6 Epistemic Evaluation and Attribution in Academic Text

6.1 Introduction

Biological understanding consists of a conceptual model of the system at study, which is collaboratively created by the scientists working on that system. In contributing a new building block to the model, authors will need to argue, first: that their experiments are appropriate and performed well; second, that they can draw certain conclusions from these experiments; and third, how these conclusions fit within the existing knowledge model for their field. Their results might confirm or contradict other thoughts about the model, expressed in other papers. This need to indicate certainty and agreement/disagreement means that biological papers will have to contain explicit truth evaluations of their own and other's propositions. This mechanism of truth evaluation or *epistemic evaluation* is therefore pivotal to the creation of biological knowledge. In this chapter, we will study epistemic evaluation and knowledge attribution, and see how it relates to the model of Discourse Segment Types connecting different mental realms, developed in the previous two chapters.

Strictly speaking, we can say that every factual proposition has an (implicit) epistemic evaluation: if a statement is given without further comment on its truth value, we read – irony aside – that the author agrees with that statement. '*Water is wet*.' – or '*LPS-induced IL-6 gene transcription in murine monocytes is controlled by NF-κB*' are statements that do not contain any epistemic modifiers, and are therefore read to be unconditionally accepted by the author. In other cases, however, this truth value can either qualified, e.g.: *'These results suggest that water is wet.'* or attributed: *'Pander Maat et al. (2010) report that water is wet.'* Here, we investigate all such 'modifiers of Propositional Content' [Hengeveld and Mackenzie, 2008], which can consist of either a specification of the degree of commitment to the proposition, e.g. '*5' untranslated exon 1 may have a regulatory function'*, where the (lack of) author commitment is explicitly indicated, or the origin of the source of the propositional knowledge, '*GATA-1 transactivates the EOS47 promoter through a site in the 5'UTR [34]*.' where the reference indicates the source of the claim pertaining to GATA-1 activity.

With Latour (p. 105), our goal is to "*specify the precise time and place in the process of fact construction when a statement became transformed into a fact*". To get closer to this goal, in this chapter, we develop a schema of the various ways in which knowledge can be attributed or evaluated, and describe how the different Discourse Segment Types we have identified partake in this attribution-driven method of knowledge construction. We begin with a brief literature review

on work in hedging, speculation, and knowledge attribution (6.2). From this, we derive a classification of epistemic evaluation types (6.3) and investigate the correlations between this typology and our Discourse Segment types, by annotating two full-text biology papers (Zimmermann, 2009) and (Voorhoeve, 2006) with epistemic types and Discourse Segment Types, and find we can classify the latter in terms of the former. Next, we define a set of candidate lexicogrammatical features found, in other studies, to identify epistemic modality and knowledge attribution (6.4), and investigate a correlation: are certain types of evaluation marked by certain cues? The answer is: somewhat. Lastly (6.5) we draw some conclusions for models of and markers for epistemic modality and knowledge attribution, and review our results with respect to the tripartite (Concepts, Objects, People) realm model developed in the previous two chapters.

6.2 Related work

Epistemic evaluation can take on many forms, and serve many purposes. We provide a brief overview of some related work pertaining to epistemic evaluations in scientific text in four fields: linguistics theory, genre studies, bioinformatics, and sentiment detection.

Within *linguistics*, truth evaluations and source attributions are an important subject within most modern theories of language; here, only a small overview of some pertinent theories can be given. Hengeveld and Mackenzie (2006) textbook on functional discourse grammar characterises truth evaluations (p. 351 pp) as modifiers of Propositional Content, concerning 'the kind and degree of commitment of a rational being to Propositional Content, or a specification of the (non-verbal) source of the Propositional Content'. These two categories – knowledge evaluation and knowledge attribution- are also indicated by 'epistemic modality' and 'evidentiality', respectively. De Haan (1999) strongly argues that they are separate phenomena – and we agree – but for our purposes, establishing modes of truth evaluation and attribution in scientific text, both are relevant. Verstraete (2001) provides an overview of work on objective and subjective modality: in an objectively modal clause, the truth value of the state of knowledge is brought into question ('*This subject is unknown'*), but the certainty the author has pertaining to the clause is not; in a subjective modal clause, the author expresses uncertainty regarding the extent of his or her knowledge ('*It might be (that this is the case)*').

In *genre studies*, a body of work has been done on hedging: 'the expression of tentativeness and possibility in language' (Hyland, 1995), with a particular focus on the rhetorical/sociological motivation for and surface features of these 'politeness markers'. Myers (1989) identifies stereotypical sentence patterns for hedging from a corpus study of fifty related articles in molecular genetics. Salager-Meyer (1994) defines hedging as presenting 'the true state of the writers' understanding, namely, the strongest claim a careful researcher can make.' She identifies three reasons for hedging: (1) that of purposive fuzziness and vagueness (threat- minimizing strategy); (2) that which reflects the authors' modesty for their achievements and avoidance of personal involvement; and (3) that related to the impossibility or unwillingness of reaching absolute accuracy and of quantifying all the phenomena under observation. Very influentially, Hyland (1996, 1998) proposes an explanatory framework for scientific hedging which combines sociological, linguistic, and discourse analytic perspectives and proposes a three-part taxonomy, distinguishing writer-oriented, accuracy-oriented and reader-oriented hedges. Countering Hyland, Crompton (1997) reviews and evaluates some of the different ways in which the term 'hedge' has been understood and defined in the literature thus far. His new definition is that 'a hedge is an item of language, which a speaker uses to explicitly qualify his/her lack of commitment to the truth of a proposition he/she utters.' Martín-Martín (2008) analyses three different hedging strategies and multiple surface features for hedging in a corpus of full-text papers in English and Spanish, and presents a detailed taxonomy of hedging types and cues, based on literature and corpus studies.

In bioinformatics and bio-computational linguistics, a body of work has been devoted to identifying 'speculative language' (Light, 2006). The main purpose here is to enable the automated identification of truth and speculation, in order to enable the construction of databases of known, and candidate, biological facts. The differences with earlier discussions are twofold: first, there is

less (or no) effort to study communicative functions; second, there is more focus on identifying different types of speculation: is the opinion presented positive or negative, strong or weak, etc. Light et al. (2004) annotate a corpus of Medline sentences as highly speculative, low speculative, or definite, and then train a classifier to automatically recognize speculative sentences. (As an interesting result, they find that almost all speculations appear in the final or penultimate sentence of the abstract). Wilbur et al. (2006) are motivated by the need to identify and characterize locations in published papers where reliable scientific facts can be found, and present a set of guidelines and the results of an annotation task to annotate a full-text corpus with a five-dimensional set of quantities *focus*, *polarity*, *certainty*, *evidence*, and *directionality.* Of these, *certainty* and *evidence* relate to epistemic evaluation. Medlock and Briscoe (2007) develop a set of guidelines for identifying speculative sentences and an annotated corpus, to test their automated speculation classification tool. Kilicoglu and Bergler (2008) explore a linguistically motivated approach to the problem of recognizing speculative language in biomedical research articles. Building on Hyland's work, they identify a set of syntactic patterns, which they use for detecting speculative sentences out of a corpus. Thompson et al. (2008) propose a multi-dimensional classification of a preliminary set of words and phrases that express modality within biomedical texts, and present the results of an annotation experiment. They mark up sentences with level of speculation, type/source of the evidence and the level of certainty towards the statement writer or other. Vincze et al. (2008) describe the BioScope corpus, a collection of Medline abstracts and four full-text papers annotated with instances of negation and speculation.

In the subfield of computational linguistics pertaining to *sentiment detection*, the goal has been to create overviews of large set of documents summarizing collective opinions and emotion about some topic. Here a more 'mathematical' definition of modality is evolving, which considers the proposition being evaluated as being 'operated on' by the evaluator. A distinction is made between the holder of the opinion, and the strength, polarity and other attributes of the opinion. Similar to work in (bio)computational linguistics, this work has focused is on different types of opinions being investigated, and the clues that allow automated detection. Most work in this field has focused on other domains, such as news and product reviews, see e.g. Wilson and Wiebe (2003), Kim and Hovy (2004), and Tang et al., (2009).

In Table A1, in the Appendix, we have summarized the proposals for epistemic evaluation types and cues from the papers discussed here.

6.3 Epistemic Evaluation and Attribution Types

6.3.1 A classification of epistemic modality

For our purposes, and following the formalism used in opinion/sentiment analysis e.g., (Wilson and Wiebe, 2003; Hovy, 2011) and Functional Discourse Grammar (Hengeveld and Mackenzie, 2006) it is useful to differentiate between two entities:

- Propositions (similar to FDG's Propositional Content), which can consist of either experimental ('*all thymocytes stained positive for GFP'*) or conceptual ('*CCR3 is expressed strongly on eosinophils'*) statements about the (conceived or acted upon/perceived) world,
- Modifiers which work on these Propositions and modify their truth value or the knowledge attribution. These modifiers have four components:
  - First of all, evaluations possess a value or level of certainty. Both Hengeveld and Mackenzie (2006) and Wilbur et al. (2006) propose a tripartite division:
    - 'doxastic' (firm belief in truth, Wilbur's category 3)
    - 'dubitative' (some doubt about the truth exists; Wilbur's category 2)
    - 'hypothetical' (where the truth value is only proposed; Wilbur's category 1).
    - Wilbur also adds the useful category 'lack of knowledge (level 0).
  - Secondly, there can be a different basis of the evaluation. These can be:
    - Based on reasoning: *('it is thought that', 'we expected'*)
    - Based on data: *('these data suggested that', 'CCR3 has been shown to be'*)
    - Implicit or absent: '*no eosinophil-specific transcription factors have been reported'*

- Thirdly, we identify the source of the knowledge. There are five options, grouped into four categories:
  - Explicit source of knowledge. The knowledge evaluation can be explicitly owned by the author *('We therefore conclude that…')* or by a named referent ('*Vijh et al. [28] demonstrated that…'*)
  - Implicit source of knowledge. If there is no explicit source but a knowledge validation or attribution, there is an implicit source for the knowledge evaluation. This can be implicitly the author ('*these results suggest…'*) or an external source ('*It is generally believed that...*')
  - No source of knowledge. Lastly, the source of knowledge can be absent entirely. An example can be found in factual statements, such as '*transcription factors are the final common pathway driving differentiation'* for an accepted statement. Also, objective modal clauses ('*There is no knowledge on this topic*') can not be explicitly attributed to a knowledge source and fall under this category.

This differentiation between knowledge value, on the one hand, and knowledge source and basis, on the other, allows us to differentiate between Hengeveld's categories of knowledge evaluation (value) and knowledge attribution (source); similarly, the value/source dichotomy allows us to differentiate between objective (source: NN) and subjective (source: A/IA) knowledge claims. Table 1 summarizes this classification.

Concept	Values
V - Value	0 - Lack of knowledge
	1 - Hypothetical, low certainty
	2 - Dubitative, higher likelihood but short of complete certainty
	3 - Doxastic, complete certainty, reflecting an accepted, known and/or proven fact.
B - Basis	R – Reasoning ('*Therefore, one can argue…*')
	D – Data ('*These results suggest…*')
	0 – Unidentified ('*Studies report that…*')
S - Source	A - Author: Explicit mention of author/speaker or current paper as source *('We hypothesize that…'; 'Figure 2a shows that…'*)
	N - Named external source, either explicitly or as a reference ('*several reports have documented expression by other cell types [11-16,42].*')
	IA - Implicit attribution to the author ('*Electrophoretic mobility shift analysis revealed that*')
	NN – Nameless external source ('*no eosinophil-specific transcription factors have been reported…*')
	0 – No source of knowledge ('*transcription factors are the final common pathway driving differentiation*')
S/F - Surprise/ Focus	F – Focus
	S – Surprise

Table 1: Proposed classification for epistemic modality and knowledge attribution

6.3.2 Correlation between discourse segment types and epistemic categories

We now investigate whether this is a useful categorization that can shed light on the various types of knowledge attribution and epistemic evaluation in scientific text, and how it correlates to our model of Discourse Segment Type. To investigate this, we have marked up a single biology paper (Zimmermann 2009) with epistemic modality classes. The paper was segmented and classified with Discourse Segment Types (DSTs) described in [Chapter 4]. Briefly, we identify 23 DSTs, - seven basic types (Fact, Hypothesis, Problem, Goal, Method, Result, Implication), with each two derived categories (Regulatory-X segments, which introduce an X segment, and Other-X segments, where the X segment is attributed to a third party).

In table A3 (see Appendix) we provide a full overview of the values of the epistemic evaluation types as a function of DST for Zimmermann. Table 2 provides a summary of these results comparing DSTs to the Epistemic Modality/Attribution classification given above.

Value	**Value**	**Basis**	**Source**
Other-Fact	3	0	N
Fact	3	0	0
Other-Hyp	1	R	NN
Hypothesis	1	R	IA/A
Reg-Hyp	1	R	IA/A
Other-Imp	2	0	N/NN
Implication	2	D	IA
Reg-Imp	2	D	IA
Intertextual	3	0	N
Intratextual	3	D	A
Problem	0	0	N/NN
Other-Res	3	D	N
Result	3	D	IA

Table 2: Summary of most occurring epistemic evaluation/evidentiality markers per segment type (values with less than 3 occurrences have been omitted)

We briefly elaborate on the components of the classification in turn.

Two segment types are generally not epistemically marked:

- Goals indicate experimental intent or motivation, e.g.: '*In order to define the proteins capable of binding to CCR3 exon 1…'* These are neither propositions, nor modifiers, but instead intentional clauses; apart from the fact that are clearly attributable to the authors of the paper, it generally does not make sense to attribute a truth value to a Goal.
- Slightly less straightforward are Methods. These segments express experimental activity, e.g.: *'Using fluorescence microscopy and luciferase assays,' or* '*Nuclear extracts from AML14.3D10 cells were incubated with the probe*.' Again – other than an author attribution, overall, assigning evidentiality or an epistemic modality level does not make sense.

Value:

- 0, 'Statement of a lack of knowledge', clearly uniquely applies to Problems.
- 1, Hypothetical knowledge, equally clearly applies to Hypotheses.
- 2, Probable knowledge, is left for own and Other-Implications.
- Lastly, 3, 'Complete certainty' is a tricky category, since by its definition it defines unmarked propositions. However, to indicate 'true and attributed' statements, and differentiate them from 'known to be true and not attributed' we believe it is useful to demarcate between Other-Facts and Facts, and Facts and Results, and therefore have marked these segments as such.

In conclusion, therefore, this seems to be a useful classification: specifically, it allows us to differentiate between a lack of knowledge (Problem), pure speculation (Hypothesis), data-based claim (Interpretation), and known fact or observation (Fact or Result). Perhaps there should be more values between 1 and 3: it can be argued that there are as many as 5 or 6 hues of certainty spanned by, for instance, the spectrum of epistemic verbs used, which include *suggest, show, indicate, imply, implicate, hypothesize, examine, enhance, demonstrate, determine, discover, define, confirm*. However, in most instances a differentiation between 'hypothetical' and 'probable' can be made, so this seems a useful category and division.

Basis:

- We distinguish between two types of claims in a scientific paper: Hypotheses, which are not yet tested or based on data, and Implications, which are conclusions the author draws from data. We see this distinction in the Basis classification: 21 Hypotheses are based on Reasoning (and 21 out of 28 segments based on Reasoning are Hypotheses) vs. 10 Hypotheses which are based on Data, and 2 are not clear. In contrast, 48 Implications are based on Data, vs. 5 based on Reasoning and 15 not clear.
- Results are a restatement of the experimental findings, and therefore naturally based on data ('Other-Results' segment contain the verb 'found' – this can not umbiguously be based on data, and are therefore classified as '0')

- **Facts generally do not contain an explicit source or basis of knowledge and are therefore generally classified as '0' – DIT IS DUS WAT ANDERS!**

Overall, both the category and its values seem to suit our needs. They confirm our domain model, containing a dichotomy between the data-based component of biological knowledge, centered around the experiment (containing Results and Implications), and the conceptual part, centered around reasoning (consisting of Facts, Problems, and Hypotheses).

Source:
- 'Other-' segment types clearly stem from an external source – the presence of an external reference or marker is the reason they are categorized as 'other' in the first place. This also implies that 'non-Other' segments are, by definition, attributable to the authors, either explicitly (A) or implicitly (IA), or not attributable (∅).
- Non-'Other' experimental segments (Results) are (generally indirectly) attributable to the authors, reflecting the personal/experiential nature of experimental work.
- Hypotheses and Implications are generally attributable to the author, since they arise in the course of reasoning of the paper. In face, out of 24 explicit author markings, 8 occur in Implications, and 11 in Hypotheses. This leads us to the conclusion that in biology papers, explicit authorial stance marking generally only occurs when stating claims, either hypothesizing or interpreting.
- Facts are the main category where the majority of segments lack epistemic attribution altogether, and always coincide with a lack of obvious source (basis = 0), and a lack of doubt (value = 3). This is quite self-evident, since it clearly differentiates factual statements from attributable ones. In other words, the difference between no attributable source (basis = 0) and the others (basis = IA/A/N/NN) is that between objective and subjective epistemic evaluation.
- Intratextual segments, by definition, refer to the current paper (source = A) and Intertextual to an external source (source = N).

In conclusion, the Source category seems useful and insightful, and shows us the other axis of differentiation – between a 'general', shared knowledge space, corresponding to Burns et al.'s (2007) 'Domain-Specific Reasoning Model', containing Facts, Problems, and Other-Segments, on the one hand, and a personal knowledge space – corresponding to Burns' 'Experimental Design Space' - which is being constructed within the document, and surrounds the discourse pertaining to the experiments performed by the authors, consisting of Hypotheses, Results, and Implications.

Lastly, we briefly mention the category 'Focus and Surprise'. There were only 6 incidences in the Zimmermann paper, which we show in Table A3. Surprise was indicated in two Results segments, and Focus in one Other-Fact, two Reg-Implication and one Reg-Goal segment. Overall, these do not form an adequate statistic. It is unclear, for now, whether this is a useful category to take into account, although they undeniably matter to the argumentation as a whole. The one thing we may note is that surprise seems to be expressable mostly about (the author's own) Results; this seems appropriate, since the experimental outcome of an experiment is perhaps one of the few times a scientist can find something he or she is not expecting.

If we arrange these results by Value and Basis, we arrive at Table 3, which shows a grouping into experimentally based statements (left-hand column), general statements pertaining to the state of knowledge (middle column) and statements that are reasoned about (right-hand column), as well as a ranking of the certainty, along the vertical axis. A third dimension can be discerned for Source, which distinguishes between (implicit) authored statements and external, general (NN) or distinctly attributed ones (N), or statements without a clear attribution (0). This delineates the field where authors have an implicit or explicit voice or presence in the text (Results, Implications and Hypotheses), and where they don't (all other segment types).

	Data	**Unknown**	**Reasoning**

3	Result (IA) Other-Result (N)	Fact (0)	
2	Implication (IA)	Other-Implication (N)	
1			Hypothesis (IA/A) Other-Hypothesis. (N/NN)
0		Problem (NN)	

Table 3: Main results from Table 2 grouped by value and basis

In conclusion, the three axes of modality we have defined offer a useful model of knowledge evaluation and attribution in life-scientific text, spanning a three-dimensional epistemic space of certainty and doubt, reasoning and data, and shared and author-specific attribution. This model offers useful insights how various roles in the knowledge evaluation and attribution process are performed by different Discourse Segment Types. Next, we will look at various cues that define these modality axes.

6.4 Epistemic evaluation and attribution markers

6.4.1 Cue types

Our next question is which lexicogrammatical features are used to identify these epistemic evaluations. Table A2 in the Appendix summarizes the types of clues found in the literature. There is widespread agreement on the effect on epistemic modality of the following cue types:

- Modal auxiliary verbs (e.g. *can, could, may, might*)
- Qualifying adverbs and adjectives (e.g. *interestingly*, *possibly, likely, potential, somewhat*, *slightly*, *powerful, unknown, undefined*)
- References, either external (e.g. *'[Voorhoeve et al., 2006]*') or internal (e.g. '*See fig. 2a'*).
- Epistemic verbs (e.g. *suggest, imply, indicate, show, seem*).

The first three categories are quite self-evident and straightforward, but the last one bears further elaboration: how exactly do we define an epistemic verb? In Chapter 5, we defined a taxonomy of verb types, which we now review briefly with respect to their 'epistemic' qualities.

- Clearly, the Sensemaking verbs are all relevant: Prediction, Interpretation, Comparison and Cognition all classify as Epistemic acts.

But there are three further categories that can be included (with examples):

- *Investigation:* "compare, demonstrate, detect, determine, elucidate, evaluate, examine, exclude, exemplify, expose, extend, find, identify, investigate, pinpoint, mimic, remain, require, require, shed [light], start identify, strengthen, substantiate, test, verify"
- *Observation:* "characterize, compare, correlate, detect, express, find, identify, monitor, note, observe, see, show"
- *Discourse verbs:* "address, base, depict, describe, mention, note, report, represent, review, show, study, suggest, term"

It seems hard to exclude these categories, so to begin with, we will include them as candidates to indicate the epistemic evaluation types. We will revisit this decision afterwards.

Two categories of epistemic evaluation cues are mentioned, which we have decided not to include:

- Personal pronouns ('*we'*,'*our results*', or something similar). Closer analysis of the papers that mention this shows that in all cases where personal pronouns are mentioned as a hedging device, epistemic verbs are present, in phrases such as: '*we show'*, '*our results suggest'*, etc.
- Likewise passives by themselves do not provide any indication of epistemic evaluation. They are e.g. often used in Methods sections *('the rats were injected…'*) and are not, by themselves, markers of epistemic modality or evidentiality.

We shall use these four categories (modal auxiliary verbs, epistemic verbs, qualifying adverbs, references) as the candidate cues, and analyze a single research paper to see whether indeed, these markers capture all cases of epistemic modality. Are all cases that are marked as being

epistemically modulated covered by these cues; and conversely, do the cases that are not marked, not have any cues? In other words, are the cues any good at predicting epistemic modality types, and can they help us to find specific Discourse Segment Types?

6.4.2 Correlation between epistemic cues and Discourse Segment Type

We will take two steps in determining this correlation: first, we look at the overlap between DSTs and linguistic cues, for our demonstration paper (Zimmermann, 2005).

Segment type	Modal y/n		Epistemic Verb		Ruled by EV		Adverbs/ Adjectives		References		No cues		Total
Other-Fact	1	9%	2	18%	2	18%	1	9%	5	45%	2	18%	**11**
Fact		0%	1	5%	1	5%		0%		0%	19	90%	**21**
Reg-Fact		0%		0%		0%		0%		0%	1	100%	**1**
Other-Goal		0%	1	100%	1	100%		0%		0%		0%	**1**
Goal		0%	13	81%	3	19%		0%		0%	2	13%	**16**
Reg-Goal		0%	2	100%		0%	1	50%		0%		0%	**2**
Other-Hypothesis	1	20%		0%	5	100%		0%	2	40%		0%	**5**
Hypothesis	8	47%	4	24%	11	65%	2	12%	1	6%		0%	**17**
Reg-Hypothesis		0%	11	100%		0%		0%		0%		0%	**11**
Other-Implication		0%	3	27%	9	82%		0%	3	27%		0%	**11**
Implication		0%	12	38%	17	53%	1	3%	2	6%	4	13%	**32**
Reg-Implication		0%	26	100%	2	8%	2	8%	1	4%		0%	**26**
Intertextual		0%	5	100%		0%		0%	2	40%		0%	**5**
Intratextual		0%	16	100%		0%		0%	13	81%		0%	**16**
Other-Method		0%	1	25%	1	25%		0%	2	50%	1	25%	**4**
Method		0%	7	23%	2	6%		0%	3	10%	20	65%	**31**
Problem		0%	9	90%	1	10%		0%	2	20%	0	0%	**10**
Reg-Problem		0%	1	100%		0%		0%		0%		0%	**1**
Other-Result		0%	10	56%	2	11%	1	6%	6	33%	6	33%	**18**
Result		0%	28	56%	5	10%	1	2%	10	20%	15	30%	**50**
Total	**10**	**3%**	**152**	**53%**	**62**	**21%**	**9**	**3%**	**52**	**18%**	**70**	**24%**	**289**

Table 4: Discourse segment type vs. epistemic cue

Table 4 shows the correlation between segment type and our candidate epistemic evaluation cue type. (The total number of cues can exceed the number of segments (e.g. for Reg-Implications), because multiple cues can occur in a single segment.) We discuss each cue in turn, and then draw conclusions about their usefulness in marking epistemic evaluation/attribution.

- First, there is not a lot of use of modal auxiliary verbs, but there is a correlation between Hypotheses: 8 out of 10 modal auxiliaries occur in a Hypothesis segment, and contrariwise, almost half of the Hypotheses contain a modal auxiliary. So although this category is not very prevalent, it is useful to include it, if only for finding Hypotheses. ***(verwijzen naar eerdere stuk)***
- The majority of cues is formed by the presence of an epistemic verb (of the form 'these results suggest that'), either directly in the discourse segment (column marked "Epistemic Verb") or in a matrix clause which the segment is a subclause to ("Ruled By EV") for a total of 152 + 62 = 214 times in 289 segments (and 14 segments contain both, so in total 200/289 = 70% of segments contain either verb form). It seems that this category is quite wide, and so we will have to review our decision to include all verb types. Specifically, almost all Goals contain an epistemic verb, whereas they do not have an epistemic attribution or evaluation, so obviously, this cue is too broad. It therefore seems useful to review the verbs found for specific epistemic evaluation types, to see whether we can refine this category.

- I did not find many epistemic adverbs and adjectives; - only 9 in the entire corpus: *important* (used 5 times), *presumably, striking, apparently,* and *interestingly*. They occur more often in Implication and Hypothesis segments, but there really is not enough data to say anything sensible about this. In 7 cases, these adverbs and adjectives indicated Focus or Surprise (the two that did not indicate Focus or Surprise were *presumably* and *apparently*, which are strictly epistemic).
- References (both internal ('See figure 2') and external ('except for a single study focused on CCR2 [24].') seem to occur most in inter- and intratextual segments (which is self-evident, since they are marked by a reference), Results segments (as discussed above, these generally refer to figures) and 'Other-' segments – again self-evident, since these are classified as being 'other' on the basis of an external reference. Overall, it is obvious that these need to be included for a study of knowledge attribution, and they will remain.
- 90% of Facts, half of Methods, and 30% of Results does not have an epistemic evaluation marker. This is quite easy to understand: the typical value of Facts and Results is 3, absolute certainty, which is not indicated by evaluation cues: the absence of these cues is precisely what makes us read them as being fully supported by the author. We are therefore not surprised to not find any cues for these segment types.

6.4.3 Correlation between Epistemic Type and Cues

As a check on our model, we investigate the correlation between this set of candidate cues and the epistemic evaluation types defined above. To do so we again annotated Zimmermann (2005). Tables A4 and 5 show the full results and a summary of the correlation between cue type and epistemic evaluation type. Specifically, we see that:

1. Modals code for potentiality. It becomes ever more apparent here that the modals ('might, can, could') code for potentiality; they only indicate clauses of value = 1.
2. Lack of epistemic cues indicates certainty. 47 out of 144 segments with *value = 3* have no epistemic cues and no segments of value < 3 have no cues. This confirms our ideas about lack of epistemic evaluation indicating certainty.
3. The epistemic verb cue is overburdened. Clearly, the most prevalent cue is that of an epistemic verb, either directly within a clause or governing it, in a matrix clause construction. However, to further distinguish between epistemic type (value/source/basis), we need to further differentiate between the verbs classes that we have all denoted epistemic verbs.
4. Adverbs and adjectives usually refer to 'value = 3' segments. There are not a lot of them, but 7 out of 10 of adverbs/adjectives refer to 'certain' segments; in particular, they indicate focus and aim to draw attention to a finding or statement.
5. References mostly occur in 'value = 3' segments. This can be because references usually occur when results are cited (3/D/N) or when reference to a figure is made (3/D/IA).

Value	Data	Unknown	Reasoning	Total
3	Epistemic Verb (63) Ruled by EV (14) References (33) None (23)	Epistemic Verb (15) Ruled by EV (9) Adverbs/Adj (4) References (8) None (22)	Epistemic Verb (3)	Epistemic Verb (81) Ruled by EV (23) Adverbs/Adj (4) Refs (41) None (45)
2	Epistemic Verb (24) Ruled by EV (18)		Epistemic Verb (4) Ruled by EV (3)	Epistemic Verb (28) Ruled by EV (21)
1	Modals (5) Epistemic Verb (5) Ruled by EV (3)		Modals (3) Epistemic Verb (5) Ruled by EV (6)	Modals (9) Epistemic Verb (10) Ruled by EV (9)
0		Epistemic Verb (7)		Epistemic Verb (7)
Total	169	65	24	

Table 5: Summary: Epistemic cue incidence mapped to the Value-Source grid

In summary, we can conclude that our epistemic cues are valuable, and there seem to be enough. Modal auxiliary verbs play a distinct role (indicating potentiality); references and adverbs support statements with a high certainty value.

The last row in Table A4 shows that in 44 cases we have not indicated a specific epistemic modality/attribution value; half of these are unmarked, and in 16 out of 22 cases, an epistemic verb is the marker. It therefore seems that epistemic verbs, as we have currently defined them, are too broadly applicable: they don't always mark a knowledge evaluation or attribution act. Combined with our observation above that the epistemic verb class is 'overburdened', we therefore make a brief excursion exploring these verbs in more detail. In Table A5, we have split up the various epistemic types by verb type, and see that indeed, Research Verbs are used for identifying Results (typical 3/D/IA segments) and Interpretative verbs are used for Implications (2/D/IA). Sensemaking verbs account for 85% (45 out of 53) of epistemic evaluations and knowledge attributions with (value < 3). In summary, for epistemic modality (i.e. a less than certain judgement of a statement) the Sensemaking verb class is most useful; for knowledge attribution, Discourse and Research verbs are mostly used.

The one segment type that remains ambiguous is that of Problems; these are marked by different verb types, not just Sensemaking verbs. In general, as we have found in Chapter [Experiment Chapter], problems, are marked by specific negational forms of adverbs, verb forms, or nouns ('has not been established', 'is unknown', etc.). Therefore, our markers do not adequately cover the 'lack of knowledge' case.

In summary, we conclude that:
- Modal auxiliary verbs usually indicate hypotheses
- Sensemaking verbs are the most useful clues for identifying epistemic evaluations
- For knowledge attribution, the presence of references is critical and Discourse and Research verbs are most used.
- Epistemic adverbs, when they do occur, indicate surprise or focus.
- None of these adequately describe 'lack of knowledge'.
- **'Zero marking'…**

Combining these with the previous two cue types which we have looked at (Verb Form, in Chapter 4, and Verb Class, in Chapter 5) we find that the first three categories are subsets of Verb Form and Verb Class, respectively. The two additional markers that we find are of use are references, for identifying knowledge attribution (a pretty self-evident finding!) and epistemic adverbs, - which mostly indicate surprise and focus.

6.5 Discussion

We have developed a model of knowledge attribution and evaluation and defined a small collection of cues by which various aspects are identified. We describe three aspects of epistemic evaluation and attribution: certainty (how certain is the statement), source of knowledge (what is the statement based on), and attribution (who makes the statement).

In previous chapters, we sketched a model of scientific discourse as consisting of five different realms and axes, which are addressed using verb form and verb class. In chapter 4 (verb tense as a biological mental space indicator), we have identified five mental realms, and two discourse axes, identified with particular verb forms: the conceptual realm, the experimental realm, the argumentational realm, and the axes of discourse and research progression. In chapter 5 (verb classes for biological text), we have seen that these five spaces are generally addressed by different semantic verb classes, for which we provided a small taxonomy. We found that each of the segment types predominantly occurs with specific verb tense and verb classes, and generally codes for relationships either within a realm or a transition between realms (see **Table XX in Chapter X**).

We can now add our findings regarding epistemic evaluations to this model:
- Epistemic evaluation with values of less than complete certainty (i.e. stating lack of knowledge, and hypothetical and dubitative statements) occur mostly in (Other-/Reg-)

Problem, Implication and Hypothesis segments. This means that the Conceptual realm can be subdivided into four subparts (each corresponding to a knowledge Value):
  - Facts – certain, often not marked
  - Implication – probable, often marked by Sensemaking verbs
  - Hypothesis – possible, often marked by Modal Auxiliaries
  - Problems – unknown, sometimes marked by Sensemaking verbs
- Within the Argumentional realm, we can differentiate three cases:
  - If the text connects statements in the Experimental to those in the Conceptual realm (i.e. Reg-Implications and Implications), an epistemic evaluation takes place, where Holder is Author, Source is Data, and the cue is usually an epistemic verb.
  - If the text originates within the Conceptual realm and move into the Experimental realm (instantiated through Goal segments), these moves are not epistemically evaluated.
- Within the Experimental realm, only Results can be said to have a knowledge attribution, generally to data *('see figure 2*' or epistemic verbs *'…clearly shows that…*'). However, if we limit epistemic verbs to the category of Sensemaking verbs described earlier, Results are often unmarked. Methods are usually not epistemically evaluated.
- Along the Discourse progression axis, Intratextual segments are usually marked by a discourse verb (e.g., '*See Figure 3A'*) - which means, again, they are not marked with an sensemaking verb. Their Source is Data, and they are (as a matter of course) attributed to the Author.
- On the axis of Research Progression, indicated by Other- and Intertextual segments, epistemic evaluation mostly takes place using a sensemaking verb ('*It has been reported that'*); its holder is another (named or unnamed) Author, and the Source can be either Reasoning ('*It has been argued that'*), Data ('*DNase I hypersensitivity studies discovered …'*), or unknown.

These results are summarized in Table 6.

Realm	Segment Type	Typical tense	Typical Epistemic Evaluation/Attribution Value/Basis/Source			Typical Epistemic Evaluation/ Attribution Cue	Typical Verb class
Conceptual Realm	Fact	Present	3	0	0	None	Properties/ Relationships
	Implication	Present	2	D	IA	Epist Verb	
	Hypothesis	Present/Modal	1	R/D	IA	Modal, Epist Verb	
	Problem	Present	0	0/D	0	**NEGATION,** Epist Verb	
Experimental Realm	Method	(Passive) Past				None	Procedure
	Result	Past	3	D	IA	None	Observation
Argumentational Realm	Reg-Implication	Present	2	D	IA	Epist Verb	Sensemaking
	Reg-Hypothesis	Present	1	R/D	IA	Epist Verb	
	Reg-Problem	Present	0	0	IA	Epist Verb	
	Goal	To-infinitive				None	Investigations
Discourse Progression	Intratextual	Present	3	D	A	Reference	Discourse
Research Progression	Other-Segments	Present perfect	1/2/3	0	N	Epist Verb, Reference	Sensemaking/ Discourse
	Intertextual	Present perfect	3	0	N	Epist Verb, Reference	

Table 6: Summary of attributes of realms and Discourse Segment Types

So how does this help us achieve the goal we set out with: to understand how *"a statement becomes transformed into a fact"*? For a graphical depiction of this process, we look at how Value and Source are attributed in the course of scientific argumentation.
To begin with,

1. Facts and

2. Problems are stated - Rumsfeld's[1] Known Knowns, and 'Known Unknowns' – neither of which the author is implicitly or explicitly attributing to himself, or evaluating.
3. To introduce the experiment – and the author's role in knowledge creation - the author can posit a Hypothesis, and
4. proceeds to 'dive' into the experimental space, where a series of moves occur to describe the experiment, generally in the order Goal>Method>Result>
5. Implication.

After several iterations, the Implications are compared with (Other)-Results, Implications and Facts, where the goal is to motivate the existence of the Implication in the realm of Facts, based on the Results. In summary, the author starts by describing the world in general, then moves to ideas, results, and conclusion that he or she is attributable for, and concludes by suggesting the Implications deserve a place in the space of Facts. In other words: the author starts in the lower right-hand corner of Table 7 and tries to enter the upper-left hand corner - using author generated data and appropriate epistemic markers, the author's statement makes a polite knock on the door of the hall of Facts.

Value/Source	**0**	**N**	**IA**	**A**
3	Fact (#1)	Other-Fact (#1)	Result (#4)	
2			Implication (#5)	
1				Hypothesis (#3)
0	Problem (#2)	Other-Problem (#2)		

Table 7: Value/Source plot of subsequent moves in Fact creation; order of moves is in brackets

In the next chapter, we will see some examples of this process and study how such tentative statements are allowed to enter that hallowed place, by a series of successive citations.

6.6 Possible Implementation.

A straightforward conclusion of our work is that the incidence of epistemic evaluation in biological text, **the majority of cases is instantiated by these regulatory segments with a sensemaking verb.** These regulatory segments are very well-structured, and since they are so pivotal to evaluative construction bear closer scrutiny. Looking at the 42 regulatory segments in Zimmermann, we see they are (generally sentence-initial) simple clauses that adhere to the following word order, where {} indicates nonmandatory elements:

> {adverb} {determiner/pronoun} {adjective} noun phrase {modal} {adverb/adjective} verb {preposition, 'to'}

For Zimmermann, the parts of speech in the 42 regulatory segments have the following values (Table 8):

Adverb/ Connective	Deter-miner/ Pronoun	Adjective	**Noun phrase**	Modal	Adjective	**Verb**	Prepo-sition/to
thus, therefore, together, recently, in summary	*it, this, these, we/our*	*previous, future, better*	***data, report, study*; method or reference**	form of *'to be', will, remain*	*often, recently, generally*	***show, obtain, consider, view, reveal, suggest, hypothesize, indicate, believe***	*that, to*

Table 8: Values of Parts-of-Speech for Regulatory segment for Zimmermann (2005)

[1] http://en.wikipedia.org/wiki/There_are_known_knowns

As a simple application of this work, we suggest implementing the above structure and investigating the incidence of constructions such as these in scientific text, and investigate a quantitative correlation to epistemic evaluation.

6.7 References

[1] Burns, G.A.P.C., Feng, D. and Hovy, E.H. (2007). Intelligent Approaches to Mining the Primary Research Literature: Techniques, Systems, and Examples, Comp Intelligence In Biomedicine, 2007.

[2] Crompton, P. (1997) Hedging in Academic Writing: Some Theoretical Problems, Eng Spec Purposes, Vol. 16, No. 4, pp. 271-287,1997.

[3] de Haan, F. (1999), Evidentiality and Epistemic Modality: Setting Boundaries. Southwest Journal of Linguistics 18.83-101.

[4] Depraetere, Ilse and Reed, Susan (2006). Mood and Modality in English, The Handbook of English Linguistics, Edited by Bas Aarts, April McMahon, Blackwell Publishing Ltd, 2006.

[5] de Waard, A., Pander Maat, H. (2009).Categorizing Epistemic Segment Types in Biology Research Articles. Workshop on Linguistic and Psycholinguistic Approaches to Text Structuring (LPTS 2009), September 21-23, 2009.

[6] Foley, William and Robert Van Valin, 1984. Functional syntax and universal grammar. Cambridge: Cambridge University Press.

[7] Hovy, E.H. (2011). Private correspondence.

[8] Hyland, K. (1995). The Author in the Text: Hedging Scientific Writing, Hong Kong Papers In Linguistics And Language Teaching 18 (1995).

[9] Hyland, K. (2005). Stance and engagement: a model of interaction in academic discourse. Discourse Studies, Vol 7(2): 173–192.

[10] Kilicoglu H., Bergler S. (2008). Recognizing speculative language in biomedical research articles: a linguistically motivated perspective. BMC Bioinformatics. 2008 Nov 19;9 Suppl 11:S10.

[11] Kim, S-M. Hovy, E.H.(2004). Determining the Sentiment of Opinions. Proceedings of the COLING conference, Geneva, 2004.

[12] Lakoff G. (1972). Hedges: a study in meaning criteria and the logic of fuzzy concepts. Chicago Linguistics Society Papers 1972, 8:183-228.

[13] Latour, B., Woolgar, S. (1979). Laboratory Life: The Social Construction of Scientific Facts. Beverly Hills: Sage Publications. ISBN 0-80-390993-4.

[14] Light M, Qiu XY, Srinivasan P. (2004). The language of bioscience: facts, speculations, and statements in between. BioLINK 2004: Linking Biological Literature, Ontologies and Databases 2004:17-24.

[15] Lyons, John, 1977. Semantics. Volume 2. Cambridge: Cambridge University Press.

[16] Hengeveld, Kees, 1987. Clause structure and modality in Functional Grammar. In: Johan Van der Auwem and Louis Goossens, eds., Ins and outs of the predication, 53-66. Dordrecht: Foris.

[17] Hengeveld, Kees, 1988. Illocution, mood and modality in a functional grammar of Spanish. Journal of Semantics 6: 227-269.

[18] Hengeveld, Kees, 1989. Layers and operators in Functional Grammar. Journal of Linguistics 25: 127-157.

[19] Hoye, Leo, 1997. AdverbsMartín-Martín, P. (2008). The Mitigation Of Scientific Claims In Research Papers: A Comparative Study. Int Jnl of English V 8/ 2 (2008): 133-152.

[20] Medlock B, Briscoe T. (2007). Weakly supervised learning for hedge classification in scientific literature. Proceedings of 45th Meeting of the Association for Computational Linguistics 2007:992-999.

[21] Myers, G. (1992). 'In this paper we report': Speech acts scientific facts, J Pragmatlcs 17 (1992) 295-313

[22] Salager-Meyer, F. (1994), Hedges and Textual Communicative Function in Medical English Written Discourse, English for Specific Purposes, Vol. 13, No. 2, PP. 149-170, 1994

[23] Shanahan, J. G. Y. Qu, and J. Wiebe (2006). Computing Attitude and Affect in Text: Theory and Applications. Springer, 2006.

[24] Swales, J. (1990). Genre Analysis, English in Academic and Research Settings, Cambridge University Press, 1990.
[25] Tang, Huifeng, Songbo Tan, Xueqi Cheng (2009), A survey on sentiment detection of reviews, Expert Systems with Applications 36 (2009) 10760–10773
[26] Thompson P., Venturi G., McNaught J, Montemagni S, Ananiadou S. (2008). Categorising modality in biomedical texts. Proc. LREC 2008 Wkshp Building and Evaluating Resources for Biomedical Text Mining 2008.
[27] Verstraete, J.-C. (2001). Journal of Pragmatics 33 (2001) 15054528
[28] Vincze, V., Szarvas, Farkas, Móra and Csirik,(2008). The BioScope corpus: biomedical texts annotated for uncertainty, negation and their scopes, BMC Bioinformatics 2008, 9 (Suppl 11):S9.
[29] Wilson, T. and Wiebe, J., (2003), Annotating Opinions in the World Press, 2003, SigDAIL
[30] Wilbur WJ, Rzhetsky A, Shatkay H (2006). New directions in biomedical text annotations: definitions, guidelines and corpus construction. BMC Bioinformatics 2006, 7:356.
[31] Zimmermann, N., Jessica L Colyer, Laura E Koch and Marc E Rothenberg, (2005). Analysis of the CCR3 promoter reveals a regulatory region in exon 1 that binds GATA-1, BMC Immunology 2005, 6:7 doi:10.1186/1471-2172-6-7.

6.8 Appendix

6.8.1 Table A1: Overview of epistemic evaluation and cues from examined literature.

Paper:	Epistemic evaluation types:	Epistemic evaluation cues:
Myers (1989):		Hedging can be done with a modal verb making a conditional statement *(would* or *could)* or with a modifier *(probably)* or with any device suggesting alternatives — anything but a statement with a form of *to be* that such and such is the case. Hedge cues include: – The first person plural pronoun – The present tense – The verb 'report' – Complements – Deictic expressions
Salager-Meyer, F. (1994);	1. Shields:	– all modal verbs expressing possibility – semi-auxiliaries like *'to appear, ' 'to seem';* probability adverbs like 'probably,' *'likely'* and their derivative adjectives – epistemic verbs (that is, verbs which relate to the probability of a proposition or a hypothesis being true) such as *'to suggest,' 'to speculate'.*
	2. Approximators: stereotyped 'adaptors' as well as 'rounders' of quantity, degree, frequency and time which express heed and coyness.	– e.g., *'approximately,' 'roughly,' 'somewhat,' 'quite,' 'often,' 'occasionally')*
	3. Expressions which express the authors' personal doubt and direct involvement.	– *'I believe, ' 'to our knowledge,' 'it is our view that* . . .'
	4. Emotionally-charged intensifiers (comment words used to project the authors' reactions)	– *'extremely difficult/interesting,' 'dishearteningly weak,' 'of particular importance,' ''particularly encouraging,' 'unexpectedly,' 'surprisingly.'*
	5. Compound hedges, ' strings of hedges' (i.e., the juxtaposition of several hedges).	– Such compound hedges can be double hedges 'It may suggest that . . . ;' 'it could *be suggested* that . . . '), treble hedges (It *would seem likely* that . . . , it seems *reasonable* to assume), quadruple hedges (It *would seem somewhat unlikely* that) and so on.
Hyland (1996)	1. Content-oriented: a. Writer-oriented: Hedges writer commitment	– Epistemic lexical verbs: judgmental, evidential – Impersonal expressions: passive voice, abstract rhetors, empty subjects – Thematic epistemic device – Attribution to literature – Impersonal reference to method, model, experimental conditions
	b. Accuracy-oriented: Hedges propositional content	– Attribute type: – Precision adverbs: content disjuncts, style disjuncts, downtoners – Reliability type: – Epistemic lexical verbs – Epistemic modal adjectives – Epistemic modal nouns – Content disjunct adverbs – Limited knowledge
	2. Reader-oriented: Hedges assertiveness	– Epistemic lexical verbs: judgmental, deductive – Personal attribution: Personal reference to

		methods, model – Offer alternatives: conditionals, indefinite articles – Involve reader: direct questions, reference to testability – Assumption of shared goals – Hypothetical e.g. *would*
Crompton (1997):		1. Sentences with copulas other than *be*. 2. Sentences with modals used epistemically. 3. Sentences with clauses relating to the probability of the subsequent proposition being true. 4. Sentences containing sentence adverbials which relate to the probability of the proposition being true. 5. Sentences containing reported propositions where the author(s) can be taken to be responsible for any tentativeness in the verbal group, or non-use of factive reporting verbs such as 'show', 'demonstrate', 'prove'. These fall into two sub-types: a. where authors explicitly designate themselves as responsible for the proposition being reported; b. where authors use an impersonal subject but the agent is intended to be understood as themselves. 6. Sentences containing a reported proposition that a hypothesized entity X exists and the author(s) can be taken to be responsible for making the hypothesis.
Martín-Martín (2008)	Strategy of indetermination	Epistemic modality markers: – Modal auxiliaries – Semi-auxiliaries – Epistemic verbs – Verbs of cognition – Modal adverbs – Modal nouns – Modal Adjectives Approximators of: – Quantity – Degree – Time – Frequency
	Strategy of subjectivization	– First-person pronouns + verbs of cognition; author's marks of doubt/certainty ('to our knowledge', etc). Quality-emphasising adjectives/adverbials
	Strategy of depersonalization	– Agentless passives ('it seems that'...) – Impersonal actives ('these data suggest'...)
Light et at (2004)		The following 14 strings were identified by Light while annotating the gene regulation abstracts: *suggest, potential, likely, may, at least, in part, possible, potential, further investigation, unlikely, putative, insights, point toward, promise, propose*
Wibur, Rhetsky, Shatkay (2006):	**Certainty:** Each fragment conveys a degree of certainty about the validity of the assertion it makes. The lowest degree (0) represents complete uncertainty, that is, the fragment explicitly states that there is an uncertainty or lack of knowledge about a particular phenomenon ('it is unknown...' or 'it is unclear whether...' etc.). The intermediate degree (1) represents a low certainty, while (2) is assigned to high-likelihood expressions that are still short of complete	**Evidence:** • E0: No indication of evidence in the fragment whatsoever, or an explicit statement in the text indicates lack of evidence. • E1: A claim of evidence, but no verifying information is explicitly given. • E2: Evidence is not given within the sentence/fragment, but explicit reference is made to other papers (citations) to support the assertion. • E3: Evidence is provided, within the fragment, in one of the following forms: – A reference to experiments previously reported (e.g. 'data indicates...', '...our results show'...) – A verb (typically in the past-tense) within the statement indicates an observation or an

	certainty. The highest degree, (3), represents complete certainty, reflecting an accepted, known and/or proven fact.	experimental finding (e.g. 'We found that...', 'We see that...'). – A reference to an experimental figure or a table of data.
Kilicoglu and Bergler (2008)		Syntactic hedge cues: <EPISTEMIC VERB> *to*(*inf*) VB <EPISTEMIC VERB> *that*(*comp*) VB Otherwise <EPISTEMIC NOUN> followed by *that*(*comp*) Otherwise *not* <UNHEDGING VERB> *no*|*not* <UNHEDGING NOUN> *no*|*not* immediately followed by <UNHEDGING ADVERB> *no*|*not* immediately followed by <UNHEDGING ADJECTIVE> *whether*|*if* in a clausal complement context
Medlock and Briscoe (2007)	The following are considered hedge instances: 1. An assertion relating to a result that does not necessarily follow from work presented, but could be extrapolated from it 2. Relay of hedge in previous work. 3. Statement of knowledge paucity. 4. Speculative question. 5. Statement of speculative hypothesis. 6. Anaphoric hedge reference.	Hedge cues include: *suggest*, *likely*, *may*, *might*, *seems*, *Taken*, *suggests*, *probably*, *Together*, *suggesting*, *possibly*, *suggested*, *findings*, *observations*, *Given*.
Thompson et al (2008)	Knowledge Type, encoding the type of 'knowledge' that underlies a statement, encapsulating both whether the statement is a speculation or based on evidence and how the evidence is to be interpreted.	– Speculative: *assume, assumption, belief, believe, claim, conceivable, estimate, expect, expectation, hypothesise, hypothesis, hypothetical, in principle, in theory, judge, model, notion, predict, prediction, proposal, propose, speculate, suggest, suggestion, suppose, suspect, theory, think, to our knowledge, view*. – Deductive: *argue, argument, deduce, imply, indicate, indication, infer, interpret, interpretation, suggest* – Sensory: *apparent, apparently, appear, observation, observe, evidence, evident, seem, see.* – Demonstrative: *conclude, conclusion, confirm, confirmation, demonstrate, find, finding, proof, prove, report, reveal, show.*
	Level of certainty, indicating how certain the author (or cited author) is about the statement:	Level of certainty, indicating how certain the author (or cited author) is about the statement: – Absolute: *certainly, known* – High: *consistent with, clear, clearly, generally, in agreement with, likelihood, likely, normally, obviously, probability, probable, probably, strongly, support, would.* – Moderate: *can, could, feasible, may, might, perhaps, possibility, possible, potential, potentially*. – Low: *unlikely, unknown*
Vincze et al (2008).		Hedge cues in Bioscope: *apparent, apparently, appear, assume, can, consider, consistent with, could, either, indicate, likely, may, no evidence, not, or, perhaps, possible, possibly, presumably, probable, probably, should, suggestion, support, think, unclear, whether, would*.

6.8.2 Table A2: Summary of epistemic modality clues from literature

Reference:	Modal Auxiliary	Epistemic Verb	Quantifying Adverbials, Adjectives	References	Other cues discussed
Myers (1989)	x		x		
Salager-Meyer (1994)	x	x	x		The present tense Complements Deictic expressions
Hyland (1996)		x	x	x	Impersonal expressions: passive voice, abstract rhetors, empty subjects Thematic epistemic device Impersonal reference to method, model, experimental conditions Offer alternatives: conditionals, indefinite articles
Crompton (1997)	x	x	x	x	
Martín-Martín (2008)	x	x	x	x	Agentless passives (‘it seems that’...) Impersonal actives (‘these data suggest’...)
Light et at (2004)	x	x	x		
Kilicoglu and Bergler (2008)		x	x		
Wilbur at al (2006)		x		x	
Medlock and Briscoe (2007)	x	x	x		
Thompson et al (2008)	x	x	x		