

ENTAILMENT AS DETERMINACY

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1. Introduction

Much has been written about the syntax and semantics of the English modals, yet more is unknown than known.

It is known that each form has several meanings, and that each meaning has several forms. For example, *can* means 'power,' 'capacity,' 'permission,' and 'possibility'; and 'possibility' can be expressed by *can*, *could*, *may*, *might*, *possible*, *probable*, *likely* and *certain*. In support of such form-meaning relations the linguistic literature contains a wealth of examples, which are often discovered (as opposed to invented) and explained or annotated (as opposed to merely presented).

The theory behind such form-meaning correlations is inadequate on all counts – observation, description and explanation. Modal meanings are given, but these meanings (e. g. 'ability,' 'permission,' 'possibility,' etc.) remain syntactically and semantically unanalyzed, whether componentially, prototypically, basically, or otherwise, with the result that they cannot be qualitatively or quantitatively compared. For example, we cannot know whether *be able to* is the result of *enable* or *empower*, and we cannot know whether and when *may* and *can* are the passive of *permit* and *allow*. Nor can we know whether the modals are polysemous or homonymous and in what manner and to what extent. Nor do we know the contexts that bind the determinacies from modal form to modal meaning, and vice versa. Nor do we know the observer-relative frequencies of the modal forms, meanings, contexts, and form-meaning determinacies, and vice versa.

In the present paper we begin to attack this formidable fortress of unknowns with the weapon of entailment, which is of the utmost relevance to semantics, including the semantics of the modals. For example, if Maria can sing Aida, then Maria is able to sing Aida, and it is either possible for her to do so or not. If she will sing, then (later) she is singing, and (still later) she sang, and (even later) she has sung, etc. However, if it is not possible for Maria to sing Aida (even though she is able) then she cannot (= not possible) and will not. If she will not, then she will not be singing, will not have been singing, did not sing, will not have sung, etc.

Modality is extremely rich in intricate syntactic, semantic, and pragmatic entailments, involving not only the modals *per se*, but also negation, tenses, aspects, voices and moods, as well as the everpresent functional sentence perspective (FSP), including the perspective of the speaker in production and the perspective of the hearer in recognition.

Much has been written about the syntax and semantics of the English modals. Yet, it must be agreed that there is indeed more that is unknown than known. More can be learned once the entailments of modals are taken into account.

2. Some Modal Entailments

The modals are often defined as isolated words, but seldom in paradigmatic and syntagmatic opposition. This insular approach is of value, but it offers little insight into the system of modal semantics. Here we approach the meanings of the modals syntagmatically, using various relations of entailment, including the ones in (2.1) as defined in Hajičová (1980).

(2.1) Meaning Proper, Presupposition, and Allegation

- a. Meaning Proper: A is a part of the meaning proper of B, if B entails A and $\neg B$ entails $\neg A$.
- b. Presupposition: A is a presupposition of B, if B entails A and $\neg B$ entails A.
- c. Allegation: A is an allegation of B, if B entails A and $\neg B$ entails neither A nor $\neg A$.

We wish to explore the entailments of B when B contains one or more modals. Consider the examples in (2.2). These serve to illustrate a few of the points we wish to make.

(2.2) Examples of Modal Entailments

- a. Boris was able to win.
- b. Boris had to win.
- c. Boris had to be able to win.
- d. Boris will be able to win.
- e. Boris will have to win.
- f. Boris will have to be able to win.
- g. It is possible that Boris will win.
- h. It is probable that Boris will win.
- i. It is certain that Boris will win.
- j. Boris will win.
- k. Boris will be winning.
- l. Boris will have won.
- m. Boris won.
- n. Boris did not win.

The first point is that entailments depend upon the modal content, not the modal expression. For example, *able* can mean 'possessed of an ability' or it can mean 'use of an ability that one is possessed of.' This multiplicity of meaning (polysemy) is evident in (2.2 a). If Boris had the ability to win and used it, then we can say "Boris was able to win (and did)." And, if Boris did not have the ability to win and, consequently, could not use it or, alternatively, if Boris had the ability but did not use it, then we can say "Boris was not able to win" (and didn't) or "Boris was able to win" (but didn't). Accordingly, (2.2 a) has two sets of entailments:

- (I) B entails A, and $\neg B$ entails $\neg A$;
- (II) B entails A or $\neg A$, and $\neg B$ entails $\neg A$.

The first entailment is Meaning Proper. The second entailment is not listed among the entailments in (1) – to our knowledge it is a new entailment type.

A different phenomenon appears in (2.2 b). If Boris had to win, "had" expresses an obligation (Boris was obliged to win) or a kind of exclamation (Boris, of all people, had to win!) of surprise or resentment. These meanings have different entailments. If obligation, then Boris either won or he did not win, i.e., B entails A or $\neg A$. When the sentence is negated (Boris did not have to win) however, the situation becomes even more complicated. On one reading, there was no need for Boris to feel obliged to win (Boris did not really have to win). On another reading, Boris did not win, but there was no necessity for him to do so. On still another reading, Boris won, but he could have placed second or even lost. On the exclamatory reading, Boris won, and the speaker regrets it, or Boris felt he had to win, but lost, and the speaker regrets the need to win that Boris felt. Accordingly, there are several sets of entailments. We restrict ourselves to two:

- (III) B entails A, and $\neg B$ entails neither A nor $\neg A$;
- (IV) B entails A, and $\neg B$ entails A.

The first entailment is an allegation entailment type and the second is another example of a new entailment type.

The second point is that modal entailments interact. This can be illustrated on the basis of (2.2 c), "Boris had to be able to win." The entailments of *able to* ((2.2 a)) and *have to* ((2.2 b)) are given again in (2.3).

(2.3) Entailments of *Able To* and *Have To*

- a. *Able to*
 1. B entails A, and $\neg B$ entails $\neg A$
 2. B entails A or $\neg A$, and $\neg B$ entails $\neg A$
- b. *Have to*
 1. B entails A, and $\neg B$ entails neither A nor $\neg A$
 2. B entails A, and $\neg B$ entails A

Boris had to be able to win (B) and Boris did not have to be able to win (\neg B) both contain the modal sequence *have to + be able to*. If Boris had to be able to win, then he either was able to win or he wasn't. And if Boris did not have to be able to win, then he either was able to win or he wasn't. Alternatively, if Boris had to be able to win, then he was able to win, and, if Boris did not have to be able to win, then he won. Thus, the entailments of *have to + be able to* are the same entailments as the entailments of *have to* alone, which are different from the entailments of *be able to* alone. Therefore, the entailments of *have to* cancel the entailments of *be able to*.

Third, the modals of possibility – *possible, probable, and certain* – are of special interest. Examples are given in (2.2 g,h,i), and the entailments are given in (2.4).

(2.4) Entailments of *Possible, Probable and Certain*

- a. *Possible*: A is possible, if B entails either A or \neg A, and \neg B entails \neg A.
- b. *Probable*: A is probable, if B entails A or \neg A, and \neg B entails A or \neg A.
- c. *Certain*: A is certain, if B entails A, and \neg B entails A or \neg A.

'It is possible to win' entails either winning or not winning and 'It is not possible to win' entails not winning. Probability is a special case of possibility. If winning is probable, then one wins or does not win, and if winning is not probable, then one also wins or does not win. Finally, certainty is a special case of probability. If Boris is certain to win, then he will win, but if he is not certain to win, he will either win or not win.

Modals of possibility precede modals of obligation and ability. Therefore, entailment cancellation predicts that entailments of possibility, probability and certainty cancel entailments of obligation and ability in constructions in which they co-occur. This prediction is easy to test. Consider the examples in (2.5).

(2.5) Entailments of Possibility, Obligation, and Ability

- a. possible to be able to win
- b. probable that Boris is able to win
- c. certain that Boris is able to win
- d. possible to have to retreat
- e. probable that John will have to retreat
- f. certain to have to retreat
- g. possible to have to be able to succeed
- h. probable that John will have to be able to succeed
- i. certain to have to be able to succeed

Just as 'able to win' is an ability, 'have to win' an obligation, 'possible to be able,' 'possible to have to,' and 'possible to have to be able' are possibilities. For example, 'possible to have to retreat' entails either having to retreat or not having to retreat, and 'not possible to have to retreat' entails not having to retreat, which are

the very entailments of possibility, as given in (2.4 a). These entailment types are also novel.

In the above, modals entail modals and main verbs. However, main verbs also entail modals. If Maria sang an aria, it was her ability and it was possible. Similarly, if Švejk did his duty, it must have been possible for him to have to be able to. Therefore, B can entail modal A or \neg A, even if A is implicit or understood.

As often remarked, the modals carry tense and aspect. Apart from this, however, there is a natural order of events (NOE) in tenses, aspects, voices, and moods. The NOE's of the English tenses are given in (2.6), where (a) precedes (b), and (b) precedes (c).

(2.6) Natural Order of Tenses and Aspects

Temporal Relation	Tense	Aspect
a. Anterior	Future	To-Future
b. Simultaneous	Present	Progressive
c. Posterior	Past	Perfect

On our view, the tenses and aspects entail each other. For tense, first we will go (Future), then we are going (Present), then we went (Past). The Future is bound by (SE), the Present by (S, E), and the Past by (ES), where S is the speech event, E is the narrated event, (X Y) means X precedes Y, and (X, Y) means X is contemporaneous with Y. Now, to the extent that an event has a Future, Present, and Past, one tense entails another, i.e., if (SE) is true, then (S, E) is also true, and if (S, E) is true, then (ES) is also true. *Mutatis mutandis*, the same applies to the aspects, at least the aspects given in (2.6). These involve two events, E1 and E2. For aspect, first we have to go (To-Future), then we are going (Progressive), then we have gone (Perfect). The To-Future is bound by (E1E2), the Progressive by (E1, E2), and the Perfect by (E2E1). As in the case of tense, one aspect entails another, i.e., if (E1E2) is true, then (E1, E2) is also true, and if (E2, E1) is true, then (E2E1) is also true. Evidently, tense and aspect involve the same temporal relations, but the relations have different relata.

Some determinacies of the tenses and aspects are given in (2.7). Here, $x \rightarrow y$, when bound by z, with precise measures of accuracy (I) and completeness (C) (for details see Chesnokov and Luelsdorff 1991).

(2.7) Some Determinacies of Tense and Aspect

a. Tense			
1.	SE	\rightarrow	Fut, I = 1.00
2.	S, E	\rightarrow	Pres, I = 1.00
3.	ES	\rightarrow	Past, I = 1.00

b. Aspect

- 1. E1E2 → To-Fut, I = 1.00
- 2. E1, E2 → Prog, I = 1.00
- 3. E2E1 → Perf, I = 1.00

By way of summary thus far, there are interesting entailment relations among the modals, tenses and aspects. In the sequel, entailments are shown to hold across modals, tenses, and aspects, and to possibly differ in production and recognition. Interesting sets of entailments are given by the modal + tense + aspect combinations in (2.8).

(2.8) Perfect Modals

- a. John must have resigned.
- b. John could have resigned.
- c. John should have resigned.
- d. John would have resigned.
- e. John might have resigned.
- f. John resigned.
- g. John did not resign.
- h. It is possible that John resigned.
- i. It is probable that John resigned.

(2.8 a) means that it seems that John has resigned, i.e., that it is probable that John resigned. Thus (2.8 a) entails (2.8 i) and $\neg(2.8 a)$ entails $\neg(2.8 i)$, i.e. B entails A and $\neg B$ entails $\neg A$, where A contains "probable," a term not contained in B. This is an extension of Meaning Proper as defined in (2.1 a).

The examples in (2.8 b-e) can mean non-fulfilment, as often observed. On this reading, B entails $\neg A$, and $\neg B$ entails A, which is another new entailment pattern. However, (2.8 b-e) can also mean fulfilment, as in "John could have resigned, and did" and "John would have resigned no matter what" or "John might not have resigned if it had not been for Judy." The entailment pattern for fulfilment, then, is B entails A, and $\neg B$ entails A, i.e., Presupposition as defined in (2.1 b).

The evidence suggests that modality (including tense and aspect) moves from external to internal position within the proposition, as schematically shown in (2.9). For example,

(2.9) Modality Movement

- a. $((W M_i X) (M_j (Y \emptyset Z)))$, where $M_i \neq M_j$
- b. $((\emptyset \emptyset \emptyset) (\emptyset (Y M_k Z)))$, where $M_j = M_k$

"It is possible that John resigned" moves to "John could have resigned," and "It is not possible that John resigned" moves to "John could not have resigned" etc. On this movement account, the ambiguity of the past perfect modals given in (2.8 b-e)

stems from the movement of many-to-one, i.e., the internalization of possibility, probability, certainty, intention, obligation, permission, ability, etc. as modals into the proposition. With so much meaning packed into so little form, the modals must be polysemous, the polysemy turning to ambiguity unless the requisite ambiguity-resolving contexts present themselves, which is seldom the case.

On the proposal in (2.9), modals transport their entailments. However, since the modal movements are most frequently many-to-one, modal entailment conflicts and ambiguities of the type discussed above are the inevitable result. And, as noted, such entailment ambiguities can only be resolved by context, whether available in the text, the situation, or prior knowledge.

There can be a difference between entailments in production and entailments in recognition, as shown by the sequence in (2.10).

(2.10) Entailments in Production and Recognition

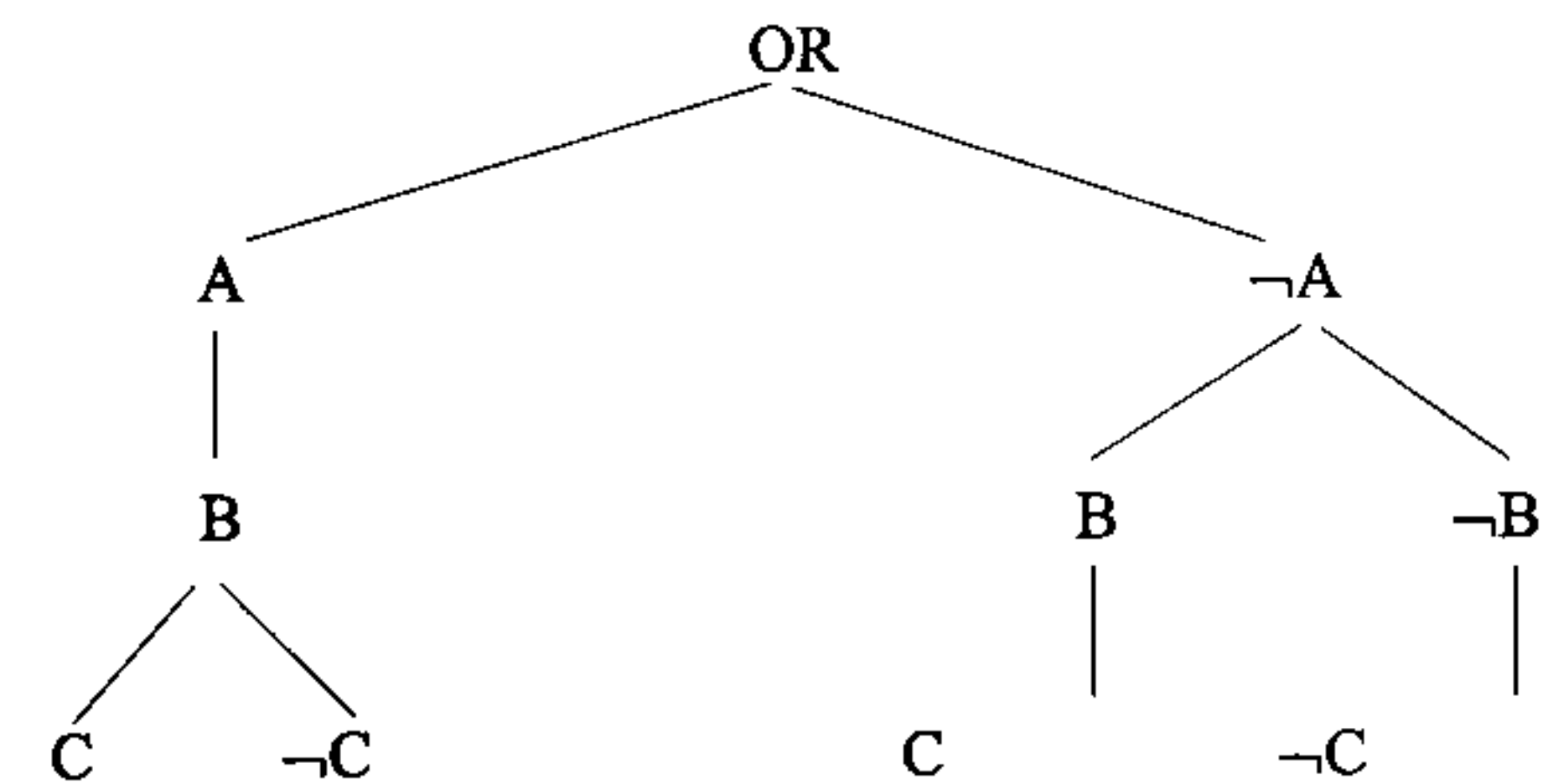
- A. John resigned.
- $\neg A$. John did not resign.
- B. It was possible for John to resign.
- $\neg B$. It was not possible for John to resign.
- C. John could have resigned.
- $\neg C$. John could not have resigned.

In production, A entails B and B entails C or $\neg C$, or $\neg A$ entails B or $\neg B$ and B entails C, and $\neg B$ entails $\neg C$. In recognition, C entails B, and B entails A or $\neg A$, or $\neg C$ entails B or $\neg B$, and B entails A and $\neg B$ entails $\neg A$.

Entailments in production and recognition can be displayed on trees or in labeled brackets, as shown for (2.10) in (2.11).

(2.11) Entailment Trees for Production and Recognition

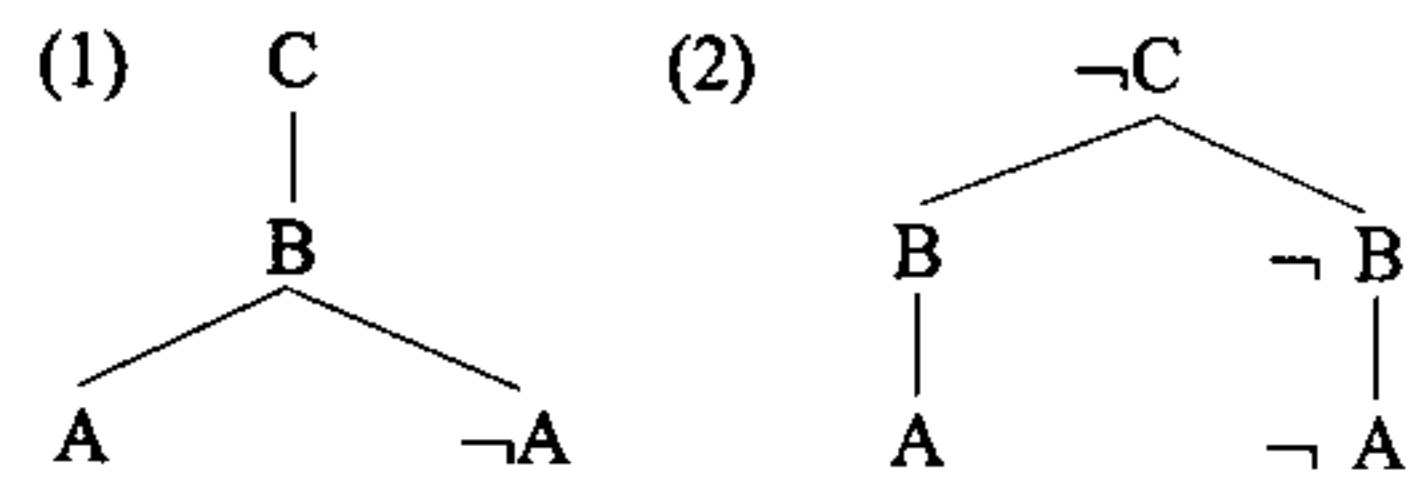
a. Production Tree



a'. Production Brackets

OR (A (B (C, $\neg C$)), $\neg A$ (B(C), $\neg B$ (C \neg)))

b. Recognition Tree



b'. Recognition Brackets

- (1) C (B (A, \neg A))
 (2) \neg C (B (A), \neg B (\neg A))

Comparison of the production tree in (2.11 a) with the recognition trees in (2.11 b) shows that the one is not necessarily the inverse of the other. For the entailments in (2.10), recognition is the inverse of production just in case the speaker and the hearer know that (A OR \neg A) but do not know if (whether) (A OR \neg A). In this case, i.e., the case in which recognition is the inverse of production, production and recognition entailments are the mirror images of one another. Otherwise, production and recognition entailments differ, and the possible differences are constrained by the actual differences between the production and recognition entailment trees themselves.

One example must suffice. Suppose the production entailment path is [A—B—C], i.e., the speaker believes that John resigned (A), that it was thus possible for John to resign (B), and says “John could have resigned (and did)” (C). Now suppose that the recognition entailment path is [C—B— \neg A], i.e. the hearer hears “John could have resigned” (C), entailing that it was possible for John to resign (B), but he concludes that John did not resign (\neg A), in the sense of “John could have resigned, but didn’t.”

A contrastive analysis of the production and recognition entailment paths might proceed as follows. The production path is [A—B—C], and the recognition path is [C—B— \neg A]. The inversion of the recognition path is [\neg A—B—C]. For contrastive purposes, the two can be juxtaposed as follows: ((A, \neg A), (B, B), (C, C)), where the first co-ordinate of each pair is production, and the second recognition, and there is a contrast just in case these two terms are different. In this case, the only contrast is (A, \neg A). Since the speaker intended A, but the hearer understood \neg A, the pair (A, \neg A) is not just a contrast, but also a misunderstanding.

Every speaker-hearer has entailment trees for production and recognition. You say what you mean when your recognition is the exact inverse of your production. For example, you produce and recognize [A—B—C]. You do not say what you mean when your recognition is the inexact inverse of your production. For example, you produce [A—B—C] but recognize [\neg A—B—C]. If you compare your recognition with your production, i.e., if ((A, \neg A), (B, B), (C, C)), you determine the contrastive difference (A, \neg A), i.e., your recognition conflicts with your production. This conflict could be an entailment ambiguity, i.e., you intended C to mean [A—B] but, on second thought, discover that “John could have resigned” (= (2.10c)) not

only expresses your intention “It was possible for John to resign” ((2.10b)) and “John resigned” (= (2.10a)) but also your non-intention “It was possible for John to resign” ((2.10b)) but “John did not resign” ((1.10) (\neg A)). In other words, you discover that your production C leads to both, the intended path [A—B—C] and the unintended path [\neg A—B—C]. In order for this ambiguity to be resolved – an ambiguity in the alternative paths [(A OR \neg A) —B—C] on the production tree in (1.11 a) – the speaker must edit or repair or reroute C to a unique path to [A—B], e. g. “John could have resigned and did.” The difference between ambiguous “John could have resigned” and unambiguous “John could have resigned and did” is the elliptical “and did (resign).” That is, “and did (resign)” resolves the ambiguity of “John could have resigned.” Therefore, “and did (resign)” is the resolving precisor (Chesnokov and Luelsdorff 1991) of the determinacies shown in (2.12), in which C and A are as in (2.10), and E is the ellipsis in question.

(2.12) Entailment Determinacy

- a. C, 0 \rightarrow A, I = 0.50
 b. C, 0 \rightarrow \neg A, I = 0.50
 c. C, E \rightarrow A I = 1.00

The determinacy in (2.12 c) reads: “C determines A, when C \rightarrow A is bound by E, with an accuracy (I) of 1.00 (unity).” Finally, consider the modal-semantic ambiguities in (2.13).

(2.13) Further Modal-Semantic Ambiguities

- a. John can go.
 b. John could have gone.
 c. John may go.
 d. John might have gone.
 e. John must go.
 f. John must have gone.

These modals have the meanings in (2.14).

(2.14) Modal-Semantic Ambiguity Resolutions

- a. can = [be possible to, be enabled to]
 b. can = [be possible to]
 c. may = [be probable that, be permitted to]
 d. may = [be probable that]
 e. must = [be certain that, be obliged to]
 f. must = [be certain that]

On this account, the modals in (2.13 a,c,e) have (at least) two meanings, but the corresponding modals in (2.13 b,d,e) have only one.

Moreover, the second meanings in (2.14 a,c,e) (= (2.13 a,c,e)) are in the passive, with the result that the active modals in (2.13 a-f) are underlying passives. Finally, as noted above, certainty entails probability, and probability entails possibility.

This modal-semantic situation becomes even more complex under negation, where it is hard to tell which of the terms in (2.14) are being negated – the first, the second, or both.

The modal-semantic theory presented predicts possible differences between production and recognition, in particular one or another circumscribed sort of modal-meaning error of commission and correction. For example, suppose the speaker and the hearer have the modal meanings as shown in (2.14), i.e. (1 or 2) or (1 and 2), where 1 is the first meaning and 2 is the second. This range of possible modal meanings in the norms of the speaker and the hearer defines the range of possible errors of modal-semantic production and recognition. For example, the speaker intends 1, but the hearer comprehends 2, or the speaker intends (1 and 2), but the hearer understands 2, or the speaker intends 2, is understood as 1, so revises (edits) 1 or refutes 1, etc. In this fashion, errors in modal semantics, like other errors, are genuine mirrors of the mind.

As noted, the modals in (2.13 a,c,e) have the meanings in (2.14 a,c,e) respectively, while the modals in (2.13 b,d,f) have only the meanings in (2.14 b,d,f), respectively, where the modal meanings in (2.14 b,d,f) are a proper subset of the modal meanings in (2.14 a,c,e). Therefore, something binds (1,2) in (2.13 a,c,e) to just (1) in (2.13 b,d,f) in both production and recognition. What might that something be?

Restricting the analysis to the sentences in (2.13), it will be seen that items (2.13 a,c,e), i.e. the items with the meanings (1, 2), are either in the Future or in the Present or in the Past. For example, “John can go” takes “tomorrow” and “now” and can be used in the Historical Present. Moreover, in (2.13 a,c,e) aspect is not involved. By contrast, the items in (2.13 b,d,f) all have the Perfect aspect. As defined above, the Perfect involves two events, E1 and E2, such that E2 comes after E1. For example, “have gone” (E2) follows “went” (E1), the Perfect (later) following the Past (earlier). Continuing, “John went” entails “John could go,” and “John did not go” entails “John not (could go),” and the Perfects of “John could go” and “John not (could go)” are “John could have gone” and “John not (could have gone).” The non-Perfect has the meanings (1, 2), but the Perfect has only the meaning (1). Therefore, the Perfect binds (1, 2) to (1).

The question, then, is why should the Perfect bind the modal meanings (1, 2) to the modal meaning (1)? That is, why does the Perfect aspect eliminate the deontic meanings (be enabled to, be permitted to, be obliged to) but retain the (epistemic) meanings (be possible to, be probable that, be certain that)? Evidently, because E1 – the event enabled, permitted, or obliged – precedes E2 – the event that becomes possible, probable, or certain as the result of the enabling, permitting, or obliging. In this sense, E1 is the cause of E2, or E1 the topic and E2 the comment. (1, 2) is earlier, (2) is earlier and (1) is later.

3. Entailment as Determinacy

The most frequently discussed modal meanings in English are given in capitals in (3.1).

(3.1) Modal Meanings

a. PERMISSION	(R)	e. NECESSITY	(N)
b. POSSIBILITY	(P)	f. ABILITY	(A)
c. INTENTION	(I)	g. HABIT	(H)
d. OBLIGATION	(O)	h. DARE	(D)

Modalities express conditions on the occurrence of events. Some modal conditions are *obligatory*, and some are *optional*. In order for an event to occur, the obligatory conditions must be met, while the optional conditions can either be met or not met. Therefore, obligatory conditions are necessary but not sufficient, and optional conditions are neither necessary nor sufficient. Consider the examples in (3.2).

(3.2) Obligatory and Optional Modal Conditions

- a. Affirmative Obligatory Conditions
 1. It was POSSIBLE for John to succeed.
 2. John was ABLE to succeed.
 3. John succeeded.
 4. John did not succeed.
- b. Negative Obligatory Conditions
 1. It was NOT POSSIBLE for John to succeed.
 2. John was NOT ABLE to succeed.
 3. *John succeeded.
 4. John did not succeed.
- c. Affirmative Optional Conditions
 1. It was NECESSARY for John to succeed.
 2. John was OBLIGED to succeed.
 3. John INTENDED to succeed.
 4. John succeeded.
 5. John did not succeed.
- d. Negative Optional Conditions
 1. It was NOT NECESSARY for John to succeed.
 2. John was NOT OBLIGED to succeed.
 3. John did not INTEND to succeed.
 4. John succeeded.
 5. John did not succeed.

Obligatory and optional modal conditions can be represented in terms of logical entailments, and the similarities and differences between these logical entailments can be used to assess the similarities and differences between obligatory and optional modal conditions. The respective entailments are given in (3.3).

(3.3) Entailments of Obligatory and Optional Modality

- a. Obligatory Modality
 1. MODAL S entails S or NOT-S,
 2. NOT-MODAL S entails S,
 3. S entails MODAL S,
 4. NOT-S entails MODAL S or NOT-MODAL S.
- b. Optional Modality
 1. MODAL S entails S or NOT-S,
 2. NOT-MODAL S entails S or NOT-S,
 3. S entails MODAL S or NOT-MODAL S,
 4. NOT-S entails MODAL S or NOT-MODAL S.

Given the sets of entailments in (3.3), obligatory and optional modality are partly the same and partly different. They are the same in that their entailments (1) and (4) are the same, but they are different in that their entailments (2) and (3) are different.

The entailments given in (3.3), and all logical entailments are *categorical*. For example, according to the entailments in (1), if MODAL S, then S or NOT-S, and according to the entailments in (4), if NOT-S, then MODAL S or NOT-MODAL S. However, human experience is not categorical, but *deterministic* (Luelsdorff 1994b, 1994c). For example, MODAL S \rightarrow (determines) S might be more frequent than MODAL S \rightarrow NOT-S or NOT-MODAL S \rightarrow NOT-S might be less frequent than MODAL S \rightarrow S. Moreover, entailment value is determined by entailment context. For example, it may be the case that John can swim, but Mary cannot, or it may be the case that John can swim, but that he cannot swim the Channel. In the first case, the choice of subject (*John, Mary*) and the choice of the predicate (*swim*) determine the affirmation and negation of the modality (*can, cannot*). In the second case, the affirmation and negation of the modality (*can, cannot*) is determined by the choice of subject (*John*), the choice of predicate (*swim*), and the choice of complement (*empty, the Channel*).

Since entailments are not categorical but deterministic, we refer to entailments as “determinacies.” According to determinacy form (DF), some subject x determines some predicate y , when the determinacy $x \rightarrow y$ is bound by zero or more binders z , with some measure of accuracy I and some measure of completeness C , where I and C are frequency-based measurements. Determinacy form (DF), the centerpiece of determinacy grammar (DG), is defined in (3.4).

(3.4) Determinacy Form (DF)

$$x, z \rightarrow y, I = m \text{ and } C = n, \text{ where } I = N(xy)/N(x) \text{ and } C = N(xy)/N(y).$$

Determinacy I and C are independent measures whose values always fall between 0.00 and 1.00.

Modal form (MF) is a special case of determinacy form, namely, DF in which x is a proposition (PROP1), which may or may not be modalized, y is a proposition (PROP2), which may or may not be modalized, and z is a complex binder consisting of B1, a system of knowledge and belief KB, and B2, the values of one or more of the modal meanings given in (3.1), i.e. the obligatory modals P and A, and the optional modals R, I, O, N, H, and D. MF is given in (3.5).

(3.5) Modal Form (MF)

$$\text{PROP1, B1, B2} \rightarrow \text{PROP2, I = m and C = n, where} \\ \text{PROP = proposition, B1 = system of knowledge and belief,} \\ \text{and B2 = P, A, R, I, O, N, H, and D.}$$

Any situation having MF is a modal situation (MS). Two major sorts of MSs can be distinguished, MS1 and MS2. MS1 are modal situations in which the modalities B2 are acquired, therefore relating to the origin or genealogy of modality, including MSs that are enabling (i.e. making POSSIBLE and making ABLE), obliging (creating OBLIGATION), necessitating (creating NECESSITY), permitting (giving PERMISSION), habituating (developing characteristics, forming HABITS), and daring (disobeying, acting at RISK to oneself or others). MS2 are modal situations in which the modals, having been acquired in MS1, are known and used in specific and general modal situations.

In principle, the reasoning involved in MS1 and MS2 can be from specific to general (induction), general to specific or general to general (deduction), or specific to specific (analogy). Language learning by analogy is argued in Luelsdorff (1994a), and problem solving by analogy is argued in Holyoak and Thagard (1995).

The emergence of modality can be investigated developmentally or historically. According to Stephany (1995), both epistemic and deontic modality are attested in the earliest stages of language development, but “the non-epistemic function at first clearly predominates [...] one of the reasons for the earlier development of deontic as compared to epistemic modality.” She observes that children first use modal verbs or the subjunctive mood only to express deontic and dynamic modal meanings, and that epistemic adverbs (such as *maybe, probably, and possibly*) are almost absent from early child speech. Moreover, according to Stephany, “the relative chronology of the development of deontic and epistemic modality in language acquisition agrees with the earlier development of language,” which she explains in terms of the egocentricity of the preoperational child, rather than in terms of linguistic complexity. In Stephany’s words, “First and foremost, young children’s social status, as well as their physical condition favour their concern with norms for actions and the possibility of performing them, then attainment of desired states of affairs with the help of others, rather than the validity of statements.” Finally, Stephany notes the limited use of epistemically modalized utterances in speech addressed to young children.

If Stephany is correct, general principles of cognitive development explain the dominance of deontic and dynamic modality over epistemic modality in language ontogeny. However, we think that a re-examination of the question is called for. For one, as we have argued, the epistemic modal POSSIBLE and the dynamic modal ABLE are *obligatory* conditions on the occurrence of an event, whereas the deontic modalities of INTENTION, OBLIGATION, and NECESSITY are *optional*. For example, the truth of "Mary is playing" requires the truth of "It is POSSIBLE for Mary to play" and "Mary is ABLE to play," even if there is no *explicit* occurrence of "possible" or "able" in the utterance. In fact, "Mary is playing" alone determines both "It is possible for Mary to play" and "Mary is able to play," each with an accuracy of 1.00. Secondly, the semantics and syntax of epistemic modality may be indeed more complex than that of deontic modality. If so, then the later emergence of epistemic modality could also be explained by the Complexity Theory of Language Development (Luelsdorff 1991). After all, we can only say "Mary should play" (deontic), whereas we can say all of "It is possible for Mary to play," "Mary can play," "For Mary to play is possible," and "Possibly, Mary can play," etc.

The frequency-based measures of determinacy I and C not only determine the several degrees of epistemic and deontic modality, but also all other linguistic structures having to do with the relations of priority (few-many, less-more, earlier-later, before-after, etc.) (Luelsdorff 1994b). A larger inventory of such structures is given in (3.6).

(3.6) Priorities as Frequencies

- a. Epistemic modalities: *possible, probable, certain*
- b. Deontic modalities: *should, ought to, must*
- c. Capability modalities: *might, may; could, can*
- d. Tenses: Future, Present, Past
- e. Aspects: To-Future, Progressive, Perfect
- f. Comparison of adjectives: positive, comparative, superlative
- g. Comparison of adverbs: positive, comparative, superlative
- h. Articles: indefinite, definite
- i. Number: singular, plural
- j. Cardinal numbers: *1, 2, 3, ..., n*
- k. Ordinal numbers: *first, second, third, ..., nth*
- l. Demonstratives: *this, that; here, there*
- m. Frequency adverbs: *never, sometimes, always*
- n. Durative adverbs: *(for) a short while, (for) a long time*
- o. Quantifiers: *none, some, all*
- p. Lexical series: *poor, good, excellent*
- q. Degree words: *not so, somewhat, rather, quite*
- r. Answers: *no, maybe, yes*

Clearly, much work remains to be done. The meaningful questions that could be answered include the following.

If it is the case that some modalities (POSSIBILITY, ABILITY) are obligatory while other modalities (INTENTION, OBLIGATION, NECESSITY; HABIT, DARE) are optional, it would seem to follow that the obligatory modalities must be acquired before the optional. For example, if POSSIBILITY and ABILITY determine INTENTION, then it ought to be the case that the former (whether implicit or explicit) become available before the latter.

Second, modalities can be affirmed, negated, and graded, as can the propositions they modalize. Evidently, at least implicit obligatory modality is needed in order for any proposition to be able to represent an event. If propositional affirmation appears before propositional negation, and propositional negation before propositional gradation, it ought to be the case that modal affirmation appears before modal negation, and modal negation before modal gradation. For example, *ex hypothesi*, "can" is learned before "cannot," and "cannot" is learned before "really able," and "really able" is learned before "quite unable."

Third, some modals must be learned before others. For example, within the category of obligatory modality, it could be that ABILITY emerges prior to POSSIBILITY and, within the category of optional modality, it could be that PERMISSION is learned before (individual) OBLIGATION, and (individual) OBLIGATION is learned before (communal or societal) NECESSITY. Finally, it could be that the modalities for HABIT (*used to, would*) and DARE (*dare, dare not*), the former involving duration or repetition, the latter involving risk-taking and danger, are learned relatively late.

Fourth, given the distinctions between modalities that are implicit (*Pierre speaks French*) and modalities that are explicit (*Pierre can speak French*) and modalities that are intrinsic (*Fish swim, Fish can swim*) and modalities that are extrinsic (*Boris plays tennis, Boris can play tennis*), it can be asked if the implicit are acquired before the explicit (or vice versa) and of the intrinsic are acquired before the extrinsic (or vice versa).

These questions seem meaningful and the associated hypotheses testable. *Mutatis mutandis*, the same questions can be asked in the cases of second language acquisition, the developmental and acquired language disorders, and normal modal attrition in forgetting and aging.

4. Conclusion

To conclude, much valuable work has been done on the modals, but this work often amounts to little more than lists of modal forms and modal meanings with more or less appropriate exemplification and annotation. This approach is necessary but not sufficient, because the binders of the determinacies from form to meaning, and meaning to form, are left unknown or, if known, left unstated. This paper is an attempt to develop a more satisfactory position on the study of modal forms and meanings.

To this end, we inquire into modality and entailment, asking what a variety of modalized sentences entail and what kinds of entailments are involved. In particular, we propose and define entailment relations for Ability and Obligation, as well as Possibility, Probability, and Certainty. In some cases, we find the established entailment types of Meaning Proper, Presupposition, and Allegation to be involved. In other cases, however, we find that additional entailment types are at play. The discussion extends to entailment interaction among the modals, tenses, and aspects.

One central theme of the paper is that entailments in production and recognition may differ, whereby entailment monitoring can lead to editing of production and recognition. There can be individual differences in entailment production and recognition, as well as in entailment ambiguity detection and resolution.

A second central theme of the paper is that entailments are determinacies of the form (DF) $x, z \rightarrow y, I = m$ and $C = n$ and that modal form (MF) is a special case of DF, namely, $PROP1, B1, B2 \rightarrow PROP2$, where B1 is a system of knowledge and belief (KB), and B2 is an array of modal meanings.

There are modal situations (MS1) in which modal meanings and expressions are acquired and modal situations (MS2) in which once acquired knowledge of modality can be used. The claim that deontic and dynamic modalities are learned before epistemic modalities is critically examined, and several explicit suggestions are made for future modal research.

REFERENCES

- Chesnokov, S. V. and Luelsdorff, Ph. A. 1991. "Determinacy analysis and theoretical orthography". In Luelsdorff, Ph. A. (ed.). 231-262.
- Hajičová, E. 1980. "Presupposition and allegation". In Hajičová, E. and Sgall, P. (eds.). 99-122.
- Hajičová, E. and P. Sgall. (eds.). 1980. *Contributions to functional syntax, semantics, and language comprehension*. Prague: Academia
- Holyoak, K. J. and P. Thagard 1995. *Mental leaps: Analogy in creative thought*. Cambridge, Mass.: MIT Press.
- Luelsdorff, Ph. A. 1979. "Some modal freezes". *Anglistik und Englischunterricht: Semantik* 6. 131-136.
- Luelsdorff, Ph. A. (ed.). 1991a. *Complexity in language. Theoretical linguistics* (special issue) 17: 1-3.
- Luelsdorff, Ph. A. 1991b. *Developmental orthography*. Amsterdam-Philadelphia: John Benjamins.
- Luelsdorff, Ph. A. 1991c. "Reversals in complexity". *Theoretical linguistics* 17. 1-3. 263-289.
- Luelsdorff, Ph. A. 1994a. "Developmental morphographemics II". In Watt, W. C. (ed.). 141-182.
- Luelsdorff, Ph. A. 1994b. "Priority as frequency". *Folia phoniatrica et logopaedica* 46/6. 271-280.
- Luelsdorff, Ph. A. 1994c. "Determinacy experience". *Folia phoniatrica et logopaedica* 46/6. 281-287.
- Ramat, A. G. and Galéas, G. C. (eds.). 1995. *From pragmatics to syntax: Modality in second language acquisition*. Tübingen: Gunter Narr.
- Stephany, U. 1995. "Function and form of modality in first and second language acquisition". In Ramat, A. G. and Galéas, G. C. (eds.). 105-120.
- Watt, W.C. (ed.). 1994. *Writing systems and cognition: Perspectives from psychology, physiology, linguistics and semiotics*. Dordrecht: Kluwer.