

Cécile Barbet¹

Representation in memory and processing of French modal verbs. Evidence from eye movements

This paper reports the results of an eye-tracking during reading experiment carried out in order to investigate the online processing of the French modal verbs *devoir* ("must") and *pouvoir* ("can/may"). The nature – ambiguous/homonymic, polysemous or monosemic/under-specified – of the modals is tested through the manipulation in sentences of the root or epistemic meaning of the modal as well as the neutral or meaning supportive nature of the context preceding it. The reading of the sentences containing *devoir* is facilitated when the modal is used in its root meaning. This effect of relative frequency (the root meaning being indeed the dominant meaning of the French modal verbs) fits with the polysemy hypothesis: if the meanings or senses are stored in memory, we therefore expect the most frequent one to be the easiest to access and process. On the contrary, the first pass reading of *pouvoir* is facilitated when it appears in its epistemic meaning, in other words its non-dominant meaning, and the reading of the sentences containing *pouvoir* is facilitated by the supportive contexts. These results better fit with the under-specification (monosemy) hypothesis with an under-specified meaning represented in memory close to the epistemic meaning, epistemic meaning in reality better described as alethic as we demonstrate. The two French modal verbs are traditionally examined together since it is assumed that one matches the other in its own modal domain – possibility or necessity. This study casts doubt on this assumption.

1 Introduction

In the literature on the semantics of French, modal verbs are usually considered as "polysemous"; however, the under-specification hypothesis (monosemy) remains too often overlooked. The question of the processing and representation in memory of the modal verbs lying beyond the reach of the traditional tools used in linguistics (linguistic intuition, corpus analysis, conceptual argumentation, *etc.*), we make use of an experimental method here, namely eye-tracking during reading.

1.1 Meaning multiplicity

The French modal verbs, as with modal verbs in other languages, can receive different interpretations depending on the context they occur in. They notably have root interpretations (deontic and dynamic):

¹ University of Bangor (Bangor, UK), Bangor University Language Electrophysiology Team, c.barbet@bangor.ac.uk

- (1) Il peut/doit venir.
He can/may/must come.
He has the ability/permission/he is required to come.

Modal verbs also have epistemic interpretations, as in (2):

- (2) Il *peut/doit* avoir manqué son train.
He *may/must* have missed his train.
It is possible/probable that he has missed his train

Whilst root uses are concerned with the possibility and necessity of actions, epistemic uses have a larger scope and express the degree of certainty of the speaker concerning the propositional content of his assertion.

Devoir and *pouvoir* have other possible interpretations than root or epistemic, they notably have "post-modal" interpretations (concessive, interrogative, *etc.*, see van der Auwera and Plungian 1998 ; Barbet and Vetters 2013) but we will not deal with them here. However, we can mention the alethic interpretation of *devoir* put forward by Kronning (1996, 2001). In this case, the modal verb does not have a meaning of obligation (root modality) or a meaning of probability (epistemic modality), but a meaning of necessity:

- (3) *Tous les hommes* doivent mourir. (Furetière, quoted by Kronning 1996: 34)
"All men must die."

Interestingly, apart from Vetters (2007), an alethic interpretation, distinct from both root and epistemic interpretations, is never put forward for *pouvoir* in French; we will come back to this point in the general discussion.

The aim of this study is to provide some elements in order to determine what can be due to the meaning multiplicity of the modal verbs. At least three options are available: their meaning multiplicity can be explained by (i) their homonymic nature, (ii) their polysemous nature, or (iii) their under-specified semantics.

1.2 Hypotheses

Fuchs and Guimier (1989), about *pouvoir*, suggest a polysemy view according to which the various interpretations are semantically related variants induced by the context and deriving from a common core meaning that we should retrieve hypothetically. These scholars, as others (see e.g., Sueur 1983; Le Querler 1996, 2001) argue against a homonymic view but the polysemy they suggest is not clearly distinguished from monosemy (under-specification). Polysemy is indeed difficult to isolate from both ambiguity (homonymy) and vagueness (monosemy/under-specification).

Although only homonymy/ambiguity and non-homonymy/non-ambiguity are often considered in linguistic or psycholinguistic literature,² in reality three options exist, as mentioned above. If we apply these options to the French modal verbs *devoir* and *pouvoir*, according to the homonymy hypothesis, both the root

2 See e.g., Durkin and Manning (1989: 578); Pickering and Frisson (2001: 558); Frisson and Pickering (2001: 153); Klepousniotou (2002: 210); Klepousniotou, Titone and Romero (2008: 1534); Klepousniotou, Pike *et al.* (2012: 12).

meaning and the epistemic meaning would be stored in memory (i.e., in the mental lexicon) and they would constitute distinct lexical entries. According to the polysemy hypothesis, both meanings would be also stored in memory, but under the same and unique lexical entry (they would be part of a semantic network, see e.g., Kronning 1996). Finally, according to the monosemy/under-specification hypothesis, only one under-specified meaning would be represented in memory, a meaning that could be specified in context if appropriate (see Papafragou 2000).

The monosemy hypothesis is not always overlooked in the literature on the semantics of French but when it is considered, it is rejected as non-suitable for the French modal verbs (see Kronning 1996 or Gosselin 2010) or it remains underdeveloped (see Honeste 2004 or Saussure 2012). In this paper, we thus quickly present the monosemic account developed by Papafragou (2000) about some English modal verbs inasmuch as the questions and arguments are quite similar in both French and English literature.

According to Papafragou (*ibid.*), the semantics of the modals is reduced to a relation R of entailment (necessity modals) or compatibility (possibility modals) between a given proposition p and a set of stored propositions constituting a domain D (unspecified for *may* or *must*, normative in the case of *should* and factual in the case of *can*), as represented as in (4):

$$(4) \quad R(D, p)$$

According to Papafragou, the linguistic facts put forward in favour of a strong distinction between root and epistemic uses of the modals, hence the facts in favour of the polysemy view (scope of negation, order in the linearity of the sentences, *etc.*) are in reality not verified or valid, or have conceptual rather than syntactic explanations. In other words, she argues that the root-epistemic distinction is not part of the grammar of the modals.

Concerning homonymy, it is usually defined as a purely accidental result of phonetic evolution. Two linguistic items would thus share the same phonetic form but no etymological or semantic link. As noticed by Croft (1998), this definition of homonymy, although consensual in cognitive linguistics, does not reflect reality. Indeed, the identity of form appears often unmotivated only for the contemporary speakers (see e.g., *voler* (to fly) and *voler* (to steal) in French which are as a matter of fact etymologically related). Nevertheless, the fact that many languages possess morphemes that can communicate both root and epistemic modality pleads against the pure accident. Moreover, the fact that a common meaning – roughly, necessity for *devoir* and possibility for *pouvoir* – can be found is also an argument against homonymy (Aristotle's test of the definition: two identical forms must be considered as ambiguous only if a common meaning cannot be found, see e.g., Geeraerts 1993; Tuggy 2006). However, from a cognitive point of view, if the common or core meaning does not serve during the interpretative processing, there is no reason to assume that it exists. Intuitively, a core meaning of possibility seems shared by the various interpretations of *pouvoir*: capacity, permission, eventuality, *etc.*, but a common meaning of necessity is less apparent for the native speakers in the obligation interpretation (root meaning) and the probability interpretation (epistemic meaning, see Huot 1974: 14–15).

Finally, Sten (1954) and Gosselin (2010) put forward that if the modals were truly ambiguous, we should not find any sentence such as (5) that can receive both a root and an epistemic interpretation:

- (5) On entend la voix d'un élève qui *a dû* appliquer sa bouche au trou de la serrure. Il crie : [...]
(Sten 1954 : 264)
We can hear the voice of a pupil who must have stuck his mouth to the keyhole. He shouts:
[...]
≈ ...has been obliged to...
≈ ...has probably...

Nevertheless, on the one hand, such sentences are extremely rare in the corpora of Palmer (1979), Coates (1983) or Kronning (1996), and on the other hand, if the interpretation can remain relatively ambiguous between a root and an epistemic reading with *pouvoir*, it is rarely the case with *devoir* (see Barbet 2013).

As a conclusion, it seems difficult to rule out with certainty both the polysemy and the monosemy/under-specification hypotheses of *devoir* and *pouvoir*, nor even the homonymy hypothesis concerning *devoir*. The three hypotheses have thus been tested experimentally in an eye-tracking experiment.

2 Experiment

2.1 Predictions

The eye movements of French native speakers have been recorded during a reading and comprehension task. Participants read sentences containing *devoir* and *pouvoir*, in which both the meaning of the modal and the context preceding it were manipulated. Thereby, modal verbs occurred in their root meaning which is their dominant meaning, that is the most frequent and the one that come first in mind (see 2.2), or in their epistemic meaning. The preceding context was either meaning supportive or neutral.

According to psycholinguistic studies interested in "ambiguity" resolution and using the eye-tracking method (e.g., notably Frazier and Rayner 1990; Pickering and Frisson 2001), the following predictions concerning eye movements can be made. In case of genuine ambiguity, i.e., homonymy, an early effect of context is expected as soon as the modal verb is fixated. Indeed, in a neutral context, the homonymic lexical entries compete for activation, whilst a supportive context permits to select the relevant entry. Moreover, as *devoir* and *pouvoir* are polarised items, that is items with a meaning more frequent and preferred compared with the other (see 2.2.1), it is also expected that the dominant entry will be selected by default in preceding neutral contexts, and as a consequence, a garden-path effect is likely to arise if the non-dominant meaning appears finally to be the relevant meaning in the sentence.

If *devoir* and *pouvoir* are polysemous, the unique lexical entry should prevent any competition effect and the interpretative process could rely on the core meaning until further contextual information is available. In other words, a later effect of

the context is expected since it does not serve to select a lexical entry but only a meaning (or sense) which is part of a semantic network (see Williams 1992; Kronning 1996). Moreover, an effect of relative frequency is also expected: indeed, if the meanings/senses are represented in memory, the most frequent ones should be the easiest to access and process.

Finally, the monosemy/under-specification hypothesis only predicts a late effect of context that does not serve to select a lexical entry or a sense represented in memory, but only to specify if appropriate an under-specified meaning. In this case, we do not expect any relative frequency effect: if the root and epistemic meanings are not stored in memory, their frequency should not *a priori* have any influence on their access or their processing.

2.2 Pre-tests

Four pre-tests examined the meaning preference of the modal verbs, their interpretation in the test sentences and the strength of the preceding contexts.

The participants (32 to 64 depending on the test) were all adult native speakers of French and naïve with respect to the purposes of the tests. They completed the tests online.

2.2.1 Meaning preference

The aim of the first pre-test was to check that the root meaning is the dominant meaning of *devoir* and *pouvoir*. The root meaning is, diachronically, the first modal meaning of both verbs (see Barbet 2013, under press), nevertheless, the dominant or most familiar meaning of a word is not always its first meaning (see Williams 1992: 197).

Participants wrote down the first sentence that came in mind using each verb. The root meaning appeared overwhelmingly dominant: it was used in 74.6 % of the answers with *devoir* (in 47 sentences out of 63) and in 96.6 % of the answers with *pouvoir* (in 56 sentences out of 58).

2.2.2 Paraphrase

This pre-test was designed in order to make sure that the stimuli sentences have the intended root or epistemic reading. We constructed 10 pairs of sentences for each modal verb. Each pair was supposed to have both a root and an epistemic reading possible until the complement of the infinitive verb which disambiguated the meaning (see examples (8) to (11), ignoring the preceding context which did not appeared in the paraphrase pre-test). We constructed and tested more than 80 sentences in order to obtain the 10 pairs per verb needed. 32 to 63 native speakers (mean: 44.9 participants) participated in the test. They were instructed to select the best paraphrase for the verb *devoir* or *pouvoir* in sentences. Four choices were proposed when the sentences contained *devoir*: "être obligé de" (to be obliged to), "probablement" (probably), "aucune expression proposée ne convient" (no expres-

sion proposed is appropriate), "je ne suis pas sûr(e)" (I am not sure). Six choices were possible for the sentences containing *pouvoir*: "être capable" (to be able to), "avoir le droit de" (to have the permission of), "avoir la possibilité matérielle de" (to have the material possibility of), "peut-être que" (maybe), "aucune expression proposée ne convient" (no expression proposed is appropriate), "je ne suis pas sûr(e)" (I am not sure). The selected sentences have been paraphrased with the intended expression – root or epistemic – in 82.8% of the answers (root sentences with *devoir*: 84.2%, epistemic sentences with *devoir*: 82.8%; root sentences with *pouvoir*: 89.6%, epistemic sentences with *pouvoir*: 74.7%).

2.2.3 Clozure

For each sentence, we constructed preceding contexts that supported either the root or the epistemic interpretation. Our aim was for these contexts to be supportive of the meaning of the modal verb but not predictive of the modal verb *devoir* or *pouvoir*. A cloze task was designed in which participants had to complete sentences segments consisting of the context up to the modal verb, as in (6):

(6) John voulait son appartement à lui quand il était étudiant, mais ce n'était pas possible, il...

The pre-test provided a cloze probability on the verb. If the completion used any form of *devoir* or *pouvoir*, then it scored 1 point; if it used one modal verb with the other or with an aspectual verb (respectively "il pouvait devoir" or "il allait devoir" for example), then it scored 0.5 point, as well as when it used the plain verb *devoir* (to owe). This procedure has been iterated and the supportive contexts rewritten until all fragments obtained a cloze probability less than 15% (19 to 36 participants in total, mean: 23.5). The selected supportive contexts have a mean score of 0.84 points, i.e., a cloze probability less than 4%.

2.2.4 Strength of contexts

We wrote another preceding context for each sentence, neutral regarding the interpretation of the modal verb. In order to determine that both the supportive and neutral contexts had the appropriate effect on the interpretation of the modal verb, we asked further participants to complete fragments of the experimental sentences consisting of the context and the modal up to the infinitive verb, such as in (7):

(7) Kenneth a étudié pendant deux ou trois ans à Cambridge au début des années quatre-vingt, il devait...

We expected the supportive contexts to elicit completions using the intended meaning of the modal, and the neutral contexts to cause completions using the root or the epistemic meaning randomly or with a preference for the dominant root meaning. The neutral contexts caused the root dominant meaning to be used 62.4% of the time. The contexts supporting the root meaning caused this meaning to be used 94.7% of the time, and the contexts supporting the epistemic meaning caused this meaning to be used 76.1% of the time. Therefore, the supportive contexts were effective, and the neutral contexts neutral with a slight bias towards the dominant root meaning.

2.3 Methods

2.3.1 Participants

Forty-eight adults were paid £10 to participate in the experiment. All were French native speakers, had normal or corrected-to-normal vision, and were naïve with respect to the goal of the experiment. They had not participated in any of the pre-tests (see 2.2). The recordings took place in Cambridge (UK) at the Cognition and Brain Sciences Unit.

2.3.2 Apparatus

Eye movements were recording with an iView XTM Hi-Speed system (SensoMotoric Instruments). The eye-tracker monitored the participants' point of regard every 2 milliseconds. Viewing was binocular but the point of regard was monitored from one eye. The participants' eye was at about 55 cm from the screen of the computer displaying the stimuli.

2.3.3 Procedure

One session, including the adjustment of the equipment, the calibration procedure and the reading task itself, lasted for less than one hour. A training phase preceded the experiment: the participant read five sentences similar to the test sentences, three of them were followed by a comprehension question. The participants were instructed to read the sentences normally and to answer as accurately as possible to the comprehension questions following them when appropriate. When the training was over and the instructions understood, the participants completed a calibration procedure which was repeated until the deviation was less than 1°, if possible 0.5°. The reading task had a break at the middle followed by a new calibration phase.

A fixation cross preceding each sentence appeared at the same location as the first letter of the sentence. The cross was displayed for 2 seconds and then the sentence was displayed until the button press from the participant. 30% of the sentences were followed by a comprehension question in order to motivate a careful reading, the participants answered to the questions by pressing the "yes" or "no" button of a response box.

2.3.4 Materials

80 sentences of interest were constructed (see 2.2): 10 sentences for each verb – *devoir* and *pouvoir* – for each interpretation – root and epistemic – and for each preceding context – neutral or meaning supportive.

(8) is an example of a sentence containing *devoir* in its root meaning and preceded by a neutral context. In (9), the modal verb is preceded by the same neutral context but its meaning is epistemic:

- (8) Kenneth a étudié pendant deux ou trois ans à Cambridge au début des années quatre-vingt, il devait à l'époque loger à Churchill College, il n'avait pas le choix.
"Kenneth studied for two or three years in Cambridge in the early eighties, he had to stay at Churchill College, he had no choice."
- (9) Kenneth a étudié pendant deux ou trois ans à Cambridge au début des années quatre-vingt, il devait à l'époque loger à Churchill College j'imagine, puisque c'était son college.
"Kenneth studied for two or three years in Cambridge in the early eighties, he was probably staying at Churchill College, since it was his college."

In (10), *devoir* has a root meaning as in (8) but the preceding context supports this meaning. In (11), the context supports the epistemic meaning of the verb:

- (10) John voulait son appartement à lui quand il était étudiant, mais ce n'était pas possible, il devait à l'époque loger à Churchill College, il n'avait pas le choix.
"John wanted to have his own flat when he was a student, however it was not possible, he had to stay at Churchill College, he had no choice."
- (11) Non, John Smith ne m'a jamais précisé où il habitait à Cambridge quand il était étudiant, il devait à l'époque loger à Churchill College j'imagine, puisque c'était son college.
"No, John Smith never told me where he was staying in Cambridge when he was a student, he was probably staying at Churchill College, since it was his college."

The experimental sentences were randomly assigned to 4 lists. Each list contained 20 sentences of interest as well as 97 further filler sentences of various types. A pseudo-randomized order was created for each participant with the program *Mix* (van Casteren and Davis 2006) so that two sentences from the same condition or containing the same verb always appeared with at least 5 sentences between them. The stimuli sentences were displayed on two rows with the context on the first row and the rest of the sentence from the pronoun subject of the modal on the second row. Sentences were displayed in lower-case letters except when capital letters were appropriate. The pronoun subject was always 2 characters long so that the verb of interest always appeared at the same position on the screen. The position of the following words varied depending on the length of the modal: 6 (*devait*) or 7 (*pouvait*) characters.

2.4 Analysis

Eye movements were detected using the package *saccades*³ which is the implementation for *R* (R Core Team 2009) of Engbert and Kliegl's (2003) algorithm. The data-driven threshold of this velocity based algorithm is efficient to reduce some part of the noise in raw data (see von der Malsburg 2009; Holmqvist *et al.* 2011: 161, 174). We excluded from analysis fixations shorter than 20 ms and longer than 1 000 ms which lead to the loss of 11.7% of all fixations. The data from 12 participants were also discarded because of a lack of precision in the recordings. The remaining fixations were aggregated into the standard fixation measures *first pass reading time*, *rereading time* and *total fixation time* using the package *em* (Logacev and Vasishth 2011) in *R*.

FPRT, RRT and TFT are standard measures in reading studies (see e.g., Rayner and Duffy 1986; Rayner, Sereno *et al.* 1989; Inhoff and Radach 1998; Rayner

3 von der Malsburg, *cf.* <http://www.ling.uni-potsdam.de/malsburg/saccades/>.

1998; Pickering and Frisson 2001; Clifton, Staub and Rayner 2007; Holmqvist *et al.* 2011). It is usually considered that the FPRT is a measure of early linguistic processing whilst the RRT reflects later processing. The stages of the processing reflected by the TFT is more open to debate (see e.g., Rayner 1998; Clifton, Staub and Rayner 2007; Holmqvist *et al.* 2011). The FPRT is supposed to reflect the early stages of the processing of a word, namely its lexical access (see e.g., Pickering and Frisson 2001: 562; Holmqvist *et al.* 2011: 390), in other words, the activation and retrieval of the meaning associated with the representation of a word in memory. Typically, a frequent word will receive shorter fixations during the first pass than a less frequent word. Some studies also showed that the FPRT increases when a word is semantically informative or unexpected in the context (see Holmqvist *et al.* 2011: 390). The measure thus seems to reflect both the lexical access and the early semantic (and syntactic) processing (see Demberg and Keller 2008: 197). The RRT reflects non-initial processes of integration of a word or a group of words into a sentence. The TFT is often considered to reflect non-initial processes of comprehension of the meaning of a word or a group of words in relation with other words or with a larger group of words in the sentence (Inhoff and Radach 1998: 41–42). However, the TFT being the sum of the first pass reading time and the rereading time, it is rather a measure of general processing. Furthermore, the TFT will reflect more the FPRT, i.e., early stages of processing, if the region of interest has not or not much been reread, and the RRT, i.e., subsequent stages of processing, if the region of interest has been re-fixated longer than it has been fixated at the first pass. The TFT can therefore reflect processes of textual integration as well as semantico-syntactic processing and lexical activation (Demberg and Keller 2008: 197).

For the purpose of the analysis, each sentence was divided into seven regions of interest (ROI from now on) as in (12):

- (12) Kenneth a étudié pendant deux ou trois ans à Cambridge au début des années quatre-vingt,|il|devait|à l'époque|loger|à Churchill College|, il n'avait pas le choix.

ROI 1 consisted of the preceding context, ROI 2 was the pronoun subject, ROI 3 the modal verb, ROI 4 the intervening region (IR from now on), ROI 5 contained the infinitive verb, ROI 6 its complement, and ROI 7 consisted of the last words of the sentence which disambiguated the interpretation in the neutral contexts.

We examined the main effects of the preceding context (meaning supportive or neutral), of the meaning of the modal (root or epistemic) and of the modal itself (*devoir* or *pouvoir*), as well as the possible two- or three-way interaction effects between the factors, on the FPRT, RRT and TFT in ROIs 3 to 7. The ROIs 3 to 6 consisted of the same words in the supportive or neutral context conditions and the root or epistemic conditions.

The ROI 3, i.e., the modal verb, is 6 (*devait*) or 7 (*pouvait*) characters long. Although a one-character difference should not have any effect on fixation times, the analyses of the fixation times in this ROI have been systematically realised in milliseconds (ms) and milliseconds per character (ms/char) and the results of the two analyses compared. However, as expected, no interesting difference was found. The IR (ROI 4) is always 10 characters long, the ROI 5 always 5 charac-

ters long and the ROI 6 always 19 characters long. The length of the ROI 7 (the last words of the sentences which differ depending on the root or epistemic interpretation of the sentence) varying, the reading times were transformed in ms/char.

Fixation measures were analysed with linear mixed-effects models (see Bates 2005, Baayen 2008; Baayen, Davidson and Bates 2008; Baayen and Milin 2010) using the package *lme4* (Bates, Maechler and Dai 2009) in *R*. Before analysis, it was determined whether a variable had to be transformed in order to afford normality (see Box and Cox 1964). Following this procedure, all analyses were performed on log-transformed fixation variables.

2.5 Results

The mean fixation times in each region of interest according to the context, the meaning and the verb are shown in Table 1.

Table 1. Mean First Pass Reading Times (FPRT), Total Fixation Times (TFT) and ReReading Times (RRT) in the different regions of interest according to the context and the meaning, and means by verb⁴

| | S – R | | S – E | | N – R | | N – E | |
|--------------------------------------|-------|-------|-------|-------|-------|-------|-------|-------|
| | M | SD | M | SD | M | SD | M | SD |
| Region 3 (modal verb) | | | | | | | | |
| FPRT (ms) | 272.5 | 155.1 | 255.8 | 157.9 | 267.6 | 152 | 246.1 | 126 |
| <i>devoir</i> | 260.4 | 141.4 | 273 | 174.5 | 281.5 | 170.3 | 243.5 | 122.3 |
| <i>pouvoir</i> | 283.1 | 166.4 | 238.4 | 138 | 253.9 | 131.3 | 248.6 | 130 |
| RRT (ms) | 398.7 | 310.6 | 426.5 | 309.7 | 396.5 | 290.1 | 462.9 | 366.3 |
| <i>devoir</i> | 444.7 | 346.5 | 429.8 | 322.8 | 362.8 | 240 | 485.4 | 406.4 |
| <i>pouvoir</i> | 375.8 | 293 | 423.2 | 300.9 | 419 | 320 | 445.9 | 336.3 |
| TFT (ms) | 435.2 | 331 | 451.6 | 333.9 | 456.4 | 323.4 | 498.1 | 388.7 |
| <i>devoir</i> | 389.3 | 332 | 466.4 | 355.7 | 420.6 | 277.9 | 476.7 | 401.9 |
| <i>pouvoir</i> | 475.8 | 326.9 | 436.6 | 311.8 | 491.8 | 361.2 | 518.4 | 377.1 |
| Region 4 (intervening region) | | | | | | | | |
| FPRT (ms) | 218.1 | 138.1 | 227.4 | 135.2 | 208.1 | 118.1 | 222.1 | 151.3 |
| <i>devoir</i> | 207.5 | 132.7 | 211.1 | 114.4 | 196.8 | 116.6 | 204.3 | 146 |
| <i>pouvoir</i> | 227.9 | 143.1 | 244.1 | 152.6 | 218.6 | 119.4 | 238.9 | 155.2 |
| RRT (ms) | 421 | 313.5 | 429.3 | 347.5 | 444.2 | 358.1 | 439 | 380 |
| <i>devoir</i> | 427.7 | 393.3 | 445.2 | 373.1 | 363.9 | 283.5 | 401.5 | 347.7 |
| <i>pouvoir</i> | 415.8 | 240.2 | 433.5 | 324.3 | 518.5 | 404.1 | 481.1 | 412.5 |
| TFT (ms) | 465.1 | 319.7 | 490.5 | 367 | 512.2 | 372.6 | 512.9 | 390.7 |
| <i>devoir</i> | 433.2 | 344.7 | 471.7 | 372.6 | 444.5 | 315.8 | 494.8 | 367.5 |
| <i>pouvoir</i> | 494.4 | 294 | 509.7 | 362.5 | 575.5 | 410.8 | 529.9 | 412.8 |

4 M = mean, SD = standard deviation, S – R = supportive context – root meaning, S – E = supportive context –epistemic meaning, N – R = neutral context – root meaning, N – E = neutral context –epistemic meaning.

| Region 5 (infinitive) | | | | | | | | |
|---------------------------------------|-------|-------|-------|-------|--------|--------|-------|-------|
| FPRT (ms) | 221.6 | 90.8 | 223.2 | 96.8 | 226.2 | 90.1 | 209.1 | 82.7 |
| <i>devoir</i> | 224 | 92.4 | 227.1 | 84.1 | 236 | 96.4 | 208.2 | 80.3 |
| <i>pouvoir</i> | 219.2 | 89.8 | 218.9 | 109.3 | 215.9 | 82.5 | 209.8 | 85.3 |
| RRT (ms) | 326.5 | 237.9 | 381.1 | 339.5 | 322.2 | 244.6 | 372.1 | 316.8 |
| <i>devoir</i> | 353.4 | 300.8 | 430.4 | 395.5 | 370.9 | 295.1 | 398.8 | 391.3 |
| <i>pouvoir</i> | 307.7 | 185.2 | 325.6 | 260.1 | 287.9 | 199 | 347.8 | 232.7 |
| TFT (ms) | 345.8 | 249.4 | 354.5 | 295.6 | 372.2 | 250.3 | 371.4 | 297.6 |
| <i>devoir</i> | 336.5 | 278.8 | 378.1 | 340.8 | 371.9 | 278.3 | 382.3 | 360.2 |
| <i>pouvoir</i> | 354.9 | 218.9 | 329 | 236.8 | 372.5 | 219.3 | 361.4 | 228.2 |
| Region 6 (complement) | | | | | | | | |
| FPRT (ms) | 516.4 | 322.3 | 506.6 | 271.6 | 481.9 | 285.2 | 501.9 | 293 |
| <i>devoir</i> | 466.3 | 260.3 | 464.1 | 256.6 | 444.3 | 238.8 | 417.7 | 254 |
| <i>pouvoir</i> | 563.3 | 366.6 | 549.6 | 281.1 | 519.1 | 321.8 | 583.1 | 306.3 |
| RRT (ms) | 735.6 | 734.8 | 752.2 | 689.1 | 756.2 | 804.3 | 658.4 | 653.4 |
| <i>devoir</i> | 818.5 | 970 | 770.9 | 636.3 | 688.2 | 1016.1 | 646.8 | 665.8 |
| <i>pouvoir</i> | 673.3 | 494.9 | 730 | 754.3 | 809.1 | 595.3 | 670.1 | 647.5 |
| TFT (ms) | 891.5 | 745 | 931.1 | 721.6 | 956.4 | 793.3 | 894.5 | 654.4 |
| <i>devoir</i> | 836.3 | 843.2 | 934.1 | 689.7 | 824.6 | 900.1 | 810.7 | 642.4 |
| <i>pouvoir</i> | 943.2 | 641 | 928.1 | 756.7 | 1086.5 | 651.7 | 975.3 | 659.5 |
| Region 7 (end of the sentence) | | | | | | | | |
| FPRT (ms/car) | 31.1 | 15.6 | 31.9 | 15.4 | 30.3 | 15.1 | 30.1 | 17.6 |
| <i>devoir</i> | 29.4 | 15.5 | 33.3 | 17.3 | 29.2 | 14.4 | 27.9 | 18 |
| <i>pouvoir</i> | 32.7 | 15.6 | 30.6 | 13.2 | 31.5 | 15.7 | 32.2 | 17.1 |
| RRT (ms/car) | 34 | 33.8 | 32.7 | 26.3 | 34.4 | 34.5 | 38.6 | 51.5 |
| <i>devoir</i> | 37.6 | 43.9 | 36.5 | 27.1 | 33.3 | 35.5 | 42.5 | 53.8 |
| <i>pouvoir</i> | 30.5 | 20.1 | 28 | 24.9 | 35.3 | 34 | 34.4 | 49.3 |
| TFT (ms/car) | 45.9 | 29.6 | 46.9 | 29.9 | 48.6 | 31.8 | 50.7 | 43.2 |
| <i>devoir</i> | 45.9 | 35.9 | 51.3 | 33.4 | 45 | 33.1 | 51.6 | 45.6 |
| <i>pouvoir</i> | 46 | 22.3 | 42.3 | 25.1 | 52.1 | 30.3 | 49.8 | 41 |

We report the measure of initial processing (i.e., FPRT) first. In ROI 3 consisting of the modal verb, the means suggest longer FPRTs in the *supportive context* condition compared with the *neutral context* condition (see Table 1). In supportive contexts, we can indeed expect processes of meaning integration which do not occur in neutral contexts. These processes explain why the FPRTs are sometimes counter-intuitively longer when the preceding context supports the meaning of a word (see Frazier and Rayner 1990; Pickering and Frisson 2001). The means furthermore suggest longer FPRTs in the *root meaning* condition compared with the *epistemic meaning* condition. However, it is also suggested that, in the *supportive context* condition, in *devoir*-sentences, FPRTs are longer when the meaning is epistemic than when it is root, while in *pouvoir*-sentences, FPRTs are longer when the meaning is root than when it is epistemic. The analysis indeed revealed a marginal three-way interaction ($t(592) = -1.90$, $p = 0.058$) suggesting that the meaning effect could be different depending on the verb and the context. The analysis of the FPRTs in the *pouvoir* condition showed a non-significant *meaning* \times *context* interaction ($t(301) = -1.51$, $p = 0.13$) which nevertheless significantly improved the regression model, whereas the analysis in the *devoir* condition did not show any predictor of the FPRTs. In the *pouvoir* – *supportive context* condition, the meaning is a significant predictor of the FPRTs which are shorter when

the modal has an epistemic meaning ($t(153) = -2.26, p = 0.025$). In the *pouvoir – neutral context* condition, as expected since the context is neutral, the meaning has no effect.

To sum up, in the modal verb region, a meaning effect is only found in the *pouvoir – supportive context* condition in which the first pass reading is facilitated by the non-dominant epistemic meaning.

In the following ROI 4 (IR), the means suggest that the FPRTs are longer when the context is supportive, the meaning epistemic and the modal *pouvoir* (see Table 1). The individual means do not suggest any interaction between these variables. The analysis of the FPRTs only showed a significant effect of the verb ($t(604) = 3.02, p = 0.0026$). IRs were read more slowly in *pouvoir* sentences.

No significant effect emerged in ROI 5 (infinitive verb). In ROI 6, only the verb has a significant effect: FPRTs are longer in the *pouvoir* condition ($t(619) = 3.96, p = 0$).

Finally, in the last ROI consisting of the last words of the sentences, no significant effect emerged.

The analyses of the measures of subsequent or general processing (RRTs and TFTs) showed a relatively weak context effect limited to the last ROIs. However, a meaning effect, albeit limited to the *devoir* condition, emerged on the TFTs from the region of the modal verb.

RRTs in the ROI 3 consisting of the modal verb seem to be longer in the *epistemic meaning* condition compared with the *root meaning* condition, and the means also suggest a *context* \times *meaning* interaction (see Table 1). However, the analysis did not reveal any significant effect.

The TFTs in this ROI seem shorter in the *supportive context* condition and in the *root meaning* condition (see Table 1). A facilitation effect is indeed expected when the context supports the meaning and when this meaning is the most frequent one. Nevertheless, the individual means suggest that in the *pouvoir – supportive context* condition, the TFTs are not shorter in the *root meaning* condition but longer. The analysis showed a significant *meaning* by *verb* interaction ($t(596) = 2.21, p = 0.0275$). The interaction seems to indicate that the TFTs are longer when the meaning is epistemic only in *devoir*-sentences. The meaning is indeed a significant predictor of the TFTs in the *devoir* condition where they are longer in the *epistemic meaning* condition ($t(292) = 1.99, p = 0.0473$). The context has no significant effect on TFTs neither in *devoir*-sentences nor in *pouvoir*-sentences.

To sum up, in the ROI 3 consisting of the modal verb, the context has no significant effect on the TFTs, and the facilitation effect of the dominant root meaning is limited to *devoir*.

In the IR, neither the context nor the meaning has any effect on the RRTs. Only the verb is a significant predictor of the RRTs which are longer in the *pouvoir* condition ($t(385) = 2.03, p = 0.043$). Regarding the TFTs in the IR, the means suggest a *meaning* by *verb* interaction (see Table 1) that the analysis also suggests ($t(605) = -1.78, p = 0.0756$). The effect of the epistemic meaning seems limited to

devoir-sentences. The meaning is indeed a marginal predictor of the TFTs in the *devoir* condition where the items in the *epistemic* condition have been read relatively more slowly than the items in the *root* condition ($t(296) = 1.79, p = 0.0745$), whereas the meaning does not predict the TFTs in the *pouvoir* condition. In other words, in the IR, we found a trend towards the same facilitation effect of the root meaning limited to *devoir*-sentences as in the preceding region.

No significant effect emerged in ROI 5. In the following region, ROI 6, there is no predictor of the RRTs; and only the *verb* is a significant predictor of the TFTs which are longer in the *pouvoir* condition compared with the *devoir* condition ($t(616) = 2.71, p = 0.0069$).

In the last ROI, the last words of the sentences, the TFTs seem longer when the context is neutral. The means also suggest a *meaning* by *verb* interaction (see Table 1). The analysis indeed showed a main effect of the context ($t(294) = 2.065, p = 0.0398$) and a *meaning* \times *verb* interaction ($t(294) = 2.555, p = 0.0111$). A supportive context thus reduced, as expected, the rereading times, and the epistemic meaning only reduced the RRTs in *pouvoir*-sentences ($t(150) = -2.246, p = 0.0262$). In the *devoir* condition, a significant effect of the meaning also emerged, but the RRTs are significantly reduced when the meaning is root and not epistemic ($t(145) = -2.241, p = 0.0265$). To sum up, in the last ROI, a root meaning eases the rereading in *devoir*-sentences whilst an epistemic meaning facilitates it in the *pouvoir*-sentences.

Regarding the TFTs in the last ROI, the means suggest longer TFTs in the *devoir* condition when the meaning is epistemic, and longer TFTs in the *pouvoir* condition when the meaning is root, regardless of the supportive or neutral context (see Table 1). The analysis indeed revealed a significant *meaning* \times *verb* interaction ($t(615) = 3.13, p = 0.0018$) and no main effect of the context. In the *devoir*-sentences, the TFTs are significantly longer when the meaning is epistemic ($t(303) = 2.52, p = 0.0123$). In the *pouvoir*-sentences, no meaning effect appeared but a marginal context effect emerged ($t(311) = 1.91, p = 0.057$). Hence, in the last ROI, the general reading is facilitated by the supportive context in *pouvoir*-sentences, and by the root meaning in *devoir*-sentences.

2.6 Discussion

We first summarise the main results obtained before discussing them in relation to the three hypotheses presented in section 1.2: homonymy, polysemy and monosemy/under-specification.

The regions of interest 4 and 6 (the intervening region and the complement of the infinitive verb) are in general easier to process when the modal verb used in the sentences is *devoir*. In the IR, the first pass reading and the rereading are facilitated in the *devoir* condition compared with the *pouvoir* condition. Nevertheless, the expressions used in this region are not always the same from a *verb* condition to the other, and the facilitation effect in the *devoir* condition can be explained by a frequency effect: the expressions used are more frequent in this condition compared with the expressions used in the *pouvoir* condition according to *Google France* (see Janssen and Barber (2012), Keller and Lapata (2003) or

Blair, Urland and Ma (2002) concerning the use of the internet search engine in order to estimate the frequency of phrases). At the end of the sentence (ROI 6), the frequency can again explain the effect. As a consequence, the facilitation effect of *devoir*, being correlated to phrases' frequency in these regions, appears spurious and it will not be discussed further.

Regarding the first pass reading of the modal verb, a facilitation effect of the epistemic meaning appeared in supportive contexts in *pouvoir*-sentences. The epistemic non-dominant meaning of *pouvoir* (see 2.3.1) seems counter-intuitively to be the easiest to process. Regarding the rereading or the general reading, a facilitation effect of the root meaning was found only in the sentences containing *devoir* in the region of the modal and, to a lesser extent, in the following intervening region. The effect of the root meaning can be explained by an effect of relative frequency here: the dominant meaning is the easiest to process. In the last region, the last words of the sentences, the root meaning has again a facilitation effect in the *devoir* condition, whereas the epistemic meaning or the supportive context have a facilitation effect in the *pouvoir* condition.

The results obtained disqualify the ambiguity/homonymy hypothesis for both *devoir* and *pouvoir*. Indeed, we did not find the early effect of the context or the potential garden-path effect expected in case of genuine ambiguity. The early effect of the epistemic meaning on the reading of the modal *pouvoir* cannot be a "subordinate bias effect" (Clifton, Staub and Rayner 2007) since it predicts the non-dominant meaning to be the most difficult to process in supportive contexts, and not the easiest. The results obtained in the *devoir* condition, namely the effect of relative frequency, fit with the polysemy hypothesis which predicts such an effect. However, this hypothesis does not account for the results obtained with *pouvoir* since it expects a facilitation effect of the dominant, and not the non-dominant, meaning.

The under-specification hypothesis better fits in the case of *pouvoir* if one assumes that the epistemic meaning requires less effort of meaning integration or enrichment than the root meaning does, and thus constitutes a meaning close to the under-specified meaning stored in memory. We could therefore assume that in root contexts, compared with epistemic contexts, in addition to the meaning activated at the reading of the verb, a process of enrichment of this meaning occurs in order to integrate the origin of the possibility and to derive a more specific meaning of capacity, permission or material possibility.

3 General discussion

The conclusion we reached according to which *devoir* would be indeed polysemous while *pouvoir* would probably only have an under-specified semantics might appear spurious at the first glance. Indeed, the two modal verbs seem to constitute a paradigm – as limited as it is – in French, and it is thus difficult to assume that the two modal verbs have different natures and behaviours. However, our conclusion fits with several circumstantial proofs (see Barbet 2013).

For example, the fact that *pouvoir* has more possible interpretations than *devoir* can be a circumstantial proof of their different natures. In addition to its root and epistemic meaning, *pouvoir* has indeed several post-modal interpretations such as "concession", "deliberation", "interrogation", *etc.* whereas *devoir* has, so to say, only one post-modal interpretation of future (see e.g., Barbet and Vetters 2013). One can assume that the more a linguistic item loses its semantic features and constraints, the more it is likely to appear in many different contexts (see Bybee, Perkins and Pagliuca 1994).

Moreover, the fact that *devoir* is non-propositional in its epistemic occurrences but propositional in its root occurrences, while *pouvoir* probably never constitutes such a non-propositional operator (see below, and Rocci 2005 about the Italian *potere*) advocates for two different natures for the modal verbs. However, if *pouvoir* is really monosemic, we still have to determine its under-specified meaning represented in memory.

Although we put forward the hypothesis that *pouvoir* only has one under-specified meaning stored in the mental lexical, we would not suggest for the French modal verb a similar monosemic analysis as the one suggested by Papafragou (2000) for some English modal verbs (R(D, *p*), see 1.2). We make the hypothesis that the stored meaning of *pouvoir* is a meaning of alethic possibility in the sense of Kratzer (1981) or Rocci (2005). We think that it is not possible to apply Papafragou's semantic analysis to *pouvoir* because the modal is not a non-propositional operator and being a non-propositional operator seems to be implied by the semantics R(D, *p*). A genuine non-propositional operator, which expresses the attitude of the speaker towards a proposition, cannot be in the scope of the negation (see e.g., Gosselin 2010: 99 or Rocci 2005: 237). Whereas epistemic *devoir* cannot be semantically under the scope of the negation, see (13), epistemic *pouvoir* can be: see (14) or (15) where *ne pas pouvoir* does not mean "possible that not" but "impossible that":

- (13) Pierre *ne doit pas* travailler.
≈ Pierre *doit ne pas* travailler.
"Pierre must not be working."
- (14) *Je sais déjà que ce ne peut pas être quelqu'un d'ici ! fit-il* (Frédéric Dard, *Une seconde de toute beauté*, quoted by Vetters 2007: 75)
"I already know that it cannot be someone local!"
- (15) *Vous pouvez pas êt' aussi mauvaise que l'nèg que vous voyez là, déclara Doosy, la langue un peu épaisse.* (Richard Jessup, *Un bruit de chaînes*, quoted by Vetters 2007: 75)
"You can't be as bad as the nigger you see there"

In other words, so-called epistemic *pouvoir* is not non-propositional (see also Rocci 2005 about the Italian *potere*) and hence it is not epistemic in the sense that it refers deictically to the beliefs of the speaker. Consequently, the epistemic meaning of *pouvoir* is better described as alethic and expressing the unilateral possibility (see also "objective epistemic" in Lyons 1977 or Coates 1983). This meaning could constitute the only meaning represented in memory, a meaning which can appear as such when no further contextual information is available, or enriched of root causes or attributed to the personal beliefs of the speaker in more specific contexts (see Barbet 2013).

References

- Baayen, R. Harald (2008): *Analysing Linguistic Data. A practical introduction to statistics*, Cambridge: Cambridge University Press.
- Baayen, R. Harald / Davidson, D. J. / Bates, Douglas (2008): "Mixed-effects modeling with crossed random effects for subjects and items", in: *Journal of Memory and Language* 59: 390–412.
- Baayen, R. Harald / Milin, Petar (2010): "Analyzing reaction times", in: *International Journal of Psychological Research* 3 (2): 12–28.
- Barbet, Cécile (2013): *Sémantique et pragmatique des verbes modaux du français. Données synchroniques, diachroniques et expérimentales*, Phd thesis, University of Neuchatel and Université du Littoral Côte d'Opale.
- Barbet, Cécile (under press): "L'évolution sémantique des verbes modaux: hypothèses à partir des emplois de devoir et pouvoir en français moderne et médiéval", in: *Journal of French Language Studies*.
- Barbet, Cécile / Veters, Carl (2013): "Pour une étude diachronique du verbe modal pouvoir en français: les emplois postmodaux", in: *Cahiers Chronos* 26: 315–336.
- Bates, Douglas (2005): "Fitting linear mixed models in R", in: *R news* 5 (1): 27–30.
- Bates, Douglas / Maechler, M. / Dai, B. (2009). *lme4: Linear mixed-effect models using Eigen and Eigen++, R package*.
- Blair, Irene / Urland, Geoffrey / Ma, Jennifer (2002): "Using Internet search engines to estimate word frequency", in: *Behavior Research Methods* 34 (2): 286–290.
- Box, G. E. P. / Cox, D. R. (1964): "An Analysis of Transformations", in: *Journal of the Royal Statistical Society Series B (Methodological)* 26: 211–252.
- Bybee, Joan / Perkins, Revere / Pagliuca, William (1994): *The Evolution of Grammar. Tense, Aspect, and Modality in the Languages of the World*, Chicago: University of Chicago Press.
- Clifton C. / Staub, A. / Rayner, Keith (2007): "Eye movements in reading words and sentences", in: van Gompel, R. (ed.): *Eye movements: A window on mind and brain*, Amsterdam: Elsevier, 341–372.
- Coates, Jennifer (1983): *The Semantics of the Modal Auxiliaries*, London: Croom Helm.
- Croft, William (1998): "Linguistic evidence and mental representations", in: *Cognitive Linguistics* 9 (2): 151–173.
- Demberg, Vera / Keller, Frank (2008): "Data from eye-tracking corpora as evidence for theories of syntactic processing complexity", in: *Cognition* 109 (2): 193–210.
- Durkin, Kevin / Manning, Jocelyn (1989): "Polysemy and the Subjective Lexicon: Semantic Relatedness and the Salience of Intraword Senses", in: *Journal of Psycholinguistic Research* 18 (6): 577–612.
- Engbert, Ralf / Kliegl, Reinhold (2003): "Microsaccades uncover the orientation of covert attention", in: *Vision research* 43 (9): 1035–1045.

- Frazier, L. / Rayner, Keith (1990): "Taking on semantic commitments: Processing multiple meanings vs. multiple senses", in: *Journal of Memory and Language* 29 (2): 181–200.
- Frisson, Steven / Pickering, Martin J. (2001): "Obtaining a Figurative Interpretation of a Word: Support for Underspecification", in: *Metaphor and Symbol* 16 (3–4): 149–171.
- Fuchs, Catherine / Guimier, Claude (1989): "Introduction", in *Langue française* 84: 4–8.
- Geeraerts, Dirk (1993): "Vagueness's puzzles, polysemy's vagaries", in: *Cognitive Linguistics* 4 (3): 223–272.
- Gosselin, Laurent (2010): *Les modalités en français. La validation des représentations*, Amsterdam-New York: Rodopi.
- Holmqvist, Kenneth / Nyström, Marcus / Andersson, Richard / Dewhurst, Richard / Jarodzka, Halszka / van de Weijer, Joost (2011): *Eye Tracking: A comprehensive guide to methods and measures*, Oxford: Oxford University Press.
- Honeste, Marie-Luce (2004): "Langue et contexte: deux sources de signification. L'exemple du verbe modal pouvoir", in: *Le Français Moderne* 72 (2): 146–156.
- Huot, Hélène (1974): *Le verbe devoir, Etude synchronique et diachronique*, Paris: Klincksieck.
- Inhoff, A. W. / Radach, R. (1998): "Definition and computation of oculomotor measures in the study of cognitive processes", in: Underwood, Geoffrey (ed.), *Eye guidance in reading and scene perception*, Oxford: Elsevier Science, 29–53.
- Janssen, Niels / Barber, Horacio (2012): "Phrase Frequency Effects in Language Production", in: *PloS one* 7.3, e33202.
- Keller, Frank / Lapata, Mirella (2003): "Using the web to obtain frequencies for unseen bigrams", in: *Computational linguistics* 29 (3): 459–484.
- Klepousniotou, E. (2002): "The Processing of Lexical Ambiguity: Homonymy and Polysemy in the Mental Lexicon", in: *Brain & Language* 81: 205–223.
- Klepousniotou, E. / Pike, G. B. / Steinhauer, K. / Gracco, V. (2012): "Not all ambiguous words are created equal: An EEG investigation of homonymy and polysemy", in: *Brain & Language* 123: 11–21.
- Klepousniotou, E. / Titone, D. / Romero, C. (2008): "Making Sense of Word Senses: The Comprehension of Polysemy Depends on Sense Overlap", in: *Journal of Experimental Psychology: Learning, Memory & Cognition* 34 (6): 1534–1543.
- Kratzer, Angelika (1981): "The notional category of modality", in: Eikmeyer, H. / Rieser, H. (eds), *Words, Worlds, and Contexts. New Approaches in World Semantics*, Berlin: de Gruyter.
- Kronning, Hans (1996): *Modalité, cognition et polysémie: sémantique du verbe modal devoir*, Uppsala – Stockholm: Almqvist & Wiksell International.
- Kronning, Hans (2001): "Pour une tripartition des emplois du modal devoir", in: *Cahiers Chronos* 8: 67–84.
- Le Querler, Nicole (1996): *Typologie des modalités*, Caen: Presses Universitaires de Caen.

- Le Querler, Nicole (2001): "La place du verbe modal pouvoir dans une typologie des modalités", in: *Cahiers Chronos* 8: 17–32.
- Logacev, Pavel / Vasishth, Shravan (2011), em, R package version 0.03.
- Lyons, John (1977): *Semantics*, Cambridge: Cambridge University Press.
- Palmer, F. R. (1979): *Modality and the English Modals*, London: Longman.
- Papafragou, Anna (2000): *Modality: Issues in the Semantics-Pragmatics interface*, Amsterdam: Elsevier.
- Pickering, Martin J. / Frisson, Steven (2001): "Processing ambiguous verbs: Evidence from eye movements", in: *Journal of Experimental Psychology: Learning, Memory, and Cognition* 27 (2): 556–573.
- R Core Team (2009). *R: A language and environment for statistical computing*. R Foundation for Statistical Computing, Austria: Vienna.
- Rayner, Keith (1998): "Eye movements in reading and information processing: 20 years of research", in: *Psychological Bulletin* 124: 372–422.
- Rayner, Keith / Duffy, Susan (1986): "Lexical complexity and fixation times in reading: Effects of word frequency, verb complexity, and lexical ambiguity", in: *Memory & Cognition* 14: 191–201.
- Rayner, Keith / Sereno, Sara C. / Morris, Robin K. / Schmauder, A. Réne / Clifton, Charles (1989): "Eye movements and on-line language comprehension processes", in: *Language and Cognitive Processes* 4 (3–4): 21–49.
- Rocci, Andrea (2005): "On the nature of the epistemic readings of the Italian modal verbs: the relationship between propositionality and inferential discourse relations", in: *Cahiers Chronos* 13: 229–246.
- Saussure, Louis de (2012): "Modalité épistémique, évidentialité et dépendance contextuelle", in: *Langue française* 173: 131–143.
- Sten, H. (1954): "Devoir + infinitif", in: *Le Français Moderne* 22: 263–265.
- Sueur, Jean-Pierre (1983): "Les verbes modaux sont-ils ambigus?", in: Jean David / Kleiber, Georges (eds.), *La notion sémantico-logique de modalité*, Paris: Klincksieck, 165–182.
- Tuggy, David (2006): "Schematic network: Ambiguity, polysemy, and vagueness", in: Geeraerts, Dirk (ed.), *Cognitive linguistics: Basic Readings*, Berlin: Mouton de Gruyter, 167–184.
- van Casteren, Marteen / Davis, M. H. (2006): "Mix, a program for pseudorandomization", in: *Behavior research methods* 38 (4): 584–589.
- van der Auwera, Johan / Plungian, Vladimir A. (1998): "Modality's semantic map", in: *Linguistic Typology* 2: 79–124.
- Vetters, Carl (2007): "Pouvoir sporadique est-il aléthique?", in: *Cahiers Chronos* 19: 63–78.
- von der Malsburg, Titus (2009): "Choice of Saccade Detection Algorithm Has a Considerable Impact on Eye Tracking Measures", in: *Proceedings of European Conference on Eye Movements*, Southampton, UK.
- Williams, John (1992): "Processing polysemous words in context: Evidence for interrelated meanings", in: *Journal of Psycholinguistic Research* 21: 193–218.

Appendix

5 supplementary examples of sentences of interest (2 using *devoir* followed by 3 with *pouvoir*) in the 4 conditions: a. supportive preceding context – root meaning ; b. neutral preceding context – root meaning ; c. supportive preceding context – epistemic meaning ; d. neutral preceding context – epistemic meaning. The symbol | marks the regions of interest delimited for the analysis.

- a. Gérard se plaignait que sa maison de vacances lui coûtait trop cher, mais c'était normal, il|devait|en Espagne|payer|des impôts fonciers|comme il était devenu propriétaire.
 - b. Je t'avoue que je n'ai pas pris de nouvelles de José depuis quelques mois maintenant, mais il|devait|en Espagne|payer|des impôts fonciers|comme il était devenu propriétaire.
 - c. Christophe est tellement avare, c'est certainement l'argent qui explique son déménagement, il|devait|en Espagne|payer|des impôts fonciers|exorbitants s'il est parti au Portugal.
 - d. Je t'avoue que je n'ai pas pris de nouvelles de José depuis quelques mois maintenant, mais il|devait|en Espagne|payer|des impôts fonciers|exorbitants s'il est parti au Portugal.
-
- a. On ne peut plus rien leur demander ! Mercredi, mon fils m'a sorti que j'étais trop stricte : il|devait|ce jour-là|finir|son devoir de maths|avant midi pour avoir le droit de sortir.
 - b. Je ne peux pas te renseigner, je ne sais pas ce que faisait Léo mercredi après-midi, mais il|devait|ce jour-là|finir|son devoir de maths|avant midi pour avoir le droit de sortir.
 - c. Comme si je suivais Hugo partout... Je ne sais pas, moi, ce qu'il faisait jeudi soir, mais il|devait|ce jour-là|finir|son devoir de maths|s'il n'est pas sorti avec vous.
 - d. Je ne peux pas te renseigner, je ne sais pas ce que faisait Jo mercredi après-midi, mais il|devait|ce jour-là|finir|son devoir de maths|s'il n'est pas sorti avec vous.
-
- a. On croyait qu'on devrait se débrouiller pour le logement toute l'année, mais c'était sûr, on|pouvait|maintenant|loger|à Churchill College|, les travaux de rénovation étant achevés.
 - b. Rien n'était vraiment sûr pour le moment, mais d'après ce que disaient certains étudiants, on|pouvait|maintenant|loger|à Churchill College|, les travaux de rénovation étant achevés.
 - c. Je me demandais pourquoi on m'avait demandé à moi où John McGregor habitait à Cambridge, il|pouvait|maintenant|loger|à Churchill College|, ou ailleurs, je n'en savais rien, moi.
 - d. Il m'avait beaucoup déçu, alors je n'avais pas cherché à avoir de nouvelles de Rodolphe, il|pouvait|maintenant|loger|à Churchill College|, ou ailleurs, je n'en savais rien, moi.
-
- a. On n'allait tout de même pas plaindre Armand avec ses deux superbes villas sur la côte, il|pouvait|à l'époque|payer|des impôts fonciers|élevés, il en avait largement les moyens.
 - b. M. Lamury n'a jamais dit pourquoi il avait déménagé du centre-ville en grande banlieue, il|pouvait|à l'époque|payer|des impôts fonciers|élevés, il en avait largement les moyens.
 - c. Je me demandais pourquoi on m'avait demandé à moi pourquoi Luc avait déménagé en banlieue, il|pouvait|à l'époque|payer|des impôts fonciers|trop élevés, qu'est-ce que j'en savais moi ?
 - d. M. Lamuroy n'a jamais dit pourquoi il avait déménagé du centre-ville en grande banlieue, il|pouvait|à l'époque|payer|des impôts fonciers|trop élevés, qu'est-ce que j'en savais moi ?

- a. Mercredi après-midi, Alexandre a encore filé avant d'avoir terminé ses devoirs, il abuse, il|pouvait|ce jour-là|finir|son devoir de maths|avant le foot, il en avait pour 2 minutes.
- b. Christopher est parti vers 15 h 30 mercredi pour s'entraîner avec l'équipe de son collège, il|pouvait|ce jour-là|finir|son devoir de maths|avant le foot, il en avait pour 2 minutes.
- c. Samedi ? Je ne sais pas, tu sais il ne me fait pas un compte-rendu de toutes ses activités ; il|pouvait|ce jour-là|finir|son devoir de maths|, ou aider son père, je n'en sais rien moi !
- d. Pourquoi Alexandre n'est pas venu jouer avec toi mercredi ? Tu m'en poses de ces questions, il|pouvait|ce jour-là|finir|son devoir de maths|, ou aider son père, je n'en sais rien moi !