Reasoning in Natural Language in Using Combinatory Logic and Topology
An Example with Aspect and Temporal Relations

Jean-Pierre Desclés
LaLIC, University of Paris-Sorbonne

Jean-Pierre.descles@paris-sorbonne.fr

Abstract

We are studying how Curry's Combinatory Logic can be used for giving an adequate analysis of different grammatical problems such as diatheses, tenses and aspects, and lexical analyses by formal representations of meanings of verbal predicates and prepositions. The paper intends to show how Combinatory Logic can solve on the one hand, the formal representations of tenses and aspects in natural languages with the help of the topology of intervals and, on the other hand, the problem of the synthesis of a lexical predicate from a formal description of its meaning by means of a semantic cognitive scheme (SCS). We want to explain, in following an example, how can be explained the "natural" inference between two utterances like *John took the Mary's pen.* > *Now, John has got the pen.*

1. Introduction

Combinatory Logic (CL) of Curry (1958, 1972) is used for giving an adequate analysis of different grammatical problems such as diatheses, tenses and aspects, lexical analyses by formal representations of meanings of verbal predicates and grammatical operators (Desclés, 1990, 2004, 2005). Conceptions of aspects and tenses are given by several logicians an philosophers (H. Reichenbach (1947) or Z. Vendler (1967) are criticisable works quoted and used by a lot of linguists) but, according to us, these analyses do not give an operational way yielding to an automatic processing. This paper intends to show how CL is an useful tool for solving on the one hand, the formal representations of temporal relations and aspects in natural languages and, on the other hand, the synthesis of a lexical predicate from a formal description of its meaning by a scheme defined with the help of semantic and cognitive primitives.

An example of a "natural inference" between two utterances like *John took the Mary's pen* -> *Now, John has got the pen* will be used to explain the different steps of a formal processing. As far as we are concerned, the formal analyses we use are anchored onto the grammatical conceptions developed by linguists as E. Benveniste (1974), B. Comrie (1976), J.A. Mourelatos (1981), Culioli (1999), Desclés (1989), Desclés & Guentchéva (1995, 2008), with semantic notions such that *event*, *state*, *unaccomplished process*, *accomplished (or completed) process*, *resultative state*[1] …We have formalized (Desclés, 2004, 2005) these notions by means of *aspectual and temporal operators* in using on the one hand, topological intervals of instants, on the other hand, the formal framework of the CL. For illustrating our formal approach, we represent the meaning of a lexical predicate *take* (x,y) with a scheme defined as an applicative cognitive representation of cognitive primitives; we show how this predicate can be obtained by a synthesis processing in using combinators of CL; we show also how aspectual and temporal operators can be represented in the same applicative formalism to explain an inferential reasoning by a formal calculus. The analysis of meaning and the formal processing of aspects and temporal relations are general and are not specific to the given example. We give here a formal explanation of the semantic relations between a "past event" (*John took the Mary's pen*) and its "resultative state" (*Now, John has got the pen*), involving changes in the lexical forms. Other examples can be analyzed by the same device, for instance *Yesterday, the hunter killed the deer* -> *Now, the deer is dead*.

We cannot present, in this short paper, neither all the steps of the formal calculus, nor the types of different operators and the types schemes of combinators.

[1] Note that the terms of 'activity', 'process', 'accomplishment' and 'achievement', used in this paper, should not be taken in Z. Vendler's sense (1967).

2. Combinatory Logic and Combinators

Combinatory Logic (CL), developed principally by H.B. Curry (1958, 1972), Hindley & Seldin (1986) - see also Quine (1960) - is a logic of operators founded on the binary operation called *application* : an operator 'X' is applied, by means of the operation'@', to an operand 'Y'; the result is an applicative expression, noted ' X @ Y' or 'XY'. CL is a relatively adequate formalism for giving formal representations of linguistic utterances and, more generally, to analyse different problems in Linguistics, Philosophy, Artificial Intelligence, Cognitive Sciences, and Nanosciences. CL is very similar to the Church's λ-calculus; but not completely equivalent for the following reasons: (i) CL uses abstract operators, called *combinators*, allowing to combine intrinsically other operators, independently from meanings of combined operators; (ii) CL does not use bound variables as λ-calculus does; thus, the implementation is easier because there is no side effect; (iii) CL is equivalent to the λ-calculus in extension but not in intension (Hindley 1986). CL verifies the Church-Rosser's property (the property of confluence) according to which a reduced form (without combinators), a "normal form", is unique, if it exists. CL allows inside of a same computational architecture, a formal articulation between different representation levels during a processing; this situation is usual in Artificial Intelligence and computer science in a compiling process. Thanks to these properties about reduction and changing of representation levels, CL is used to express, by means of a formal calculus, a synthesis of a lexical (or grammatical) predicate from a formal representation of its meaning. CL and functional types of Church are adequate to study natural languages when linguistic units are considered as operators of different types, like in Categorial Grammar (CG) and its extensions (Biskri & Desclés, 2005), the theory of operators of Z. Harris (1982), Applicative Grammar of S.K. Shaumyan (1977, 1987) and Applicative and Cognitive Grammar (ACG) of J-P. Desclés (1990, 2004).

The action of each combinator of CL is defined by a β reduction rule. The actions of elementary combinators are as follows:

- **I** (identity):
  $\mathbf{I}\,X \geq_\beta X$
- **B** (functional composition):
  $\mathbf{B}\,X\,Y\,Z \geq_\beta X\,(Y\,Z)$
- **C** (conversion):
  $\mathbf{C}\,X\,Y\,Z \geq_\beta X\,Z\,Y$
- **C*** (type raising):
  $\mathbf{C^*}\,X\,Y \geq_\beta Y\,X$
- **W** (diagonalization):
  $\mathbf{W}\,X\,Y \geq_\beta X\,Y\,Y$
- **K** (cancelling an argument):
  $\mathbf{K}\,X\,Y \geq_\beta X$
- **S** (composition and duplication):
  $\mathbf{S}\,X\,Y\,Z \geq_\beta X\,Z\,(Y\,Z)$
- **Φ** (application in parallel):
  $\mathbf{\Phi}\,X\,Y\,Z\,U \geq_\beta X\,(Y\,U)\,(Z\,U)$
- Ψ (distribution):
  $\mathbf{\Psi}\,X\,Y\,Z\,U \geq_\beta X\,(Y\,Z)\,(Y\,U)$

The action of a combinator can be presented in the Gentzen's style, by an introduction and by an elimination rules (Fitch 1974). From a combinatory '**X**', we derive the iterate combinator '$\mathbf{X}^n$', which is the functional composition, by **B**, in *n* steps of the combinatory 'X' with itself and the combinatory '$\mathbf{X}_n$', acting at distance above *n* terms (Curry 1958) ; Desclés, 1990).

3. Formal processing of an aspectual and temporal analysis

How to explain the intuitive inference between the *event* (*John took the Mary's pen*) and its *resultative state* (*John has got the pen*) by means of a formal calculus? This semantic inference is carried out at several steps; we present them briefly, in a bottom up analysis, without giving, here, all the formal steps. We start with the utterance (1):

(1) *John took the Mary's pen*

Applicative and Combinatory Categorial Grammar (Biskri & Desclés, 2005) is an operational process that builds an applicative expression with operators applied to operands (written with a prefixed notation, as all other applicative expressions in this paper):

(2) (took (the ('s (Mary) pen))) John

The operational role of linguistic units is indicated by a *syntactic functional type* that takes into account the concatenations of operator positions with regard to operands.

To analyze of the finite form *took* of the verb *to take*, we define operators of English including the past verb suffix for regular verbs; to simplify notations, we use the following identifications:

- <T^2 := *the Mary's pen*>, <T^1 := *John*>
- <P2 := to take> ;

- $(V_{conjugate\text{-}past}\ T^2)\ T^1$
  i.e. predicative relation containing the past conjugated verb ;

- (P_2 *past-suffix* T^2) T^1
  i.e. predicative relation of the infinitive with the past verb suffix[2] ;

- $(even_{\text{-}past}\ P_2\ T^2)\ T^1$
  i.e. the aspectual operator directly associated to the morphological operator *past*.

[2] The verb *to take* being irreguliar, the metalinguistic operator *past suffix* is interpreted here as a vowel interchange of the stem.

4. Aspectual operators

From a general viewpoint, *Aspect* is analysed as an operator 'ASP_I' applied to a predicative relation '$P_2 T^2 T^1$', hence an *aspectualized predicative relation* '$ASP_I (P_2 T^2 T^1)$', realized onto a topological interval 'I' of instants (that is: true at each instant of this interval 'I'). Different aspectual values of 'ASP_I' are concerned and defined in (Desclés, 1989, 2005; Desclés & Guentchéva, 1995, 2008): *state* (STATE) or *process* (PROC) or *event* (EVEN). For instance, in (1), the value of the aspect is an event. According to the values of the aspectual operator 'ASP_I', the topological type of the interval 'I' is specified: it is closed in an event, open in a state and closed to the left and open to the right.

How to represent together, on one hand, the meaning of the aspectual operator (with its aspectual value) applied of the predicative relation and, on the other hand, how to localize the aspectual predicative relation with respect the speaking act? Indeed, a speaking act is not a punctual event but an *unaccomplished process* realized on the interval 'J^0' of instants, where the left boundary is closed and the right boundary 'T^0' ($[T^0 = \delta(J^0)]$ [3] is open (Descles, 1989, 2005). The *speaking operator* '$ENONC_{J0}$' (or enunciative operator '*I-am-saying*') is the result of the functional composition of the process '$PROC_{J0}$', with the speech-act operator '(SAY (…) (EGO))' - where 'EGO' is an abstract symbol for representing any speaker.

4.1. In the example (1), chosen for illustrating the formal analysis, the predicative relation is an operand of an operator '$even_{-past}$' which means an 'event-in-the-past' and implies a more abstract grammatical aspectual operator 'EVEN', hence the expression (3):

(3) $EVEN (P_2 T^2 T^1)$

This aspectual operator 'EVEN' specifies the zone of validation of the predicative event realized on some closed interval 'F'. The meaning of the operator 'EVEN' is an applicative combination of: (i) the speaking operator '$ENONC_{J0}$', (ii) an event operator '$EVEN_F$' where 'F' is an interval where the predicative is realized, and (iii) a temporal constraint establishing a relation between the intervals 'F' and 'J^0': 'F' is before 'J^0', ($[\delta(F) < \gamma(J^0)]$). The applicative combination is expressed by means of a non elementary combinator '**X**' which express a functional program to compose the operators '$ENONC_{J0}$' and '$EVEN_F$' with a temporal constraint. The grammatical and abstract aspectual operator 'EVEN' is defined by introduction of an existential quantification, yielding to (4) (where the temporal relation $[\delta(F) < \gamma(J^0)]$ is expressed by means of an infixed notation):

(4) [$EVEN =_{def} \exists$ intervals (closed) F and J^0 ;
$\mathbf{X}$ & $([\delta(F) < \gamma(J^0)])$ $ENONC_{J0}$ $EVEN_F$]

4.2. In the framework of CL, the more elementary combinators - the components of '**X**' - are successively applied, hence (5), deduced from (3) and (4):

(5) $PROC_{J0}$ (SAY
(& ($EVEN_F (P_2 T^2 T^1)$) ($[\delta(F^1) < \gamma(J^0)]$)) EGO)

The applicative expression (5) express that the predicative event '$EVEN_F (P_2 T^2 T^1)$' is embedded into the speaking process realized on the interval 'J^0'; it express also that this event is realized on the closed interval 'F' with implicit temporal constraints: the interval 'F': it is limited by the two open intervals 'O^1' and 'O^2' where the right boundary '$\delta(O^1)$' of 'O^1' is identified with the left boundary '$\gamma(F^1)$' of 'F^1' (the beginning of the event) and the right boundary '$\delta(F)$' of 'F' is identified with the left boundary '$\gamma(O^2)$' of 'O^2' (the end of the event); 'O^1' and 'O^2' are the zones of validation of the states denoting respectively that the event has not yet taken place and that the event has already taken place.

5. Representation of the verbal Meaning

We continue with the previous analysis going to a new step of the calculus. The meaning of the lexical predicate P_2 in (3) (we recall that [P_2 = *take*]) is represented with the help of a *semantic-cognitive scheme* (SCS), that is an applicative combination of primitives defined inside a theory of cognitive and semantic representations (Desclés 1990, 2004), where each primitive is anchored onto the field of human perception and action. We give here some primitives used in our semantic analysis:

'ACCS' is a binary relator for locating an entity relative to another (a locator), defining an accessibility domain of located entities from the locator[4].

'MOVT' is a binary operator expressing a spatio temporal movement of an entity from one location to another location.

'FAIT' is a binary operator expressing an effectuation of an action by an agent (or an instrument) of a movement or a change.

'CONTR' is the expression of a control by an agent on a movement (or a change).

'TELEO' is teleonomy binary operator between an agent and a wanted situation.

'TRANS' is an operator which is the result of a functional composition, by '**B**', of the primitives 'CONTR' and

[3] We note '$\delta(I)$' the right boundary of an interval 'I' and '$\gamma(I)$' the left of 'I'.

[4] The notion of "possession" is not a primitive. Possession becomes a particular case of "accessibility" in which an entity is accessible from another entity (a locator) (Ivanova 2009).

'FAIT'; it means that an agent controls and carries out an action[5].

5.1. The corresponding SCS associated to the meaning of the lexical predicate *take* is expressed by the applicative expression (6):

(6) $\& (TRANS_F^{12} (CHANG_F^{12} (SIT_O^{12} [y, x]) (SIT_O^{21} [y, x])) x) (TELEO (SIT_O^{21} [y, x]) x)$

whith:

$SIT_O^{12}[y, x] = STATE_O^{12} (NOT (ACCS\ x\ y))$
$SIT_O^{21}[y, x] = STATE_O^{21} (ACCS\ x\ y)$

and the temporal constraints:

$[O^{12} < F^{12} < O^{21}] \& [\gamma(F^{12}) = \delta(O^{12})] \& [\delta(F^{12}) = \gamma(O^{21})]$

The meaning of (6) is: "an agent 'x' controls and makes a changing, affecting an entity 'y', from an initial situation, where 'y' is not accessible to 'x', into the other situation, where the same entity 'y' is accessible to 'x', this last situation being intended by the agent". The aspectual operator '$EVEN_F^{12}$' specifies the zone of a transition where the predicative event can be realized on a closed interval 'F^{12}' nested between the two adjacent temporal zones of states 'O^{12}' and 'O^{21}'. The transition realized on 'F^{12}' is completely independent of the speech act and thus of enunciative conditions.

5.2. The lexical predicate 'P_2' (*take* in our example) is the result of a *synthetic integrative process* by means of combinators successively introduced (by introduction rules) from (6) (a SCS). The exact form of this integrative process is a combinator '**Y**' which combines the kinematical and dynamical primitives '$TRANS_F^{12}$', '$CHANG_F^{12}$', the primitives '$STAT_{01}$ **0** NOT', '$STAT_{O21}$' , 'TELEO **0** $STATE_{021}$' where :

(7) $[STAT_{012}\ \mathbf{0}\ NOT =_{def} \mathbf{B}\ STATE_{012}\ NOT]$

$[TELEO\ \mathbf{0}\ STAT_{021} =_{def} \mathbf{B}\ TELEO\ STAT_{021}]$

with the static primitive 'ACCES' and the arguments 'y' and 'x'. After a λ-abstraction of places of arguments of the lexical predicate, we obtain the relation between the *definiendum* 'P_2', and its *definiens*:

(8) $[P_2 =_{def} \lambda y.\lambda x. \{ (\mathbf{Y}\ \& TRANS_F^{12}\ CHANG_F^{12} (STATE0_{012}\ \mathbf{0}\ NOT) (STATE_{O21}) (TELEO\ \mathbf{0}\ STATE_{O21})\ ACCES)\ y\ x \}$

[5] These semantic and cognitive primitives are more precise than the "classical" primitives of Schank, often used in Artificial Intelligence.

When '**Y**' is applied to its different arguments, the "normal form" (6) is deduced, specifying the meaning of the predicate 'P_2'.

6. Inferential Reasoning

Let us introduce a rule describing a general property of events (Desclés 2005, Ro 2008):

IF an event applied to any underlying predicative relation 'Λ', is realized on the closed interval 'F' which precedes the interval 'J^0' of speaking act

THEN :

(i) there are two open intervals 'O^1' and 'O^2' such as the event provides a transition between an initial state, realized on the interval 'O^1' and a following state, realized on the interval 'O^2', both states being adjacent to 'F', i.e. the two instants '$\gamma(F)$' and '$\delta(F)$' are two *continuous cuts* (in the mathematical Dedekind's sense) between the closed interval 'F' and two respective intervals 'O^1 and 'O^2';

(ii) the predicative relation 'Λ' *is true* at the final instant '$\delta(F)$' of realization of the event;

(iii) the state following the transition is realized at each instant of the open interval 'O^2' which is going on until the right boundary '$\delta(J^0)$' of the unaccomplished speaking process.

The event '$EVEN (P_2 T^2 T^1)$' is realized *in the past*, before the enunciative process. Thus, there is some closed interval 'F' where the transition implied by the event is realized between the two open intervals 'O^1' and 'O^2'. From the above rule, we deduce, that a *resultative state* (expressed by the morphological form of "present perfect" in *John has got the pen*) of this event; the resultative state is realized at each instant of the intersection of the two intervals 'O^2' and 'J^0' where $[\delta(O^2) = \delta(J^0) = T^0]$; it is deduced from the utterance *John took the Mary's pen* denoting an occurrence of an event in the past.

6.1. After inserting the meaning of the predicate into the instancied scheme (5) (i.e. after the embedding of the meaning of the predicative relation into the speaking process), we get (9) from an unification $[F^{12} := F]$ of 'F^{12}' with 'F' (hence: $[O^{12} := O^1]$, $[O^{21} := O^2]$); 'F^{12}' is a closed interval relating to the meaning expressed by a SCS; 'F' is also a closed interval relating to the aspectual operator '$EVEN_F$' of the predicative relation located inside the enunciative referential framework defined by the speaking act.

(9) $[EVEN_F (\& (TRANS_F (CHANG_F (SIT_O^1 [T^2, T^1]) (SIT_O^2 [T^2, T^1])) T^1) (TELEO\ (SIT_O^2\ [T^2,T^1])\ T^1)) \& ([[O^1 < F < O^2] \& [\gamma(F) = \delta(O^1)] \& [\delta(F) = \gamma(O^2)]] \& [\delta(O^2) = \delta(J^0)])]$

6.2. The situation 'SIT_{O2} [T2, T1]' is realized on the interval 'O^2'. Since the event '$EVEN_F$ ($P_2 T^2 T^1$)' is realized on 'F' it is inferred that this event has generated the resultative state

John has got the pen

whose meaning is represented by (10):

(10) $[(STATE_O{}^2 (ACCS\ T^1 T^2)) \ \&\ [\delta(O^2) = \delta(J^0)]$

This 'resultative state' is embedded into the speaking process, hence the expression (11):

(11) $PROC_{J0} (SAY (\& (STATE_O{}^2 (ACCS\ T^1 T^2)) ([\delta(O^2) = \delta(J^0)])) EGO)$

which means literally that the enunciator 'EGO' is saying that the state of accessibility of 'T^2' (=: *the pen*) by 'T^1' (=:*John*) is true during all the instants of the open interval 'O^2', the right boundary '$\delta(O^2)$' being concomitant to that of the speech-act interval '$\delta(J^0)$'; it follows from it that the morphological form of "present perfect" encodes this meaning. By this formal calculus, we explain how *John has got the pen* is "naturally" deduced by any listener who understands *John took the Mary's pen*.

7. Conclusion

This analysis shows that the CL with the topology (of intervals) is very useful to take into account: (i) representations of verbal meanings by SCS; (ii) aspectual values and temporal relations between topological intervals. It is possible to explain inferential relations between utterances inside the same formal applicative language (a metalanguage) used to give formal representations of utterances and to infer consequences from these formal representations. Such a calculus allows to show how it is possible, thanks to the combinators of CL, to develop progressively a 'logic of natural language' since the classical first-order logic is unable to give a deep analysis of aspectual representations and lexical meanings. The framework for our analysis is the Cognitive Applicative Grammar - CAG - (Desclés 1990, 2004) which provides an interplay between several cognitive representation levels and morpho-syntactic configurations by means of both the CG techniques and composition of operators by combinators of the CL.

The formal analysis of aspects and SCC is general ; it is applied to different languages : French, Bulgarian (Daynovska, 2008), Greek (Van den Haandel, 2008), , Polish Gwiarzdercka, 2006), Russian (Ivanova 2009), Korean (Son, 2006). The implementation is in working in the functional programming languages HASKELL and CAML (Ro, 2008).

Bibliographical References

Benveniste, E. (1966) *Problèmes de linguistique générale*, Paris: Gallimard.

Biskri I. & J.P. Desclés (2005) "Applicative and Combinatory Categorial Grammar and Subordinate Constructions in French", *International Journal on Artificial Intelligence Tools*, Vol 14, N°1 & 2, pp. 125 136.

Comrie B. (1976) *Aspect, an Introduction to the Study of Verbal Aspect and Related Problems*. London: Cambridge University Press.

Culioli A. (1999) *Pour une linguistique de l'énonciation, For malisation et opérations de repérage,* tome 2, Paris: Ophrys.

Curry H.B., Feys R. (1958) *Combinatory logic*. Vol. I. Studies in logic and the foundations of mathematics,Amsterdam:North Holland Publishing.

Curry H.B., Hindley J.R. & Seldin J.P. (1972) *Combinatory Logic*, vol. II, Amsterdam: North Holland Publishing.

Daynovska D. (2008) *Analyse des interactions entre préposi tions et préverbes français et bulgares dans une perspective cognitive et computationnelle*, PhD University of Paris Sorbonne.

Desclés, J. P. (1989) « State, event, process and topology » *General Linguistics* vol 29 n°3, The Pennsylvania University Press, University Park and London, pp 159 200.

Desclés J. P. (1990) *Langages applicatifs, langues naturelles et cognition*. Paris: Hermès.

Desclés J P., (2004) "Combinatory Logic, Language and Cogni tive Representations", in Weingartner P. (ed.), *Alternative Lo gics. Do Sciences Need Them ?*, Springer, pp. 115 148.

Desclés J. P. (2005) "Reasoning and Aspectual Temporal Calcu lus" in Vanderveken D. (ed), *Logic, Thought and Action*, Springer, pp. 217 244.

Descles, J.P. & Z. Guentchéva (1995): "Is notion of process ne cessary?" in P.M. Bertinetto and alii (eds) (1995) *Temporal re ference aspect and actionality, vol. 1 : Semantic and Syntactic Perspectives*, Torino: Rosenberg & Sellier, pp.55 70.

Descles, J.P. & Z. Guentchéva (2008) "Analyse sémantique du temps, de l'aspect et des modalités :analyse formelle et cogni tive", *The 18th International Congress of Linguists,* July 21 28, Korea University, Seoul.

Gwiazdecka E. (2005), *Aspects, prépositions et préverbes dans une perspective logique et cognitive. Application au polonais : przez/prze , do/do , od/od* , PhD University of Paris Sorbonne.

Fitch F. (1974) *Elements of Combinatory Logic*. New Haven:Yale University Press.

Harris Z.S. (1982) *A Grammar of English on Mathematical Principles*. New York:Wiley Interscience.

Hindley J.R., Seldin J.P. (1986) *Introduction to Combinators and Lambda Calculus*. Cambridge University Press.

Ivanova E. (2009) *Approche cognitive et formelle de la polysémie verbale : les verbes de transfert en français et en russe*. PhD, University of Paris Sorbonne.

Langacker R. W. (1989, 1991) *Foundations of cognitive gram mar*, Volume 1, *Theoretical prerequisites*, Volume 2, *Descrip tion Application*, Stanford University Press.

Mourelatos A. (1981) “Events, Processes and States”, in Tedeschi et Zaenen (eds), *Tense and Aspect*, Syntax and Seman tics 14, New York : Academic Press, pp. 192 212.

Pustejovsky J. (1995) *The generative lexicon*, Cambridge Massachussts, Londre: MIT Press.

Quine W.V. (1960) " Variables explained away", *Proceedings of the american philosophical society*, 104, pp. 343 347.

Reichenbach, H. (1947) *Elements of Symbolic Logic*, New York, reprinted in J.M. Moravcsik (editor), (1974) *Logic and Philoso phy for Linguists, A Book of readings*, The Hague: Mouton, pp. 122 141.

Ro H. J. (2008) *Traitement automatique de l’analyse d’inférences aspecto temporelles : modélisation logique et in formatique*. MD thesis. University of Paris Sorbonne.

Shaumyan S.K. (1977) *Applicationnal Grammar as a semantic theory of natural language*. Chicago University Press.

Shaumyan S.K. (1987) *A Semiotic Theory of Natural Lan guages*. Bloomington: Indiana University Press.

Son Ho Geun (2006), *Représentation sémantico cognitive des verbes de « transfert » : une approche de la polysémie de verbes du coréen*. PhD, University of Paris Sorbonne.

Talmy L. (2001) *Toward a cognitive semantics*, volume 1. Con cept Structuring Systems, Cambridge Massachussts, Londre: MIT Press.

Van Den Handel M. (2006), *Les temps verbaux en grec et en français : analyse sémantique et problèmes de traduction de l’aoriste, du parfait et de l’imparfait*, PhD, University of Paris Sorbonne.

Vendler, Z. (1957) “Verbs and Times”, *Philosophical Review* 66, 143 160; Revisited in Vendler, 1967, *Linguistics in Philoso phy*, Cornell University press, pp. 97 121.

niversity Press, pp. 97 121.