Cognitive Approaches and Transdisciplinarity: *two examples*[1]

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Résumé

Les “ sciences cognitives ” fédèrent les diverses disciplines scientifiques concernées par tel ou tel aspect du ***système cognitif***, toutes confrontées à la même difficulté, à savoir la ***complexité*** de ce système. Cette fédération est propre à susciter des *interactions conceptuelles* entre disciplines très éloignées - par exemple entre la neuropsychologie et l’intelligence artificielle - pouvant se révéler fructueuses.

La ***neuropsychologie,*** avec notamment l’étude de l’***aphasie*** (pathologie du langage “ acquise ”, suite à une lésion du cerveau), constitue un moyen privilégié d’explorer les traitements qu’effectue le *système cognitif* ***normal***. Les lésions du cerveau peuvent en effet être considérées comme de véritables ***expériences in vivo*** sur ce système, susceptibles d’en réduire partiellement la complexité. Elles entraînent parfois des phénomènes langagiers très spécifiques, qui reflètent des traitements cognitifs ponctuels qu’il devient possible d’inférer – alors qu’ils sont usuellement indécelables, car trop imbriqués dans la complexité cognitive.

Les recherches en ***intelligence artificielle*** (I.A.) peuvent également amener à inférer certains aspects de notre *système cognitif*. En effet, en matière de langage, ce système ainsi que ceux de l’I.A., doivent faire face à un ensemble de ***problèmes communs***, à savoir, tous ceux ***inhérents*** au langage. Par conséquent, les systèmes d’I.A. peuvent être considérés en quelque sorte comme des ***expériences in vitro*** permettant d’étudier ces problèmes, et de déterminer les caractéristiques des traitements (cognitifs ou autres) nécessaires pour les résoudre.

Deux exemples concrets d’***interactions*** entre expériences *in vivo* et *in vitro* seront présentés, afin d’illustrer la pertinence de ce mode de ***transdisciplinarité***, aussi bien pour la conception de systèmes “ intelligents ” de traitement du langage, que pour l’exploration de questions aussi fondamentales que “ ***qu’est-ce que comprendre*** ? ”.

Summary

"Cognitive Sciences" is a federation of the various scientific fields dealing with some aspects of the ***cognitive system***; all these very different fields are facing the same difficult problem, namely the ***complexity*** of this system. Their federation aim to trigger fruitful conceptual interactions between very different cognitive approaches, as for instance Neuropsychological vs. Artificial Intelligence (A. I.) ones.

Neuropsychology, with namely "***Aphasia***", the study of Language Pathology occurring after a brain lesion, provides an irreplaceable source of ideas on normal language components. In such a framework, brain lesions could indeed be viewed as a kind of *experiments* ***in vivo*** on our cognitive system, able to slightly reduce its complexity. Lesions are inducing, in the behavior of patients, linguistic phenomenon pointing to specific selective components, normally hidden in the complexity of the whole redundant ***cognitive system***, and therefore indecipherable.

[1] Examples from "Guberman S.A. & Andreewsky E. (1996)

On the other hand, **Artificial Intelligence** may brings to light the functional relevance of such components in the framework of our cognitive system. Indeed, both automatic processing *and* cognitive mechanisms are confronted with a set of ***common problems*** - namely, when concerning our language, those ***inherent*** to natural language. Therefore, A.I. systems could be somehow viewed as *experiments* ***in vitro*** on our cognitive processing.

Examples of **interaction** between these experiences will be given to illustrate the relevance of such a transdisciplinary framework, both for building "intelligent" A. I. systems, and to explore new answers to the fundamental cognitive question**:** ***what does it mean to understand"?***

I. - Introduction

Neuropsychology (and more precisely ***Aphasiology***, the study of the language pathologies occurring after brain lesions) is able to provide some insight into the properties of our ***normal*** cognitive system. Brain lesions could indeed be viewed as a kind of *experimentation* ***in vivo*** on this system, enabling - out of patients linguistic behaviors - the detection of specific functions, normally embedded in the complexity of the whole redundant ***cognitive system***, and therefore indecipherable.

On the other hand, ***Artificial Intelligence*** (A. I.) approaches may also provide some insight into the functional properties of this complex system. The pertinence of using computational concepts to study cognitive linguistic mechanisms derives from the fact that to deal with natural language, both automatic processing and cognitive mechanisms must handle a set of ***common problems*** - those ***inherent*** to our language. Therefore, an A. I. system processing natural language represents a kind of *experimentation* ***in vitro*** on the functional aspects of language.

To study aphasic behaviors is a irreplaceable way toward the understanding of normal language ***components*** - and the function of these ***cognitive components*** may be understood through Artificial Intelligence systems. On one hand, Aphasiology may indeed trigger for A. I. systems new ways to handle natural language, and, on the other, A. I. may help the understanding of *cognitive functions*. The relevance of conceptual interaction between these two remote domains will be illustrated out of aphasiological researches on ***dyslexia*** (and therefore ***reading***), and A. I. researches on ***automatic handwritten recognition.***

II. Reading pathologies and the traditional /b, a/ ⇒ /ba/ approaches to reading

"Aphasia" is the generic name of neuropsychological language disturbances following a brain lesion. It does not refer to an impairment of all language performances. On the contrary, one may observe specific behavioral features, suggesting certain properties of the normal psycholinguistic mechanisms[2]. ***Alexia*** is a specific form of this disease, where the main language problems occur in ***reading***.

[2]The general conceptual framework allowing to take aphasic behavior as data to study normal mechanisms relies on the assumption that these pathological behaviors reflect the action of spared sub-mechanisms. Aphasia provides,

II. - 1 "Clobal alexia"

"Global" alexia, a specific case of alexia, denote patients who seem (at first) totally incapable of any processing of written material. This is assessed by ensuring that patients are *completely* unable either to recognize any isolated letter, nor to match capital with lower case letters, etc. These patients cannot recognize nor read aloud, nor match with pictures, any written word, be it printed or handwritten - nevertheless a number of them are perfectly able to find out if a given sequence of letters (even an handwritten sequence) is a word vs. a non-word (such as table vs poble). Therefore, patients totally unable to recognize letters demonstrate at least some knowledge related to written words. A number of them, also unable to show any written word understanding, are nevertheless grasping some semantic properties of these written words. For instance, given a written list of words with one odd-word such as "hat" in :

cat, dog, pig, hat, cow

patients are able to point to the odd word. Their first claim is that such a task is impossible, given their drastic difficulties with written material. Most patients are nevertheless perfectly able to point to the odd-word, i.e., *hat* (without however being able to explain their choice).

Therefore, without the slightest recognition of any letter, a written word may nevertheless be linked to some of its semantic properties. It means that word reading is not necessarily only rooted in the recognition of a sequence of letters, in terms of some /b, a/ $\Rightarrow$ /ba/ process, but may occur at the level of the whole written word - the level of this whole, and not of its components.

II. - 2 Deep Dyslexia or "reading without letters recognition"

There is many other different kind of reading pathologies. One of them, Deep Dyslexia, demonstrate even more obviously that reading does not necessarily involve the analysis of sequences of letters; indeed, deep dyslexic patients behavior seem to result from some cognitive reading component, working at the whole word level. These patients (E. Andreewsky et al, 1980) present a set of very specific reading behaviors which will be detailed hereafter. But let us begin with the following one:

- Deep dyslexic patients are completely unable, exactly like the above "global alexic" patients, to recognize any letter, to match a given letter lower class with the same one in capital, etc;

- These patients demonstrate nevertheless some ability to "read" - as far as reading is finding some meaning out of written materials -. But for deep dyslexic patients such meaning is only a (more or less fuzzy) understanding of content words (that is nouns, verbs and adjectives). Indeed, if deep dyslexic patients read aloud content words (and only this class of words), show some understanding of these words, this understanding is rather fuzzy, as attested namely by the fact that, when reading aloud, they may either correctly utter the given written word, or utter some synonym or a semantically more or less related word, as for example:

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therefore, a kind of "pseudo-experimentation" on the brain which may result in behavioral data accounting for mechanisms usually embedded in the redundant psycholinguistic system. Such data, lacking with normal subjects, are essential pieces to complete the puzzle of language understanding mechanisms.

Church, instead of the written word "cathedral"
Whisky instead of "cognac"
Teacher instead of "student"
etc.

Therefore, here again, without the slightest recognition of any letter, a given written word may nevertheless be understood and linked to some of its semantic properties. It means that word reading is not necessarily only rooted in the recognition of a sequence of letters, in terms of some /b, a/ ⇒ /ba/ process, but may occur at the level of the whole written word - *the level of this whole, and not of its components.*

II. - 3 Handwriting recognition: the dynamic of words image

Alexandre Luria, the father of Neuropsychology, found out of a huge variety of cases of alexia, several key features pointing to specific reading functions. In the mid 60's[3], he described a patient with alexia. After the brain damage, this patient lost the ability to read: he was unable either to recognize or to utter handwritten characters or words. During the rehabilitation process, it was discovered that he could read words if he traced this word with his finger. In a month, the patient could do it by tracing the word in the air, without touching the paper. In six months he did it while holding his hand in his pocket, but still moving the finger in the pocket. This case introduces the idea that a handwritten word is not only an *image pattern* but also a *dynamical pattern*.

III. Automatic handwriting recognition in terms of /b, a/ ⇒ /ba/ vs. written words as wholes?

It seems obviously much more interesting to design A.I. handwriting recognition systems for letters - that is only 26 items (the letters of the English alphabet) than to design such a system for directly recognizing whole words - that is many thousands of items! Indeed, as far as a given handwritten word can be analyzed letter by letter, the recognition of only 26 items enable the recognition of every written word (or non-word). But a very difficult problem arise in this framework, namely if the number of letters of a given handwritten word is not a priori given, it is almost impossible to split this word (that is its image) into (image of) letters ... And in consequence, impossible to use any letters recognition system! Therefore, with the above alexic behavior in mind, it becomes rational to develop approaches recognizing handwritten words as wholes.

- A language to describe handwritten words

[3] In the framework of a seminar, Burdenko Neurosurgery Hospital, Moscow.

The relevance of dealing with the whole image of handwritten words, evidenced above out of alexic patients behavior, triggered in 1972, in Moscow, a computer handwriting recognition project based on the ***description*** of writing images (Guberman & Rozentsveig, 1976), with an appropriate "language" describing these images. Twenty years later, based on these principles, a technology has been developed for cursive handwriting recognition (on-line and off-line), triggering the first handwriting recognition notebook computer.

Working on the very different aspects of the same written word demands a special description language, able to deal with all variants of its image. Seven elements were proposed to define this language:

Fig.1

along with a simple rule to describe these element's usual transformations. That is a given element can only be transformed, while writing, into its neighbor (fig. 1). This rule determines the distance between elements (the topology of the writing trajectories space).

IV. - From automatic language processing to reading models

IV. 1 - Syntactical processing of grammatical ambiguities

Cognitive functions are complex ***systems***, made out of interactive components. This is obviously also the case of any A.I. computational function, somehow *connected* with *language.* Let us present the case of such a component, shared by most computational linguistic functions, i.e. ***syntactical processing***. This component is required not only for traducing, but even for the simplest linguistic tasks. For instance, to be merely able to decide whether or not the two following sentences (make up of ***identical*** items) "***I can leave a will***" vs. "***I will leave a can***" have or not a ***different*** meaning, one must taking into account the grammatical class of each occurrence of the grammatically ambiguous items 'can' and 'will'. In other words - given the great number of grammatical ambiguities in natural language - *it is impossible for a system (be it automatic or cognitive) to perform this kind of task without at least a* ***syntactical disambiguation*** *of these items.*

III. 2 - A "puzzling" behavior: deep dyslexic patients

With the above logical evidence in mind, i.e. the impossibility for any system to handle even the simplest aspect of sentences meaning without syntactic processing, the reading behavior of a class of alexic patients, the ***deep dyslexics***', becomes very puzzling. If we take for granted the traditional description of deep dyslexia, patients demonstrate altogether some understanding of written language, that is a "first idea" of its meaning, and are known as having "lost their syntax"... Hence, the obviously strong contradiction with the former logical evidence: indeed, there is here a system (the deep dyslexic patients reading one) which, in spite of the fact it is unable to deal with syntax - as assessed by several tests - nevertheless demonstrates some understanding of written language...

Puzzled by such a contradiction, we began to investigate some more the syntactical abilities of deep dyslexic patients. Specific items, namely French grammatical ambiguities, were proposed to those patients unable to read aloud function words, either isolated or in sentences. If in a given sentence[4] the ambiguous item to read was in position to be a noun, it was *always* read aloud; the same item, in position to be a conjunction, was *never* read aloud. Such a clear cut behavior clearly demonstrates that these patients, far from having "lost their syntax", are performing an (implicit) *syntactical disambiguation*... The above puzzling contradiction (deep dyslexic understanding without syntactical processing) is therefore over.

Let us underline that such an experiment should be understood as a kind of ***pseudo-experimentation*** *on our normal reading system, enabling to point to some normally hidden function of a component of this system (such as here the syntactical disambiguation, a process which may occur without any other syntactical processing, as it is the case for DD patients).*

III. 3 - The Deep Dyslexia syndrome 'generation'

Let us recall the "*imitation principle"* that applies to any recognition problem. According to this principle any device that has to recognize certain class of objects must imitate the process that *generates* these objects. Hereafter, the object to recognize will be the ***deep dyslexic patients' syndrome*** - and we will try to logically generate such a syndrome.

In the framework of A.I., *knowledge retrieval* is the main problem of ***automatic information retrieval systems***. Keeping in mind that A.I. systems should be considered as some kind of experimentation "*in vitro*" on cognitive processes, we present the logic underlying automatic documentation indexing procedures, as straightforward generating DD syndrome[5].

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[4] For instance, the first occurrence of the French word "car" means "bus" (a noun), and the second one "because" (a conjunction), in the following sentence: "Le **car** ralentit **car** le moteur chauffe" (The bus slows down because the engine overheats).

[5] To begin with, the *indexing* of a given text gives by definition an *approximation* of its meaning - therefore its relevance to generate (or to model) the DD *cognitive* "first approximation".

Let us now bring together the rather strong similarities between automatic indexing - that is to say detection and "packaging" of key-words - and phenomenon characterizing DD utterances:

- a) To define the key words of a given text, indexing systems should first select the ***content words*** of this text (let us recall that patients only utter and understand those words ...).

- b) This selection bring the system about a *syntactical disambiguation* procedure to handle grammatical ambiguities - such as in: "I *can* leave a ***will***". vs. "I *will* leave a ***can***"- this is in keeping with the patients behavior for grammatical ambiguities. For indexing, this disambiguation enable to select content words, and therefore there is no more requirement for more syntactical processing (we have seen that patients have been considered as having "lost their syntax", given their seemingly absence of syntactical processing, which is in fact, such as for indexing systems, *restricted* to disambiguation ...).

- c) Since the relevance (or the weight) of each content-word must be checked, indexing procedures should include a dictionary. The indexing system must find *the roots* of content words, to match with the dictionary entries. (DD patients often do not utter a given word, but rather its root, or some other word built on the same root ...).

- d) Indexing systems also rely on *thesaurus*. Linked to the system dictionary entries, a thesaurus enables for obvious reason of normalization to sort relevant content words into semantic classes of equivalence (synonymous). In this framework, one key-word stands for all the words of a given class (this is in keeping with deep dyslexic patients often uttering either a synonymous or a semantically related word, such as *church* for *cathedral*).

In short, the indexing logic implies many processing to automatically point to the *key-words* of a given text. Such processing (i) generates a set of data strikingly similar to the set of patients behavior (see note 2), (ii) provides, such as for patients, a first idea of the meaning of a given text. Therefore the claim that ***indexing procedures somehow mimic the DD syndrome***.

It must be clear that the deep dyslexic syndrome is classically understood as an *heterogeneous* set of phenomena - the simultaneous presence of which in the behavior of DD patients being nothing else than a mere chance (or else, reflecting some (doubtful) proximity in underlying brain supports...). Behind this heterogeneous set, this "puzzle" of remote phenomena, indexing procedures bring to light the ***logic of a functional component***. Such a logic allows an understanding of deep dyslexia, in terms of a *normal reading system*, reduced to a specific component (component normally hidden, given the speed and redundancy of the normal cognitive processes), endowed with a specific *pre-understanding function*, i.e. the retrieval of some knowledge linked to the written material.

III. 4 - Revisiting language understanding classical approaches

Such an understanding of deep dyslexia directly leads to rely on re-interpretation of the whole reading and understanding system:

- For classical approaches, sentence understanding is taken to be a mere function, a "***construction***" on the meaning of the words they include. There is no place for any fuzzy meaning as postulated above, and not any rationale to interpret DD behavior in the framework of such a construction.
- On the contrary, assuming understanding as an ***emergent process*** (cf. Winograd & Flores, 1986) - out of interactions between: (i) locutor theories, feelings, knowledge and experience, (ii) context and situation at hand, and (iii) lexical item's morpho-syntactical data -, concepts such as reading first *steps*, *fuzzy meaning*, or *interfacing* morpho-syntactical data and knowledge, become obvious. In terms of such an emerging, understanding a written sentence - *somehow like carving a stone* (Andreewsky, 1991) - is a step by step refining (out of complex interactions) of a "*first draft*", a fuzzy object provided by a preliminary step, that is a *first approximation of meaning.* In this framework, DD syndrome directly reflects this preliminary step, i.e. the elaboration of the "first draft".

The theoretical relevance of such a "draft" is not restricted to an explanation of pathological data. It also explains a set of normal reading phenomena, only provided with some "ad hoc" explanation in the classical framework. Such phenomena range from *subliminal experiments* (relying on some meaning of unnoticed words - very hard to explain out of the traditional lexicon model) to *speed reading* (which enables readers to get very quickly a general view, although fuzzy, of a whole text).

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The relevance of transdisciplinary approaches for modeling cognitive functions has been pointed out of examples of interactions between Artificial Intelligence and Neuropsychology. This illustrates the view of aphasiology as a method for better understanding of some components of language. It leads to revisit both pattern recognition and language understanding classical approaches, and to explore new answers to the fundamental question**: *what does it mean to understand language?***

IV. - References

- Andreewsky E. (ed.), (1991), *Systémique et Cognition*, Paris, Dunod.
- Luria A.R. (1976), *Basic problems of Neurolinguistics*, Mouton,The Hague.
- Guberman S.A. & Andreewsky E. (1996), “From Language Pathology to Automatic Language Processing… and Return,” *Cybernetics and Human Knowing*, Vol. 3, N° 4, 41-53.
- Vygotsky L. S. (1985), *Pensée et langage*, trad. F. Sève, Paris, Messidor.
- Winograd T. & Flores F. (1986), *Understanding Computers and Cognition: a new foundation for Design*,. Norwood, NJ: Ablex.