

Must Children be Vaccinated or not? Annotating Modal Verbs in the Vaccination Debate

Liza King and Roser Morante

CLTL Lab, Vrije Universiteit Amsterdam

De Boelelaan 1105, 1081 HV Amsterdam, The Netherlands

e.a.king@student@vu.nl, r.morantevallejo@vu.nl

Abstract

The study of modal verbs in the growing vaccination debate reveals important insights into perspectives on vaccination: must children be vaccinated or are parents allowed not to vaccinate? How strong are the recommendations by pro- and anti-vaccination supporters? We present experimental work on annotation of modal verbs and their senses in texts related to the vaccination debate, as well as the resulting corpus. The results from our pilot study suggest that the most frequent type of modality was epistemic – indicating that participants in the debate appear to be more concerned with the safety and efficacy of vaccines than with moral arguments. Those against vaccination appear to be more committed or convinced of their views than those in favor, as evidenced by the use of the modal *must*.

Keywords: modality, annotation, vaccination debate

1. Introduction

In this paper we analyze the use of modal verbs in a corpus of texts related to the vaccination debate. Broadly speaking, the vaccination debate centers around whether vaccines are safe, and whether it is morally acceptable to enforce mandatory vaccination (Wolfe and Sharp, 2002; Mollema et al., 2015). In order to successfully intervene and curb the spread of preventable diseases due to low vaccination rates, health practitioners need to be adequately informed on public perception of the safety and necessity of vaccines. Public perception can relate to the strength of conviction that an individual may have towards a proposition (e.g. ‘one **must**¹ vaccinate’ versus ‘one **should** vaccinate’), as well as qualify the type of proposition, be it related to morality (‘government **should** not interfere in my personal choice’) or related to possibility (‘too many vaccines at once **could** hurt my child’). Text mining and analysis of modal auxiliaries are economically viable means of gaining insights into these perspectives, particularly on a large scale due to the widespread use of social media and blogs as vehicles of communication.

The two central arguments of the vaccination debate relate to epistemic and dynamic modality (the safety of vaccines), as well as deontic modality (relating to permission and obligation to vaccinate), as exemplified in the following excerpt:

1. “This **cannot** just be a debate about health statistics. It’s really a debate about who takes care of our children. It’s become naïve and passé to believe it **should** be the parents’ responsibility! Yet the parents **have to** live with the mess forever afterwards, if a vaccination goes wrong and produces serious damage to the child. And when I talk about mess, I’m talking incapacitating neurological damage by vaccines, which **can** be severe and permanent.” (Scott-Mumby, 2015)

Modality can be defined as “a category of linguistic meaning having to do with the expression of possibility and necessity [where] a modalized sentence locates an underlying

ing or pre-jacent proposition in the space of possibilities” (Von Stechow, 2006). In describing the work of Kratzer (1991), Von Stechow (2006) explains that one way of conceiving of ‘the space of possibilities’ is to think of modal constructions expressing ‘quantification over possible worlds [and that] different kinds of modal meaning correspond to different choices of sets of possible worlds as the domain of quantification’ von2006modality.

The meaning of modals has been broadly studied from a theoretical perspective. Palmer (1986) classifies modal meaning as being propositional or relating to an event. Propositional modality is ‘concerned with the speaker’s attitude to the truth-value or factual status of the proposition’ whereas event modality ‘refers to events that are not actualised, events that have not taken place but are merely potential’ (Palmer, 1986). Palmer further distinguishes between two types of propositional modality: epistemic (Example 2), which is used to ‘express [...] judgement about the factual status of the proposition’ and evidential (Example 3), which is used to ‘to indicate the evidence that [speakers] have for its factual status’ (Palmer, 1986). Event modality is further distinguished between deontic (Example 4) and dynamic (Example 5) modality. Deontic modality relates to permission and obligation, as well as conditions ‘that are external to the relevant individual’, whereas dynamic modality relates to internal conditions or ability (Palmer, 1986).

2. Someone **might** be home because the lights are on.
3. He **must** be home now because he just phoned me from the land line.
4. You **should** visit your grandmother more often.
5. Tim **can** play the piano really well.

Analysing how modals are used can reveal important insights into language users’ perspectives on what is being communicated, and are therefore integral to investigations of understanding why individuals are opposed (or not) to vaccinating children. While modality has been studied by

¹Modals are marked in bold in all examples.

linguists and philosophers alike, there still not many corpora where modality cues and their senses are annotated. Previous research has investigated how language use differs according to vaccination stance (Mollema et al., 2015), but these efforts have thus far neglected to address the phenomenon of modality.

One of the linguistic resources used to express modality in English are modal verbs. In a survey of the British National Corpus (BNC), (Kennedy, 2002) reports that 1.45% of all tokens in the BNC are marked as modals, the most common of which are *will*, *would*, *can* and *could* (together, accounting for 72.7% of all modal tokens). In this survey, (Kennedy, 2002) considers ‘modals’ to be the auxiliaries *will*, *would*, *can*, *could*, *may*, *might*, *shall*, *should*, *must*, and the semimodal verbs *ought to*, *need to*, *dare* and *used to*. When annotating auxiliary modals, (Sauri, 2008) found that the vast majority of instances of *will* and *would* do not communicate modality.

To facilitate investigations into modal use in texts surrounding the vaccination debate we annotated 50 documents with modals and their senses. The texts have been selected from the Vaccination Corpus (Morante et al., 2020), which contains scientific articles, blog posts, government publications and editorials, from a pro- and anti-vaccination stance in relation to the Disneyland Measles outbreak of 2015 (McCarthy, 2015) that occurred in the United States. The annotations are publicly available from <https://github.com/cltl/VaccinationCorpus>. We will refer to the the subcorpus annotated with modals as Vaccination Corpus Modals (VCM).

Our investigation aims to answer the following research questions: can existing modal annotation schemes devised for news texts be applied to the domain of the vaccination debate? Are cases of annotator disagreements dependent on the characteristics of the vaccination debate?

In Section 2. we present related work. Section 3. describes the annotation task with pair-wise inter-annotator agreement and specific cases of disagreement. Section 4. provides an error analysis of disagreement followed by the description of the adjudicated corpus in Section 5. We discuss our findings in Section 6. Finally, in Section 7. we put forward some conclusions and future work.

2. Related Work

Ruppenhofer and Rehbein (2012) research modality in the English news domain. They annotated the modal auxiliaries *can*, *could*, *may*, *might*, *must*, *shall*, *should*, and the semimodal verb *ought to* with six modal senses, as informed by previous research conducted by Kratzer (1991). The first three senses of Table 1 are equivalent to the epistemic, deontic and dynamic senses presented by (Palmer, 1986).

The classification scheme used by Ruppenhofer and Rehbein (2012) largely overlaps with other modal sense taxonomies:

- *Epistemic*: given the state of knowledge, the speaker is compelled to come to a particular conclusion.
- *Deontic*: this sense relates to what the world should be like, according to a source. It can extend to permission being

granted, or an obligation being imposed by a source on an agent. Neither the source nor the agent need to be explicit.

- *Dynamic*: this sense concerns the ability or potential for involvement in events or behaviour.
- *Optative*: this special sense of ‘may’ is used when the speaker is communicating a wish, rather than speculating on a state of affairs (epistemic) or granting permission (deontic) (*Long may she live*).
- *Concessive*: this sense is related to the epistemic sense, but rather than being speculative, the speaker considers the state of affairs to be true (*But, fool though he may be, he is powerful*).
- *Conditional*: commonly occurring in if-clauses, this special sense of ‘should’ is used in cases expressing a condition (*Should you see him, please tell him to call me*).

The modals and their permitted senses (epistemic, deontic, dynamic, optative, concessive, conditional) are summarized in Table 1.

	can/ could	may/ might	must	ought	shall/ should
epistemic	+	+	+	+	+
deontic	+	+	+	+	+
dynamic	+	-	-	-	-
optative	-	+	-	-	-
concessive	-	+	-	-	-
conditional	-	-	-	-	+

Table 1: Modal sense classification scheme used by Ruppenhofer and Rehbein (2012).

Ruppenhofer and Rehbein (2012) annotate a corpus to investigate where annotators disagree on senses and consequently resolve possible ambiguity. They report that the most difficult senses to agree on were those associated with *can*, and that the two main cases of confusion were differentiating between dynamic and epistemic senses, and dynamic and deontic senses.

In the second part of their research, Ruppenhofer and Rehbein (2012) use the annotated corpus as training data for a maximum entropy classifier. For all modals, apart from *must*, their system outperformed the baseline (using the most frequent sense of the relevant modal as default). While our goal is not to train a classifier, the results from Ruppenhofer and Rehbein (2012) are a good indication that their modal auxiliary classification scheme is meaningful and useful for future computational linguistic tasks.

Building upon insights from Ruppenhofer and Rehbein (2012) and Römer (2004), Moon et al. (2016) conduct a similar modal annotation task, testing two hypotheses: (i) “uses of *can*, *could* and *would* are more difficult to classify than other modal auxiliaries, predicting lower IAA” (Moon et al., 2016). (ii) “Results would be comparable to those of previous studies when *can* and *could* are classified according to traditional taxonomic labels”. In their annotation scheme, the three difficult modal auxiliaries can have three senses, based on the most common readings as reported by (Römer, 2004). The other modals (*should*, *ought to*, *may*, *might*, *must*, *have to* and *will*) were allocated two senses

each: the most dominant one reported by Römer (2004) and the second most significant sense. Figure 1 presents distributional data from Römer (2004), showing the percentages of the most frequent senses for each modal, as well as cases where the modal sense was unclear.

	ability	possibility	permission	hypothet. meaning	prediction	volition	obligation/ advice	inference/ deduction	unclear
<i>can</i>	36%	31.5%	23.5%						9%
<i>could</i>	34%	41.5%	3.5%	14.5%					6.5%
<i>may</i>		83%	13%						4%
<i>might</i>		95%	3.5%						1.5%
<i>will</i>					87.5%	7.75%			4.75%
<i>would</i>				28.5%	50.5%	15.5%			5.5%
<i>shall</i>					31%	65%			4%
<i>should</i>				30%			62.5%		7.5%
<i>ought to</i>				16%			79%		5%
<i>must</i>							52%	39%	9%

Figure 1: Distribution of modal senses in BNC spoken corpus (Römer, 2004).

The first three senses of Figure 1 are analogous to those used by Ruppenhofer and Rehbein (2012), where ‘ability’ relates to dynamic modality, ‘possibility’ to epistemic modality, and ‘permission’ to deontic modality. The categories of ‘obligation/advice’ and ‘inference/deduction’ can arguably be likened to deontic and epistemic modality, respectively. The remaining three modal senses presented by Römer (2004) – hypothetical meaning, prediction and volition – are not addressed by Ruppenhofer and Rehbein (2012), likely because *will* and *would* are not included in their annotation task and that *shall* was treated the same as *should*.

Based on the work by Ruppenhofer and Rehbein (2012), Zhou et al. (2015) conducted further research with two main aims: (i) overcoming unequal modal sense distribution through the creation of an additional, balanced corpus, and (ii) to train the same maximum entropy classifier as used in Ruppenhofer and Rehbein (2012), but with richer features. Zhou et al. (2015) extended the MPQA corpus annotated by Ruppenhofer and Rehbein (2012) with sentences from MASC (and other resources)² in order to balance the unequal distribution of modal senses. MASC³ is a sub-corpus of the Open American National Corpus (OANC) and contains multiple genres of American English written text and transcriptions of spoken language. The same annotation scheme was used, but the concessive and conditional senses were subsumed into the epistemic sense, and the optative sense was subsumed into the deontic sense (Zhou et al., 2015). Zhou et al. (2015) omit the modal *might* from this corpus as the most frequent sense baseline was 100%. The features that Zhou et al. (2015) use are significantly more complex, and include features ‘that relate to lexical, proposition-level, and discourse-level semantic factors’ (Zhou et al., 2015). Zhou et al. (2015) report improved performance, particularly for the more difficult senses, but found that when training the classifier on balanced data, ac-

²Available for download here: <http://projects.cl.uni-heidelberg.de/modals/>

³<http://www.anc.org/data/masc/>

curacy scores were lower.

3. Annotation task

For the modal sense annotation task we selected 50 documents from the Vaccination Corpus (Morante et al., 2020). All articles selected for the corpus adhere to the following criteria: (i) the publication date of all articles is during or just after the Disneyland measles outbreak of 2015 (McCarthy, 2015); (ii) all articles are written with a recognizable pro- or anti-vaccination stance; (iii) all articles contain at least one mention each of the terms ‘vaccination’ and ‘measles’ and contain at least one modal auxiliary, not including *will* or *would*; (iv) all articles are able to stand alone as a coherent piece of work.

The publication period criterion (i) was implemented as a temporal control. Some modal senses (e.g. epistemic) are more influenced by the temporal relation or distance of the author to the event or proposition that is being written about than others (e.g. deontic). Keeping the publication time period as short as possible, and uniform across all articles in the corpus, should help ensure that the senses annotated across the corpus are appropriately comparable. One of the reasons to conduct this annotation task is exploring whether it is possible to establish why people choose to vaccinate or not, through studying modal use. This is why we decided to include documents with a clear stance. Criterion (iii) aims at controlling that all texts are about the same topic and use modals. The final criterion of selecting only full articles (vi) was chosen to exclude comment chains. The reasoning for excluding comments is that there is likely to be more context present in a longer, self-standing article, which is important for selecting the correct modal sense. Furthermore, in comment chains there are likely to be multiple stances (for or against vaccination), which would conflict with criterion (ii).

The focus of the annotation task is to annotate the eight modal auxiliaries and their senses defined by Ruppenhofer and Rehbein (2012), which were presented in Table 1. The semimodal verbs *need to*, *dare* and *used to* were a significantly rare occurrence in the BNC (Kennedy, 2002), and are therefore also omitted from our research. We adopted the annotation scheme by Ruppenhofer and Rehbein (2012) because (i) previous work indicates that the sense classification is meaningful and able to be learned by a classifier; (ii) the scheme has wide coverage without being too fine grained (as the granularity can affect the agreement between annotators); and (iii) because the scheme has solid theoretical foundations in semantics, based on the seminal work by Kratzer (1991). Unlike the scheme used by Ruppenhofer and Rehbein (2012), annotators for the present task were not asked to mark the proposition that is being modalized. Furthermore, an additional ‘ambiguous’ attribute was permitted for cases where the annotators were unsure of the correct sense.

The annotation guidelines can be found in the GitHub repository of the corpus. Examples 6 - 11 were provided to aid the annotators’ understanding of the modal senses being annotated.

6. He got autism straight after he was vaccinated. It **must** be the vaccine.

Epistemic: considering the evidence (correlation of onset of autism and vaccination), we can infer that vaccination caused his autism.

7. Infants **must** receive the MMR vaccine between 8-12 months.

Deontic: implicit agents have the obligation to vaccinate their children between 8-12 months of age.

8. Not all people **can** get vaccinated.

Dynamic: some people are not able to get vaccinated. In this case it is due to compromised immune systems or some other physical attribute – not because of permission (that would be deontic).

9. Long **may** she live.

Optative: the author expresses a wish that she lives a long life.

10. Harmful as they **may** be, it is still better to vaccinate than not.

Concessive: similar to epistemic modals, but here the author considers vaccination to be better than the alternative, and that it is a given rather than a possibility.

11. **Should** you refuse to vaccinate your child, they will not be permitted to enter public school.

Conditional: the penalty of refusing to vaccinate your child is that they are refused entry to public school.

Two annotators performed the task (A1 and A2), both graduate students in computational linguistics. Annotators went through a brief training process, where both annotated two documents of the corpus according to the scheme presented above. They were encouraged to give feedback on the guidelines and to discuss cases where instructions were unclear. Annotators were instructed to not annotate (sub)headings as these are frequently incomplete sentences and tend to lack necessary context for selecting the correct modal sense. They were also asked to not use the ‘ambiguous’ attribute too liberally – only for cases where they were ambivalent about the correct sense. A1 was the lead annotator and had prior annotation experience relating to modal auxiliaries, whereas A2 did not.

We used the open source annotation tool eHOST⁴ because it is very flexible to define linguistic annotation tasks. The input for the tool are raw text files and the output are xml files. The inter-annotator agreement (IAA) scores presented below has been calculated with the options provided by the tool.

3.1. Inter-Annotator Agreement

The initial pair-wise agreement results are presented in Table 2, where ‘agreement’ indicates that annotators selected the same sense for a given modal auxiliary. The agreement reaches F-score 61.3%.

A contribution to annotator disagreement was the combination of missed modals (no annotation or attribute given) and A2 marking some modals that occurred in (sub)headings. The latter is likely due to the lack of formatting in the documents as the annotation tool requires raw text files as input. Table 3 shows the instances of disagreement between the

Gold	Comp.	True pos.	False pos.	False neg.	Prec.	Rec.	F
A1	A2	276	133	215	56.2%	67.5%	61.3%
A2	A1	276	215	133	67.5%	56.2%	61.3%

Table 2: Pair-wise agreement.

two annotators per modal, when both annotators marked the senses (i.e. not including cases where A2 marked modals in (sub)headings or where either annotator missed a modal entirely). The modal *can* was associated with the highest disagreement between senses and every instance thereof entailed disagreement between the senses epistemic and dynamic, or the ‘ambiguous’ attribute. *Can* and *could* were also the only modals that were given the ‘ambiguous’ attribute, which is further evidence that these are the most difficult to annotate, and corroborates the findings of Ruppenhofer and Rehbein (2012) and Moon et al. (2016). No instances of *ought to* were marked in the corpus, and there is therefore no agreement or disagreement to report.

Modal	#	Senses
Can	83	Epist., dyn., ambiguous
Could	12	Dyn., epist., ambiguous
May	12	Conc., epist., deon.
Might	3	Epist., dyn., conc.
Shall	1	Epist., deon.
Should	9	Cond., deon., epist.

Table 3: Instances of disagreement with the respective senses responsible for the disagreement.

Both annotators adhered to the instruction that the ‘ambiguous’ attribute should not be used liberally (i.e. frequently and without restraint). The only case in which both annotators used the attribute is shown in Example 12.

12. If other people breathe the contaminated air or touch the infected surface, then touch their eyes, noses, or mouths, they **can** become infected.

Because there was only one case of ‘false agreement’ (in that they agreed that a case was ambiguous and not an actual modal sense), the IAA can be seen as representative of the difficulty of the task of annotating modal senses in the current corpus.

The concessive and conditional senses did not occur frequently in the corpus, in relation to the other senses. A1 annotated them at a greater rate than A2, and of the two instances that A2 did annotate a modal as having a concessive sense, both were incorrect (according to the classification scheme presented above).

4. Disagreement Analysis

In order to gain insight into the complexity of the task we analyze cases of disagreement between the two annotators. We have grouped the disagreements in three categories: subjectivity of modal scope, overlap of the boundaries between epistemic and dynamic senses, and metaphorical extension of verb senses.

⁴<http://ehostdoc.com>

4.1. Subjectivity of modal scope

This category refers to the subjective interpretation by annotators (and by extension, language users in general) of the scope of influence of a modal. If one annotator perceives the scope of a modal's influence to be larger than what the other annotator does, different readings of the modal are likely to occur, resulting in disagreement.

Recall that A1 was the lead annotator and had prior annotation experience relating to modal auxiliaries, whereas A2 did not. The prior experience of A1 could be responsible for the difference in instances of annotating the concessive and conditional senses. Both of these senses are present in main clause-relative clause (or vice versa) constructions, according to the scheme presented by Ruppenhofer and Rehbein (2012), and therefore operate over a larger scope than the other modal auxiliaries (Example 13). Furthermore, as noted by Ruppenhofer and Rehbein (2012), "the concessive use is in principle also compatible with the epistemic one. We use it in those cases where it is clear from the context that the speaker actually thinks the proposition holds rather than it merely possibly holding". Sentence 13 is an example where both of these principles are present: when limiting the scope of the modal *may* to the first clause, it has an epistemic reading; when considering both the main clause and relative clause in selecting the modal sense, the reading would be concessive, which is consistent with what Ruppenhofer and Rehbein (2012) report.

13. While some parents **may** have concerns about the MMR vaccine, there is no evidence that this vaccine causes autism or other chronic adverse conditions.

A1 marked *may* in sentence 13 as concessive, whereas A2 marked it as epistemic. Neither of these readings are strictly incorrect (according to the scheme), as the reading depends on the subjective interpretation of the scope of the modal auxiliary *may*.

As the conditional sense is also present in the main clause-relative clause structure that was demonstrated with the concessive sense above, predictably similar cases of disagreement occurred in Examples 14 and 15.

14. If you do not have written documentation of measles immunity, you **should** get MMR vaccine.
15. If vaccines work, the vaccinated **should** be protected.

Both readings of *should* in sentences 14 and 15 were marked as conditional by A1, and as deontic by A2. When limiting the scope of the modal *should* to the second clause in sentence 14, it would be deontic. However, if the scope was increased to include the whole sentence, *should* would be conditional. Similar reasoning can account for A1's marking *should* in sentence 15 as conditional, but it is unclear why A2 gave the deontic sense in this case. Limiting the scope to the second clause would result in an epistemic reading instead (where the property of being vaccinated is why one would be protected).

Another common case occurs with the epistemic and deontic reading of *may* in Example 16:

16. MMRV vaccine is licensed for children 12 months to 12 years old and **may** be used in place of MMR vaccine if varicella vaccination is also needed.

A1 assigned *may* a deontic reading, while A2 assigned an epistemic reading. Considering that A1 frequently interprets modals as having a broader scope of influence (shown above), it is likely that the context of a vaccine being 'licensed' influenced her decision to read *may* as deontic. The epistemic reading is also appropriate in Example 16 as it can be interpreted that the vaccine is possible to 'be used in place of the MMR vaccine'. Both readings for *may* are permitted by the annotation scheme, leaving the meaning up to interpretation by the individual.

4.2. Boundary overlap: epistemic and dynamic senses

Can is the modal associated with the most disagreement. This is partly due to it having the two senses that are most difficult to agree on: epistemic and dynamic. This also mirrors the results of Ruppenhofer and Rehbein (2012), as discussed previously.

The concepts 'ability' and 'possibility' are highly linked, adding to the confusion between dynamic and epistemic senses. For something to be able to occur (dynamic modality), it is necessary that there is a possibility that it occurs (epistemic modality). Ruppenhofer and Rehbein (2012) differentiate between the three senses of *can* in the following way: 'the dynamic use concerns ability or potential for involvement in events or behavior[...] the deontic use is about giving permission [...] the epistemic use concerns the possibility for the speaker to come to certain conclusions.' These distinctions were reproduced in the guidelines for this task to aid the annotators in their decisions. In the results of this annotation task there were no cases of disagreement regarding the deontic sense of *can*, as reported in Table 3, and thus we focus on the first and last senses of this modal.

The simplest way to analyze the disagreement between these senses is to compare it to cases where there *was* agreement. Some of these instances are presented in Table 4.

In the dynamic instances, one is able to test the sense with substituting parts of the text with 'is/are/am (not) able to x'. Instances from Table 4 can be used as examples: 'I am not able to find my prescription meds!' and 'two doses provides protection that is able to be confirmed with blood titers'. Similarly for epistemic senses, one can use the template 'it is (not) possible that/to x': 'it is possible that children are left unprotected for longer...' and 'it is possible that encephalitis leads to convulsions...'. These 'testing templates', however, are not always helpful as there are cases where both templates work. This was frequently the case when the two annotators disagreed, as shown in Table 5.

Firstly, it is important to note that neither annotator showed preference for a particular reading (i.e. the ratio of epistemic to dynamic senses annotated were roughly equal for both annotators). Secondly, all of the instances in Table 5 are able to be reformatted according to the 'testing templates' mentioned above, and still hold their original meaning. One can use the first instance from Table 5 as an exam-

Sense	Extract
Dynamic	Once you allow the toxic cocktails of heinous vaccine materials to enter your child's body, you can't retrieve them
Dynamic	Americans, surely you can tell when something sounds too good to possibly be true!
Dynamic	"I can't find my prescription meds!"
Dynamic	Two doses provides protection that can be confirmed with blood titers.
Dynamic	These are child [sic] who can't be vaccinated
Dynamic	A health care provider can help decide which vaccine to use
Epistemic	Measles is a highly contagious disease. It can be serious for young children.
Epistemic	About one child out of every 1,000 who get measles will develop encephalitis (swelling of the brain) that can lead to convulsions and can leave the child deaf or mentally retarded.
Epistemic	That can leave their children unprotected for longer than they would have been otherwise

Table 4: Examples of agreement on epistemic and dynamic senses of *can*.

A1	A2	Extract
Epistemic	Dynamic	... before it can even be observed or determined in the case of fetuses, newborns, infants, and toddlers
Dynamic	Epistemic	People who receive live-virus vaccines, such as the MMR, can then shed that live virus
Dynamic	Epistemic	...and can infect others
Epistemic	Dynamic	Effectiveness cannot be determined unless one is then knowingly exposed to the disease entity following vaccination
Epistemic	Dynamic	Looking at more comprehensive incidence data, we can see a drop in incidence in 1963 at the introduction of the measles vaccine
Dynamic	Epistemic	Measles can spread when it reaches a community in the United States where groups of people are unvaccinated

Table 5: Examples of disagreement on epistemic and dynamic senses of *can*.

ple: 'before it is able to be observed' and 'before it is possible to be observed'. In most of the agreed upon cases for the dynamic reading, the subject is a human agent accompanied with a more dynamic verb. The epistemic modals tend to modify stative or static verbal constructions such as 'leave [...] unprotected', and 'be serious'. However, some of the difficult cases have a non-human subject and a range of static and dynamic verbs that are being modalized, further obfuscating any sort of distinguishing 'rule'.

The lack of an obvious systematic 'rule' raises a number of methodological and conceptual questions. Firstly, are the guidelines inadequate for the task of modal sense annotation? This is likely not the case, as Ruppenhofer and Rehbein (2012) have far better agreement for *can*, and the guidelines here used were, for all intents and purposes, the same (the only difference being that the current task refrained from annotating the proposition). Ruppenhofer and Rehbein (2012) also report relatively good performance when training a classifier on the senses obtained from annotating modals with the same scheme used presently.

Further questions arise from the first: is there some property of the vaccination debate, or the language used within, that makes this modal more difficult to annotate than in the English news corpus of Ruppenhofer and Rehbein (2012)? Do these cases of disagreement suggest that there is not enough contrast between the senses, or that it can be read both ways and still make sense? There were definite cases of agreement between the annotators, suggesting that these senses are actually sometimes meaningful and discrete. Thus, these categories cannot be collapsed entirely. Perhaps in these highly ambiguous cases then, it is preferable

to have a joined sense of epistemic/dynamic. Some of the authors of the documents in the corpus could have chosen to use an ambiguous modal because it covers both meanings, rather than use a more specific one with a single meaning. This, however, requires further research to ascertain whether there are other means of distinguishing between modal senses (in particular, senses for *can*) that have not been addressed here. If further investigation is not fruitful, the alternative is to create a combined modal sense that may be used in cases where the epistemic and dynamic readings of the modal are equally suitable.

4.3. Metaphorical extension of verb senses

One process that drives language change is metaphorical extension (Lakoff, 1993), an example being linking money and time in expressions such as 'spent too much time on *x*'. Similar processes are apparent in language about disease, as well as using physical processes to convey reasoning and conclusions. In this subsection we address a few cases where metaphorical extension of the modalized verb can lead to cases of ambiguity and disagreement.

Examples 17-19 are instances where the modal *can* is ambiguous due to the governing verb (in italics) being used metaphorically rather than literally:

17. You **can** *catch* it [measles] by [...]
18. Infectious people **can** *spread* the disease for up to eight days [...]
19. We **can** *say* that the current vaccination rate is far below the level necessary to achieve herd immunity.

‘Spread’ and ‘catch’ are dynamic verbs (cf. ‘she spread butter’; ‘he can catch a ball’), but in 17 and 18, the human subjects are not the agents of the verb. Rather, the *disease* is able to spread and infect others, regardless of human agency. Furthermore, while dynamic modality relates to internal ability, and being infectious is an internal state, the modal is not entirely dynamic as there are still elements of epistemic modality (the possibility of becoming infected, or spreading the disease simply by being a host). In example 19, ‘say’ is a physical action that has been used to describe coming to a conclusion, based on evidence. This can lead to ambiguity as one is both able to say something (dynamic modality) and it is possible to say it due to logical processes informed by evidence (an epistemic stance).

5. Adjudicated corpus

The adjudicated version of the corpus was produced by the first author of the paper. It contains 450 modals (*can*, *could*, *may*, *might*, *must*, *should* and *shall*). Table 6 provides the total occurrences of modals as compared to Ruppenhofer and Rehbein (2012).

Modal	VCM	RR2012
can/could	242	598
may/might	103	195
must	19	183
shall	86	182
Σ	450	1158

Table 6: Number of modals annotated in the VMC corpus and in Ruppenhofer and Rehbein (2012)

Due to the infrequent instances of the concessive and conditional senses, as well as high level of annotator disagreement, the two senses were subsumed into the epistemic and deontic categories where appropriate. The optative sense as well as the modal *ought to* were omitted as they were not present in the corpus.

The epistemic and dynamic senses associated with the modals *can* and *could* can be conceived of as either ends of a spectrum, rather than discrete categories. The center of the spectrum contains the ambiguous cases where the majority of the disagreement between annotators occurred. As shown in Section 4., these cases are equally able to be read as epistemic or dynamic. Where these cases occur, a combined epistemic-dynamic sense was allocated.

Table 9 presents the results of the adjudication process, with the number of times that each modal occurs per sense for either stance and the total number of occurrences. A value of zero is given for cases where a modal is permitted to have a sense (according to the scheme), but is not present in the corpus, and ‘-’ is given for cases where the sense is not applicable to the modal. The most frequent and ambiguous modal is *can* and the most frequent sense is the epistemic. The high frequency of the epistemic sense indicates that, in this particular corpus, those participating in the debate are more frequently offering perspectives on epistemic arguments such as the possibility of the spread of measles, the efficacy and safety of vaccines, and the severity of the epidemic, than arguing a moral standpoint (e.g. civil liberties and mandatory vaccination).

Stance	Modal	Dyn.	Deo.	Epis.	E-D	Σ
Pro	can	44	0	7	53	104
	could	4	0	18	6	28
	may	-	1	34	-	35
	might	-	0	15	-	15
	must	-	5	1	-	6
	shall	-	0	0	-	0
	should	-	44	4	-	48
	Σ	48	50	79	59	236
Anti	can	40	9	4	41	94
	could	0	0	10	6	16
	may	-	0	37	-	37
	might	-	0	16	-	16
	must	-	10	3	-	13
	shall	-	1	0	-	1
	should	-	31	6	-	37
	Σ	40	51	76	47	214
All	can	84	9	11	94	198
	could	4	0	28	12	44
	may	-	1	71	-	72
	might	-	0	31	-	31
	must	-	15	4	-	19
	shall	-	1	0	-	1
	should	-	75	10	-	85
	Σ	88	101	155	106	450

Table 7: Distribution of modal senses according to vaccination stance in the VCM corpus.

The number of modals with the deontic and epistemic sense are similar per stance, whereas modals with the dynamic and the combined epistemic-dynamic sense are more frequent in texts with a pro-vaccination stance. *Must* is arguably the modal that communicates the strongest conviction – in terms of both obligation and possibility – and is used more frequently by those opposed to vaccination, particularly in the deontic sense. *Should* is the most frequently used deontic modal, regardless of stance, but is used more by those supporting vaccination. Further annotation of the proposition that is being modalized is needed in order to ascertain which types of propositions are more strongly held. Furthermore, the corpus needs to be expanded for better coverage and representation.

6. Discussion

The methodology used to test the first hypothesis by Moon et al. (2016) “that uses of *can*, *could* and *would* are more difficult to classify than other modal auxiliaries, predicting lower IAA”, differs from our research in that they extracted single sentences that contain the target modal, which leaves out useful context to determine the sense. However, providing context can provoke disagreement between annotators. This was demonstrated in Section 4.1, where we showed that annotators interpret the scope of the modal differently, leading to different sense assignments. The likely solution to the scope problem, in the future, is to instruct annotators to first attempt to select a reading at the clausal level, and if that is not sufficient context, then incrementally increase the scope until a modal sense can be established.

The results of the annotations conducted in Ruppenhofer and Rehbein (2012) are largely comparable to our results:

annotators more frequently disagreed on the senses of *can* than on the senses of other modals, and the cases of disagreement were largely between epistemic and dynamic senses. Where the current research and that of Ruppenhofer and Rehbein (2012) differ, however, is that Ruppenhofer and Rehbein do not report about cases where both epistemic and dynamic senses, regardless of scope, are appropriate readings of the modal *can*. The need of a combined epistemic/dynamic sense category in the current research could indicate that there might be some difference between the use of modals in the VCM and the news corpus of Ruppenhofer and Rehbein (2012). More annotation experiments would be study this issue.

A last important observation that has to be made is that the annotated corpus is small and thus the results would have to be confirmed in future annotation experiments, which are part of our future research goals.

We have started by applying our annotation scheme to a subset of the MASC corpus, which was already annotated with modal senses by Zhou et al. (2015). The following genres were chosen applying a criterion of similarity with the VCM corpus: blog, court transcript, debate transcript, essays, fiction, government documents, and newspaper articles. All existing annotations were manually checked by the first author of this article for accuracy and adherence to the annotation scheme of the VCM corpus. Some modal senses needed correction.⁵ The documents containing the modals *can* and *could* were analysed for cases where the novel combined epistemic-dynamic sense would be appropriate. There were 46 such cases, and the original annotations of (Zhou et al., 2015) were manually changed from either epistemic or dynamic to the combined epistemic-dynamic sense.

A superficial analysis of the data shows that the most frequent modal is *can* in both datasets, although *could* is also very frequent in the MASC corpus. The most frequent sense in epistemic in VCM, followed by epistemic-dynamic and deontic, whereas in MASC the most frequent sense is dynamic followed by deontic and epistemic. In future work we will perform a deeper analysis of the data as well as continuing with the annotation process.

7. Conclusion and Future Work

Our research has focused on annotating modal verbs and their senses in the Vaccination Corpus. The modal auxiliaries annotated were: *can*, *could*, *may*, *might*, *must*, *shall*, *should* and *ought to*, and the senses included epistemic, dynamic, deontic, optative, concessive and conditional, which we adopted from Ruppenhofer and Rehbein (2012). Our goal was to ascertain whether similar IAA can be achieved when using the modal sense classification of Ruppenhofer and Rehbein (2012) on texts from the vaccination debate, and to investigate whether there are similar cases of disagreement, or whether there is a unique property of the vac-

⁵There were two cases where a modal was given the incorrect sense, as it was not permitted according to the annotation scheme. Additionally, some sentences were very short and contained ambiguity. In these cases it was impossible to adjudicate and the sense as given by Zhou et al. (2015) was assumed to be correct.

cination debate that makes annotating modal senses more difficult.

Modal	Dyn.	Deo.	Epis.	E-D	Σ
can	202	36	13	35	286
could	106	11	55	16	188
may	n/a	33	91	n/a	124
must	n/a	44	8	n/a	52
should	n/a	88	10	n/a	98
Σ	308	212	177	51	748

Table 8: Distribution of modal senses in the reannotated files of the MASC corpus.

Modal	Dyn.	Deo.	Epis.	E-D	Σ
can	84	9	11	94	198
could	4	0	28	12	44
may	-	1	71	-	72
might	-	0	31	-	31
must	-	15	4	-	19
shall	-	1	0	-	1
should	-	75	10	-	85
Σ	88	101	155	106	450

Table 9: Distribution of modal senses according to vaccination stance in the VCM corpus.

It was found that, while present IAA scores were lower overall, the general observations are comparable to those reported by Ruppenhofer and Rehbein (2012). Furthermore, our results largely corroborate those of similar studies done by Ruppenhofer and Rehbein (2012) and Moon et al. (2016), in that the modal associated with the most disagreement was *can* and the most disagreed upon sense boundary was between epistemic and dynamic senses. Our findings suggest that there are some cases where the disagreement between epistemic and dynamic senses could be solved by including a combined epistemic/dynamic sense category as both senses are equally viable or appropriate. As a result of these findings, the annotations were adjudicated to include the combined epistemic-dynamic senses for cases where both are equally suitable. Additionally, the conditional and concessive senses were subsumed into the epistemic and deontic sense categories, where appropriate. There were no cases of *ought to* or the optative sense, and are therefore not reported.

Future research in this domain is necessary to establish whether the boundary between epistemic and dynamic senses is always meaningful. We plan to perform additional annotation experiments in order to improve the criteria to differentiate senses and we plan to extend the annotations to the full Vaccination Corpus, since we are aware of the fact that the results provided are exploratory due to the small size of the corpus.

8. Acknowledgements

This research is supported by the Netherlands Organization for Scientific Research (NWO) via the Spinoza-prize awarded to Piek Vossen in the project “Understanding Language by Machines” (SPI 30-673, 2014-2019).

9. Bibliographical References

- Kennedy, G. (2002). Variation in the distribution of modal verbs in the British National Corpus. *Using corpora to explore linguistic variation*, pages 73–90.
- Kratzer, A. (1991). Modality. In von Stechow & Wunderlich (eds.), *Semantics: An international handbook of contemporary research*.
- Lakoff, G. (1993). The contemporary theory of metaphor.
- McCarthy, M. (2015). Measles outbreak linked to Disney theme parks reaches five states and Mexico. *BMJ: British Medical Journal (Online)*, 350.
- Mollema, L., Harmsen, I. A., Broekhuizen, E., Clijnk, R., De Melker, H., Paulussen, T., Kok, G., Ruiters, R., and Das, E. (2015). Disease detection or public opinion reflection? Content analysis of tweets, other social media, and online newspapers during the measles outbreak in The Netherlands in 2013. *Journal of medical Internet research*, 17(5).
- Moon, L., Kirvaitis, P., and Madden, N. (2016). Selective annotation of modal readings: Delving into the difficult data. *LiLT (Linguistic Issues in Language Technology)*, 14.
- Morante, R., van Son, C., Maks, I., and Vossen, P. (2020). Annotating perspectives on vaccination. In *Proceedings of LREC 2020*, Marseille, France.
- Palmer, F. (1986). *Mood and Modality*. Cambridge: Cambridge University Press.
- Römer, U. (2004). A corpus-driven approach to modal auxiliaries and their didactics. *How to use corpora in language teaching*, pages 185–199.
- Ruppenhofer, J. and Rehbein, I. (2012). Yes we can!? Annotating the senses of english modal verbs. In *Proceedings of the 8th International Conference on Language Resources and Evaluation (LREC)*, pages 24–26.
- Saurí, R. (2008). *A factuality profiler for eventualities in text*. Brandeis University.
- Scott-Mumby, K. (2015). Measles outbreak of 2014... are vaccinations worthless? Accessed January 2018.
- Von Fintel, K. (2006). Modality and language.
- Wolfe, R. M. and Sharp, L. K. (2002). Anti-vaccinationists past and present. *BMJ: British Medical Journal*, 325(7361):430.
- Zhou, M., Frank, A., Friedrich, A., and Palmer, A. (2015). Semantically enriched models for modal sense classification. In *Proceedings of the First Workshop on Linking Computational Models of Lexical, Sentential and Discourse-level Semantics*, pages 44–53.