2[All X: NEG S1[PRO]]
Note: Requires E[Some X: NEG S1[PRO]]
E.g., The boys either went fishing or they went to a festival
∴ The boys who did not go fishing went to a festival

2a. NEG E[~Some X: S1[PRO] & S2[PRO]~]; S2[☐]; [☐] ⊆ [X] ∴ NEG S1[☐]
E.g., There are no package tours that stop both in Salvador and Maceio; The package tour that leaves at 3 p.m. stops in Salvador
∴ The package tour that leaves at 3 p.m. does not stop in Maceio

2b. NEG (S1[All X] & S2[PRO-All X]) ∴ NEG S2[All X: S1[PRO]]
(Note: This schema requires that there is some X that satisfies S)
E.g., The boys did not visit Manaus and travel by bus
∴ The boys who visited Manaus did not travel by bus

3a. S[X]; [☐] ⊆ [X] ∴ S[☐]
E.g., The third grade children went to the museum
\ The third grade children from Porto Velho went to the museum

3b. NEG S[~Some X~]; [α] ⊆ [X] ∴ NEG S[α]
E.g., None of the boys wore silly hats
∴ Fernando and Henrique did not wear silly hats

evaluated. When *q* is evaluated as true, then the conditional conclusion is judged to be true; when *q* is evaluated as false, then the conditional conclusion is judged to be false. This latter judgment differs from what one would conclude if one were reasoning on the basis of a standard logic of the sort presented in contemporary textbooks, where the judgment would be withheld because of the possibility that *p* might be false. We shall return to this below.

An additional way in which the DRR effects the application of the conditional-proof schema (Schema 12 of Table 1) is through a constraint on what propositions can be used in a line of reasoning following from a supposition. No proposition can be introduced into a line of reasoning following from a supposition unless that proposition would be true given the supposition. This constraint differs from what is found in standard-logic systems of the sort typically found in logic textbooks, but it follows from the general constraint that inferences can be drawn only from premises assumed to be true (to ensure that an inference is inheriting the truth of the propositions on which it is based). As we shall describe below, in this and in other cases in which the mental-logic system differs from the standard textbook logic, human reasoning appears to be consistent with what is described by the mental-logic theory.

Note that the model makes clear predictions about when a conclusion presented for evaluation will be judged true—when the proposition to be evaluated can be derived from the premise assumptions by the DRR it will be judged true—and when a conclusion will be judged false—when the proposition leads to application of the two incompatibility schemas, such as Schemas 12 and 13 of Table 1. The model does not made predictions with equal clarity, however, about what responses will be made when a conclusion can be neither derived nor falsified through the use of an incompatibility schema. For example, imagine being asked to evaluate the truth or falsity of *there is a blue marble in the box* given the premise assumption that *there is a marble in the box*. One reasonable response would be "can't tell," that is, that there is insufficient information to make an evaluation, and many participants in laboratory make such responses (e.g., O'Brien, Braine, Noveck, Fisch, & Fun, 1989). O'Brien et al., found, however, that many people are reluctant to make "can't tell" responses, seemingly assuming that they ought to make a more determinate response, such as "true" or "false." "False" responses often are made in such situations, and O'Brien et al. argued that such responses indicate a judgment that it is wrong to assert the conclusion in the absence of sufficient justification. Of course, in such situations it often is possible to make all sorts of sound responses that follow from more sophisticated reasoning strategies (e.g., there is either a blue marble or not in the box, if there is a not a marble in the box then there is a blue marble in the box), but such responses almost never are made. At any rate, unlike the clear predictions about when "true" and "false" responses will be made, applications of "can't tell" responses always rely of auxiliary sets of pragmatic processes. This fact will be of importance in discussions later.

Empirical Support From the Laboratory for the Mental-Logic Theory

Mental-logic theory has been successful in predicting which reasoning problems people solve, the relative difficulties with which people perceive those problems that they do solve, the order in which inferences are made when lines of reasoning are being constructed, which logical inferences are made effortlessly and routinely during discourse comprehension, and research has established that the mental-logic inference are made on-line during text comprehension as the information enters working memory and not only when a problem-solving task requires that such inferences are made. Further, when the predictions of mental-logic theory differ from the predictions that would follow from the application of a standard logic of the sort typically found in a logic textbook, experimental comparisons support judgments that are consistent with the predictions of mental-logic theory.

Braine et al. (1984/1998) reported data that clearly supported the prediction that people routinely make those inferences that follow from application of the DRR, whereas those inferences that requiring strategic sophistication that goes beyond what is available from the DRR alone are be made far less frequently. The experiments in Braine et al. presented two types of sentential-level problems: 54 problems were solvable by application of the sentential-level schemas of Table 1 and the DRR, whereas solution of another 19 required reasoning strategies of a sophistication that went beyond the DRR. Each problem presented a conclusion to be evaluated as true or false given a set of premises. To minimize problem content as a possible source of responses, problem content referred to letters written on an imaginary blackboard (e.g., "There is a T on the blackboard or there is a D."). Errors were almost nonexistent on the DRR problems, but errors were much more frequent on problems that needed more sophisticated reasoning strategies. Thus, whether a problem could be solved could be predicted accurately by knowing whether the problem could be solved solely by use of the DRR or whether a problem required use of more sophisticated reasoning strategies.

An additional sort of evidence was provided by Braine et al. (1984/1998) and Yang, Braine, and O'Brien (1998). These experiments demonstrated that not only were the DRR problems being solved, but that they reasonably were being solved in by use of the sorts of reasoning processes described by mental-logic theory. Braine et al. (1984/1998) presented sentential-level problems and Yang et al. (1998) presented predicate-level problems that directed participants to rate the perceived relative difficulty of each problem on a Likert-type scale. In both studies regression models were constructed using the perceived-difficulty rating data with a weight assigned to each schema. This enabled a regression model to predict the difficulty of each problem as being equal to the sum of the weights of each schema required in the mental-logic theory for each problem to be solved using the lines of reasoning as predicted by the DRR. For example, the DRR predicts that a sentential-level problem that presents premises of the form *p or q, if q then r, not both r and s*, and *not p*, and requires evaluation of *not s* results first in the application of Schema 1 of Table 1 (to the first and last of the premises), which yields the inference of *q*, which then leads to the application of Schema 2 of Table 1, which yields the inference of *r*, which finally leads to the application of Schema 3 of Table 1, which yields *not s* as an inference; the predicted perceived difficulty of this problem thus is the sum of the difficulty weights for Schemas 1, 2, and 3. Braine et al. reported that for sentential-level problems the correlations between observed difficulties and the difficulties predicted by the regression equation accounted for 66% of the variance (53% with problem length partialed out), even when the weights were obtained with one set of problems and participants and the observed ratings were obtained with another set of problems and with different participants. Yang et al. reported that on predicate-level problems, the observed ratings again were correlated highly with those predicted by the schema weights (69% of the variance; 56% when problem length was partialed out), even when observed ratings came from different problems and different participants than those used to generate the schema weights.[1]

The sorts of evidence just described are supportive of our argument that people solve such problems using the lines of reasoning predicted by the mental-logic model, but such data addressed only indirectly whether participants were constructing the predicted lines of reasoning. A more direct sort of evidence was reported by O'Brien et al. (1994) and Braine et al. (1995) to demonstrate that sentential-level problems were being solved by construction of the lines of reasoning predicted by the DRR. Participants were asked to write everything down in the order that they figured things out from sets of premise assumptions. Some problems were presented with

[1] Johnson-Laird et al. (1992) claimed that the perceived difficulty ratings of the sentential-level problem also could be accounted for by mental-models theory; O'Brien et al. (1994) showed, however, why the models theory is unable to provide as good a fit for the data as does the mental-logic theory. The arguments are too detailed to present here.

conclusions, and participants were asked to evaluated the conclusions and to write down everything they figured out on the way to making their final judgment; on other problems participants were presented only premises, and on these problems they were asked to write down everything they could figure out from the premises in the order that they figured things out. In some experiments the orders in which the premise sets were presented were varied, testing the prediction that participants would write down their reasoning steps in an order that would correspond to the order in which the schemas became available rather than in the order the information became available; thus the prediction was that the order in which inferences would be written down would not differ when the order in which the premises were presented was altered.[2]

Take as an example two parallel problems that were presented in O'Brien et al. (1994), with premises that referred to letters written on an imaginary blackboard:

Problem 1	Problem 2
(a) N or P	(a) Not both Z and S
(b) Not N	(b) If H then Z
(c) If P then H	(c) If P then Z
(d) If H then Z	(d) Not N
(e) Not both Z and S.	(e) N or P

The mental-logic theory makes the following predictions for these two problems. On Problem 1 the DRR applies Schema 1 of Table 1 to the first two premises (a) and (b), deriving *P*; Schema 2 of Table 1 then is applied when premise (c) is read, deriving *H*, which allows Schema 2 to be applied again when premise (d) is read, deriving *Z*, which allows Schema 3 to be applied when premise (e) is read, deriving *not S*. In Problem 2 the same premises are presented in the reverse order. When the premises of Problem 2 are read, the DRR is unable to apply any of the core schemas until all of the premises have been read, but then it applies Schema 1 to premise (e), *N or P,* and premise (d), *Not N* (now the last two premises encountered), to infer *P*, which then allows Schema 2 to be applied (to the output of Schema 1 together with premise (c) *if P then H*) to infer *H*, which then leads to application of Schema 2 again to derive *Z* when premise (b) *If H then Z* is considered, and then finally to application of Schema 1 when premise (a), *Not both Z and S,* is considered to derive *not S*. The prediction thus is that the two problems will lead to exactly the same lines of reasoning, with the same inferences being made in the same order on the two problems. Thus, because the order of the predicted inferences is determined by the order in which the core schemas become available and not by the order in which the premises are presented the two problems will have the same output even though the information is received in the same order. O'Brien et al. found that the order in which participants wrote down inferences on both problems corresponded to those predicted by the DRR.

[2] The problems were designed so that varying premise orders would not change the order in which the schemas became available. Other problems could be constructed so that alteration of the orders of the premises would alter the order in which schemas become available.

Similar results were obtained on problems presenting predicate-logic premises (O'Brien et al., 2002) with problems referring to bags of beads of various colors, sizes, shapes, and materials. Consider the following problem, which was presented with a companion problem that presented the same premises in a scrambled order:

(1) None of the red beads are square
(2) All of the beads are triangular or square
(3) The triangular beads are striped
(4) None of the striped beads are wooden

Participants were asked to write down everything they could figure out about the red beads. The DRR predictions begin by applying Schema 1 of Table 2 to premises (1) and (2) as they are encountered to infer that the red beads are triangular; Schema 2 of Table 2 then can be applied as premise (3) is read to infer that the red beads are striped; then Schema 3 of Table 2 can be applied as premise (4) is read to infer that none of the red beads are wooden. When the premises were presented in another problem in a scrambled order (premise [2] first, followed by premise [3] second, and then by premise [1] third, and finally by premise [4] fourth), participants wrote down the same inferences in the same order as they did on the problem just described. Thus, both for the sentential-logic problems reported by O'Brien et al. (1994) and Braine et al. (1995) and the predicate-logic problems reported by O'Brien et al. (2002), the order in which inferences were drawn was determined by the order in which the schemas became available as the premises were entered into working memory, rather than by the order in which the premises were presented.

Other investigations demonstrated that the mental-logic inferences are not merely something to be used to solve laboratory reasoning problems, but are used as a first step in discourse comprehension. Investigations by Lea, O'Brien, Fisch, Noveck, and Braine. (1990) and Lea (1995) provided evidence for the use of the sentential-level schemas of Table 1 in text processing, and an investigation by O'Brien, Soskova, Roazzi, and Dias (2002) did so for the predicate-level schemas of Table 2. These studies reported that the core inferences are made routinely when their premises are embedded within short story vignettes; further, these inferences are made so easily that people usually do not realize that any inferences are being made at all. Further, the mental-logic inferences, unlike other sorts of inferences made while reading, such as inferences from story grammars, scripts, etc., that are made only when they are bridging inferences (i.e., required to maintain textual coherence), the mental-logic inferences are made so long as their requisite premises are held conjointly in working memory. This conclusion follows from the use of on-line measures of reaction times investigating sentential-level schemas (Lea, 1995) and predicate-level schemas (O'Brien et al., 2002). One story version presented by Lea (1995), for example, told the reader that Mary will wear her black dress if a party is a Halloween party, and that Mary subsequently discovers that it is a Halloween party; in a control version of the same problem the reading is told that Mary does not discover whether or not it is a Halloween party. Participants subsequently were presented a naming task on which they were to say the word "black" when it was presented on a computer screen, and they responded faster following the former story than the latter, showing that inferences can be measured on-line and that they are made automatically during discourse processing and not only when required by a logical problem-solving task.

Some of the predictions that are made by mental-logic theory differ from what one would predict if people were reasoning using the sorts of procedures typically found in a standard-logic textbook. As an example, the procedures of mental-logic theory make predictions about the judgments that will be made when a conditional proposition is to be evaluated as a conclusion. According to the procedures of the DRR, when a participant is presented with a conditional conclusion to evaluate against a set of premise assumptions, a reasoner adds the antecedent of the conditional conclusion (the *p* of an *if p then q* conclusion) to the set of premise assumptions as an additional suppositional premise, and then seeks to evaluate the consequent of the conditional conclusion (the *q* of the *if p then q* conclusion). When *q* can be deduced, the conditional is judged as true on the premises alone, but when the negation of the consequent can be deduced (i.e., when *not q* can be derived), the conditional is judged as false. This latter evaluation of *if p then q* as false when *not q* follows from the premise assumptions taken together with the supposition of *p* would not be made following the procedures for a logic of the sort found in a typical standard-logic textbook, because such a judgment would be withheld on standard logic because of the possibility that the antecedent of the conditional might be false (i.e., because of the possibility that *p* might not be true). To illustrate this difference between the mental logic procedure for evaluation of a conditional conclusion and what would follow from the procedures of standard logic, consider that from the premise *p or q*, the mental-logic procedure leads to the conclusion *if not p then q* (because the supposition of *not p* leads to the conclusion of *q* on Schema 3 of Table 1), but this conclusion would not be valid in standard logic, which holds that any conditional is true if its antecedent is false, and *p* might be false in this problem.

This difference in predictions between mental logic and standard logic was tested with adults by Braine et al. (1984) and with school-age children by O'Brien, Dias, Roazzi, and Braine (1998). Problems with forms like the following were presented:

(5) there is either a pineapple or a breadfruit in the box; therefore if there is not a breadfruit there is a pineapple
(6) there is either a pineapple or a breadfruit in the box; therefore if there is not a breadfruit there is not a pineapple
(7) there is not both a pineapple and a breadfruit in the box; therefore if there is a pineapple there is not a breadfruit
(8) there is not both a pineapple and a breadfruit in the box; therefore if there is a pineapple there is a breadfruit

The procedures of the DRR would evaluate the conclusions in (5) and (7) as true, and the conclusions in (6) and (8) as false. Someone following standard logic, however, would not make these judgments on (6) and (8), however, because of the possibility that the antecedent of the conditionals might be false. Braine et al. (1984) and O'Brien et al. (1998) found that both adults and children consistently made the judgments predicted by mental logic theory.

A Recent Experimental Field Investigation in the Tukano Language

The studies described above have established, we believe, that our mental-logic theory provides a plausible psychological model for human logical reasoning, and no alternative theory yet provides explanations for all of these data. Because these investigations were conducted in laboratory settings with educated participants from "European-Western" communities (the experiments were conducted with university students and with school children—usually middle class—in North and South America and in Europe), however, they did not address the claim of universality that follows from our assumption that the basic structures of the language of thought are part of our bio-evolutionary inheritance that resulted from the environmental demands placed on our hunter/gatherer ancestors. If we are right about our claim of universality, then a basic ability to represent, and to make logical inferences about, relations such as conjunctions, alternatives, negations, and suppositions, as well as about quantifiers and quantificational scope, exists across languages and cultures, including those that are not reliant on European-Western culture and education.

The literature provides reasons to doubt our assumption about the availability of such logical reasoning skills in untutored non-Western societies. Cosmides (1989), for example, claimed that a hunter/gatherer society would develop in its members a specialized cognitive module to find violators of social contracts in the form *if p then q*, e.g., to recognize that *if one is to take the benefits of a hunt, one must first participate in the hunt* is violated by someone who did not participate but who takes the benefits of a hunt, but a hunter/gatherer group would not have developed a general logical reasoning ability for *if p then q* that is independent of such a module for finding violators of social contracts. This claim, or course, is completely opposed to our principal suggestion. Further, various investigations of reasoning among non-literate populations suggest an inability to reason in terms that are logical per se (e.g., Cole, Gay, & Glick, 1968; Cole, Gay, Glick, & Sharp, 1971; Cole & Scribner, 1974; Denny, 1991; Luria, 1976; Olson, 1991). Such investigators have taken positions that vary from Luria, whose investigation in the 1920s of illiterate Uzbeki peasants led him to conclude that without literacy and schooling people were not able to connect premises as a syllogistic unit in order to draw logical inferences but could rely instead only on personal experiences in order make judgments, to Cole and his colleagues who emphasized cultural-contextual features in reasoning and found a lack of general cognitive processes such as those of logical processes. Cole et al. (1968), for example, reported that conjunction, disjunction, and negation were understood much better by literate Kpelle schoolchildren in rural Liberia than by their illiterate compatriots. Olson (1991) and Cole and Scribner (1981) have suggested that literacy per se may not be responsible for the putative limitations on thought processes, but rather that institutions of the sort made possible by a literate society may be needed for the development of abstract context-free thought.

D'Andrade (1995) argued, however, that failures to reason logically reported in such research typically result from a failure to attend to the premise information as intended by researchers, and proposed instead that participants typically have interpreted problem information so that it fits their cultural expectations. He thus suggested that the data demonstrate not a failure in reasoning processes, but a failure to encode the problem information in the way the investigators had in mind, and he suggested that logical reasoning abilities of the sort that are described in our mental-logic theory ought to be available across cultures. In any case, we know of no published data with illiterate non-Western populations that demonstrate the use of logical reasoning abilities of the sort we have proposed and it was this lacunae that we sought to fill with this investigation.

The data described here were collected with speakers of the Tukano language in the Alto Rio Negro district in the State of Amazonas in Brazil. The motivation was to investigate in the Tukano language the formats for representation of the logic particles for conjunction, disjunction, negation, and supposition, and for universal and existential quantification, and to investigate the abilities of Tukano speakers to make basic logic inferences from such representations. The Tukano speakers who participated in our investigation live in the Iauaratê region along the Rio Waupês in the border region between Brazil and Columbia. Until recently they lived in semi-nomadic groups as hunter/gatherers with some intermittent farming, although in the past two-to-three decades they have been settling into communities largely supported by subsistence farming and some fishing.

The Terra Indígena Alto Rio Negro is a reserved area that stretches west and north from the town of São Gabriel da Cachoeira on the Rio Negro to the Columbian border, with an area of 79,993 square kilometers (approximately twice the size of the country of Switzerland) and has an official population of only 14,599 (FOIRN-ISA, 2000). Access to the area is limited to the indigenous population, to government functionaries, such as members of the military and the federal police, and workers from FUNASA (the Brazilian federal ministry for health), with only a few researchers given permits to travel there. The general population is not permitted into the area. The trip from São Gabriel da Cachoeira to Iauaratê is approximately 375 km of travel on the rios Negro and Waupês and can be accomplished in 12 hours or so on a small, uncovered boat with an outboard motor. Because of its remoteness from outside populations, the area and its inhabitants are extremely isolated.

Younger members of the Tukano-speaking communities in the Iauaratê area typically have learned to speak some Portuguese (and/or Spanish, depending upon which side of the border they have lived), and have received some formal schooling provided by the Amazonas state government, and have learned at least the rudiments—and often much more—of Portuguese literacy; their daily communications, however, still take place almost exclusively in the Tukano language. Older members of the community typically do not speak Portuguese beyond a rudimentary level (or at all), have not been exposed to any formal schooling, and do not have any literacy skills in any language. Of course, there are exceptions to these generalizations, and there are some older members of the community who are literate and conversant in Portuguese and some younger members of the community who are lacking in these skills; for the most part, however, the presence or absence of exposure to schooling and of literacy is a function of age. Typically, both younger and older members of the community are multilingual, almost all speaking Tukano, and many speaking three or more of the other local indigenous languages, including Miriti-Tapuia, Dessana, Tariano, Siriana, Piratapuia, Uanano, Hupde, Baré, and a scattering of others. (Younger members, however, are far less likely to speak multiple indigenous languages than are the older members.) This situation allowed us to compare types of participants—i.e., those with and without formal school experience and with and without literacy skills—allowing an assessment of any possible effects of exposure to Western languages or of schooling and literacy on obtained judgments requiring logical inferences. This situation also allowed us to recruit to work with us on the project two young male colleagues in their mid-twenties from the Tukano-speaking community in Iauaratê who were fluent both in Tukano and in Portuguese.

Not all languages convey logical information in the same way. A Chinese dialect with which we have some familiarity, Cantonese, for example, does not have a word that functions in the same way as the existential quantifier, *some*, in English, but Cantonese provides a different mechanism to convey the same sort of conceptual information. Whereas English uses an adjectival marker (e.g., *some person[s], some house[s], some horse[s]*), Cantonese uses an existential verb, *yau*, to do much the same work. Thus the verb-noun expression in Cantonese, *yau yan*, which literally translates as *exists man*, can be used to convey the same meaning as the adjective-noun phrase *some person* in English, and *yau ma*, or *exists horse*, can convey the meaning of *some horse*. (For example, the English sentence *some person left a footprint here* is expressed in Cantonese as *exists person left footprint here*.) Our expectation that we would find that Tukano has ways to express the same sorts of logical semantics that are captured in English with words such as *if*, *and*, *not*, *or*, *all*, and *some*, thus did not mean that we would find words in Tukano that matched these English words. Rather, we realized that we would need to be sensitive to the possibility that the means to convey these semantic concepts might differ in some ways.

A descriptive-linguistic study of the Tukano language (Ramirez, 1997a, 1997b, 1997c) provided lexical items for universal and existential quantifiers (the former typically is rendered in English with words such as *all*, *each*, *every*, *always*, and the latter with words such as *some*, *few*, *many*). In Tukano such quantifiers can be found with variants of *pe'ti, nîî pe'ti, nîî pe'tiro* or *niki* for universal quantification and with *ni'karé* for existential quantification. (Words in Tukano vary grammatically as a function of gender and quantity, and the logic particles are not immune from this general tendency. We will not address such variations here.) Ramirez also provided ways to convey conjunctions (typically conveyed, e.g., with *and* in English, and with *tohonikã* in Tukano), and negations (typically conveyed in English with words such as *no*, *not*, *none*, *never*, etc., and in Tukano with a variety of expressions including *neê* or *marí*, or with the verbal suffix *–ti*). Supposition (most commonly expressed in English with *if*) can be expressed in Tukano with the verb suffix, *kã*. Although Ramirez did not provide any ways of expressing alternatives (i.e., disjunctions) in Tukano (most commonly expressed in English with *or*), we discovered the expression, *toho-wee-tí-go*. For example, the English sentence *the boy is running or swimming* would be rendered as *boy runs not being in such a way boy swims*; in more natural English one might say that *in case the boy is not running, he is swimming*.[3] There thus are clear ways to express each of the logical relations for which we looked.

Once we had established a basic lexicon with which to express these logical relations, we constructed logical-reasoning problems in Tukano with our two Tukano-

[3] Details about these logic particles and their interactions with other aspects of the Tukano language will be presented in greater detail in O'Brien, Roazzi, Athias, and Brandão (in preparation).

Portuguese bilingual colleagues. Although we presented three sorts of reasoning problems, including one set that embedded the premise information for logical inferences within short narratives, we shall describe here only a set of problems that was constructed to be similar to the neutral-content reasoning problems that typically have been presented in our laboratories in Recife and in New York. These problems used materials that were procured locally in the Iauaratê area, with the premises referring to bracelets in baskets. The problems were structured so that each problem had a corresponding companion problem so that one problem of each pair was "affirmative" and the other problem of the pair was "negative" or "can't tell." The problem pairs can be illustrated with the following examples for "or" and for universal and existential quantification.

The affirmative "or" problem presented three identical baskets and one bracelet. The experimenter placed the bracelet in one of the baskets and demonstrated that a bracelet existed inside only one of the three baskets. The baskets then were closed and shuffled underneath a blanket, and the experimenter said that he no longer knew where the bracelet was, and said that the bracelet is inside this basket, *or* is inside this basket, *or* is inside this basket, pointing each time to one of the baskets in turn. The experimenter then opened the first two boxes in turn (without letting the participant see inside them) and said each time that there is no bracelet inside this basket. Then pointing to the last basket and the experimenter asked whether there a bracelet inside this basket, or whether there is no bracelet inside this basket, or whether it is impossible to know whether or not there is a bracelet inside this basket. (The appropriate response, following from Schema 3 of Table 1, was that there is a bracelet inside this basket.) The companion problem was identical except that the experimenter looked inside only the first of the three boxes and said that there is no bracelet inside this basket. The experimenter then pointed to the second basket and asked whether the bracelet was in this second basket (The appropriate answer was to respond that the participant cannot know.)

The same basic strategy was followed with the problem pair for universal quantification. The affirmative version began by showing the participant three baskets of different colors. The experimenter said that a friend had been asked to put bracelets into the baskets, but because this friend is lazy, he had put all the bracelets into the red basket because it was the basket that was nearest to him. The experimenter held up a bracelet and said that it is a bracelet that the friend had put in a basket and asked, "Did it come from the red basket?" The participant was then given three response options: (a) Yes, it definitely came from the red basket; (b) No, it definitely did not come from the red basket, and (c) It is not possible to say whether it came from the red basket. (The appropriate answer is that it definitely came from the red basket.) The companion problem was identical except that question referred to a blue basket rather than to a red basket. (The correct answer was that it definitely did not come from the blue basket.)

The existential-quantification problems provided "can't tell" as the appropriate response. In one of these problems participants were told that a friend had put some bracelets in a red basket and some bracelets in a yellow basket, and asked whether a particular bracelet that the friend had placed in a basket definitely had come from the red basket, or definitely had not come from the red basket, or whether one cannot know whether it came from the red basket. Of course, in the problem presented with universal quantification, a participant has logical grounds to make a definite response about which basket the bracelet was taken from, whereas in the problem presented with existential quantification there is no such logical justification.

Altogether six pairs of basket-content problems were constructed, one pair each for conjunction, alternatives, conditionals, negations, and for universal and existential quantification. For all problems the experimenter frequently asked the participants to repeat the problem information, and the final question was not posed until the experimenter was satisfied that the information had been heard correctly and remembered. Further, each time a response was made, the experimenter asked for an explanation of why the participant had provided that response. (Pilot testing had demonstrated that unless such measures were taken to ensure that each problem was understood, useful data would not be forthcoming, and that responses were best interpreted in reference to the explanations that were provided for them.)

The problems were presented to 12 literate and to 12 literate adult speakers of Tukano. We had planned to score responses twice, once in terms of the initial judgment and a second time following consideration of the subsequent conversation that followed the initial judgment. This second scoring counted a response as correct when the interview revealed that an initial response that had been scored as incorrect had resulted from a misunderstanding of the premises or of a response category, and when the subsequent interview showed that the participant understood the problem when the misunderstanding was clarified. In practice, this plan to rescore responses rarely was applied because errors were made infrequently during the initial phase. Indeed, on all problem pairs except one between 82% and 100% of both the literate and the illiterate participants solved both problems of the pair—a rate that exceeds what would be expected by chance when measured on a binomial expansion (where chance = .25 and $p < .05$). The only problem that had fewer than 82% correct responses on the initial scoring was the *or-undecidable* problem described earlier that required a “can’t tell” response. On this problem, 45% of the literate participants (and 18% of the illiterate participants) responded that the conclusion was “wrong,” although their subsequent explanations revealed that they intended this response to indicate that it was wrong to make a definite assertion on the basis of indefinite evidence rather than to indicate that the assertion was false. When rescored following discussion of their explanations, 83% of the literate participants were scored as correct on this problem, as were 100% of the illiterate participants. This use of the “false” response option on a *can’t-tell* problem also was common among participants in earlier investigations in New York (e.g., O’Brien et al., 1989). The Tukano-language data thus show that logically appropriate judgments about conjunctions, alternatives, negations, suppositions, and universal and existential instantiation are made routinely by untutored non-Western participants and are not limited to literate problem solvers who have been exposed to Western schooling.

Discussion

The most basic question facing our proposal concerns whether the language-of-thought hypothesis and its companion model of mental logic are useful notions on which to base a research program. We began with what is essentially a philosophical reason to propose a language of thought: In order to represent propositional information in a declarative memory, one needs a propositional format in which to record the information. Because such a representational format would need to distinguish between properties and the entities that have those properties, the representational format obviously would include some sort of predicate/argument structure, that is, it would include some sort of logic structure. The assumption that this mental structure evolved as a result of the environmental pressures that existed for our hunter/gatherer ancestors led to the expectation that it would not have developed to construct sophisticated lines of proof, such as those needed for metalogical proofs of the sort found typically in journals of symbolic logic, but instead would have been developed to make short immediate inferences based on information about conjunctions, alternatives, suppositions, and negations, as well as about some rudimentary quantifiers such as those for universal and existential quantification. We have reviewed various laboratory investigations that have provided ample evidence that such inferences are indeed made routinely by both college students and school children, and no other theory has provided an explanation for all of these data.

The bio-evolutionary assumption also led to the expectation that such a representational format, and the inference forms associated with it, thus would be available across languages and cultures and would not be limited to literate cultures with specialized professional classes of logical reasoners and the resultant educational structures needed to train logical reasoning skills. Although this assumption ran counter to previous research that had suggested that people in non-literate cultures were lacking an ability to reason logically—and that their languages may even be lacking the representational capacities for such thought—our investigation of the Tukano language and of reasoning by speakers of Tukano revealed that the same basic representational and inferential abilities that had previously been discovered for literate Western-educated populations were available for members of the Tukano group. Representing logical information, and the subsequent making of logical inferences, thus are not limited to literate and educated peoples. In summary, the language-of-thought hypothesis and its companion mental-logic theory have provided the basis for a vigorous and fruitful program of empirical research into human propositional reasoning.

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RÉSUMÉ

Cet article fait la description d'une hypothèse de langage-de-la-pensée, que commence par admettre que, pour qu'il soit possible de stoker de l'information propositionnelle dans la mémoire déclarative, il faut qu'il y ait un format quelconque qu'on puisse adopter pour représenter cette information. Étant donné qu'il faut que ce format puisse distinguer parmi les propriétés et les entités qui possèdent ces propriétés, il devra inclure un structure prédicat/argument; autrement dit, il devra inclure un logique mentale quelconque. On présente une logique détaillée de ce type, qui a été proposée par Braine et O'Brien (1998) et on décrit un ensemble très varié d'évidences empiriques qui soutiennent cette proposition, parvenant de recherches menées en laboratoire avec des enfants et des adultes. Enfin, une prédiction de disponibilité universelle se suit de la présupposition selon laquelle cette logique mentale est un résultat du développement bio-évolutionnaire de notre espèce. On fait le compte rendu d'une recherche sur le raisonnement logique menée parmi une population illetrée au Amazonas Brésilien. Cette recherche vise la question de la disponibilité d'adresses de raisonnement logique indépendamment de la lecture et des apprentissages scolaires. On fait le rapport de données qui montrent qu'une appréciation basique d'inférences logiques de base propositionnelle est disponible parmi cette population, aussi bien que parmi les populations éduquées et lettrées en Europe et en Amérique.

MOTS-CLÉ: Logique mentale; Langage de la pensée; Développement bio-évolutionnaire; Apprentissage de la lecture; Apprentissages scolaires.

ABSTRACT

This article describes a language-of-thought hypothesis that begins with the recognition that in order to store propositional information in declarative memory there must be a format in which to represent this information. Because such a format needs to distinguish between properties and the entities that have those properties, it would need to include a predicate/argument structure, that is, it would include some sort of mental logic. We describe a detailed proposal for this mental logic that was presented by Braine and O'Brien (1998), and describe a wide variety of empirical evidence for this proposal that comes from laboratory investigations of both children and adults. Finally, a prediction of universal availability follows from an assumption that this mental logic has resulted from the bio-evolutionary development of our species. We describe an investigation of logical reasoning in an illiterate population in Brazilian Amazonas that addresses the availability of logical reasoning skills independently of literacy and schooling, and we report data showing that a basic appreciation of propositionally based logical inferences is available in this population as well as in educated and literate American and European populations.

KEYWORDS: Mental logic; Language-of-thought bio-evolutionary development; Literacy; Schooling.

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