

# Temporal Reasoning with Aspectual Adverbs

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## 1. Introduction

Adverbs are aspectual when they refer to or quantify over the internal structure of an event. They may refer to the onset of an event, as in (1a-b) and (2a-b), describing John's current action as related to its starting point, or to its end, as in (1c-d) and (2 c-d), describing John's current action as related to its termination.

- (1) a. John was not yet reading.
- b. John was already reading.
- c. John was still reading.
- d. John was not reading anymore.

Aspectual focus adverbs, marked in English with specific stress and high pitch prosody, induce additional semantic complexity, contributing information about expected alternatives in various temporal parameters, as in (2).

- (2) a. John was STILL not reading.
- b. John was alREADY reading.
- c. John was STILL reading.
- d. John was NO LONGER reading.

In using aspectual focus adverbs the position of the current temporal reference point in the course of events is contrasted to later or earlier alternatives. With *already* in (2b) and *no longer* in (2d) the actual course of events is evaluated by the speaker as faster than expected. With *still not* in (2a) and *still* in (2c), in contrast, the actual course of events is evaluated as slower than expected. This tension between actual value and expected value is absent in the four regular aspectual adverbs *not yet* in (1a), the unstressed use of *already* and *still* in (1b, c) and with *not... anymore* in (1d).

Our central aim is to account for the validity of reasoning patterns involving focus adverbs in contexts where the temporal reference point may change during the process of interpretation of the premises. Consider the inference in (3), where the premises (3a, b) are presented in the order indicated, and (3c) is a valid conclusion (indicated by |=), but (3d) is invalid (indicated by ≠).

- (3) a. John is still not asleep.
- b. John is asleep.
- c. |= John is finally asleep.
- d. ≠ John is already asleep.

In dynamic semantics the dynamic information in (3b) changes the information state created by (3a): some of it is updated, whereas other information is not affected. The valid conclusion in (3c) preserves the focus information of (3a) ('slower than expected'), whereas in (3d) it is not preserved. Established expectations and attitudes are generally not affected when new factual information becomes available. This paper proposes a dynamic semantics of such temporal inferences, determining what is updated in the interpretation and what information is preserved. In order to capture the various informational dimensions involved in this dynamic reasoning a basic polarity grid is proposed, generalizing the distinction between positive and negative polarity of event -types. Corresponding to this polarity grid, a binary bit-string calculus is introduced, which is three-dimensional for the aspectual adverbs in (1), but five-dimensional for the focus aspectual adverbs in (2). This calculus serves first to characterize valid static temporal reasoning, i.e. inferences which concern one and the same information state. Valid dynamic temporal reasoning across changing contexts or information states, as illustrated in (3), is subsequently characterized by polarity reversal operations in this calculus.

## 2. Adverbs of aspect

### 2.1 The 3-D representation

Starting point of our analysis is the basic distinction between the positive polarity in (4a) and negative polarity in (4b), which is labeled POLARITY DIMENSION A in (5):

- (4) a. John is asleep <sleep, j, + >
- b. John is not asleep <sleep, j, - >
- (5) polarity dimension A: actual polarity
- A = 1           positive polarity:
- property is currently true
- A = 0           negative polarity:
- property is currently false

With *already* in (1b) and *still* in (1c) the actual polarity is positive (i.e. the current temporal reference point is located within the sleeping-event), whereas with *not yet* in (1a) and *not anymore* in (1d) the actual polarity is negative (i.e. the current temporal reference point is

located before or after the sleeping-event, respectively). However, these adverbs also involve two other polarity dimensions, namely the on/off transition represented in dimension B (6), and the speaker's perspective on the event, represented in dimension C (7).

(6) polarity dimension B: event-internal polarity transition

B = 1 beginning:

transition from negative to positive polarity

B = 0 finishing:

transition from positive to negative polarity

(7) polarity dimension C: speaker's perspective in describing the event

C = 1 retrospective:

looking backward to a past transition

C = 0 prospective:

(8)

	3-D POLARITY GRID	A	B	C
(4a)	John is asleep	1	-	-
(4b)	John is not asleep	0	-	-
(1a)	John is not yet asleep	0	1	0
(1b)	John is already asleep	1	1	1
(1c)	John is still asleep	1	0	0
(1d)	John is not asleep anymore	0	0	1

The composition of the paraphrases of *not yet asleep* as *will start sleeping* or *will fall asleep*, or in that of *not asleep anymore* as *having finished sleeping* or *having woken up* can straightforwardly be derived from the three different polarity dimensions, as in (9).

(9) a. not yet asleep

start sleeping (B=1)

not sleeping (A=0)

will be sleeping (C=0)

An important observation in connection with the polarity grid in (8) is that, although the interaction of three binary parameters yields eight logical possibilities ( $2^3$ ), only four of them are realized. Since the presuppositions of *start* and *finish* constrain combinations with the A polarity, e.g., in order to start some activity you must not now be engaged in it, the three dimensions are not logically independent. If the combinations 11 and 00 are called CONVERGENT, and 10 and 01 DIVERGENT, these constraints can be formulated as the entailments in (10-12).

(10) [(AB = convergent) => (C = 1)]

and [(AB = divergent) => (C = 0)]

(11) [(AC = convergent) => (B = 1)]

and [(AC = divergent) => (B = 0)]

(12) [(BC = convergent) => (A = 1)]

and [(BC = divergent) => (A = 0)]

This reveals a certain logical redundancy in the 3-D polarity grid, as two binary parameters would suffice to distinguish four expressions. But it is not a configuration of primary versus secondary parameters,

looking forward to a future transition

If (1a) is true, John is now not sleeping, but his falling asleep is imminent. If (1b) is true, John is now sleeping and he has just fallen asleep. Accordingly, the positive B-polarity of beginning (i.e. falling asleep) holds for *not yet* in (1a) and *already* in (1b). The negative B-polarity of finishing (i.e. waking up) holds for *still* in (1c) and *not anymore* in (1d), as (1c) entails not only that John is now asleep, but also that his waking up is ahead; similarly, (1d) entails that John is not now asleep and his waking up is past. Looking back to the past event, the retrospective adverbs *already* in (1b) and *not anymore* in (1d) get positive C-polarity, whereas the prospective ones, *not yet* in (1a) and *still* in (1c) get negative C-polarity. The polarity assignments are summarized in the 3-D grid in (8):

but rather a matter of mutual predictability: given the assignment of any combination of two parameters, the value of the third parameter can be predicted.

## 2.2 Static temporal reasoning

Representing the meaning of aspectual adverbs in the 3-D grid of polarities leads to a straightforward and intuitively appealing calculus of temporal inferences. Some simple static inferences, concerning one and the same context, are given in (13) and (14), where the aspectual adverb is eliminated for a simple polarity to remain in the conclusion.

(13) a. John is already asleep

= John is asleep

b. John is still asleep

= John is asleep

(14) a. John is not yet asleep

= John is not asleep

b. John is not asleep anymore

= John is not asleep

The validity of these inferences obviously depends on the preservation of the A-polarity. The sentences containing an aspectual adverb with a positive A-polarity, i.e. *already* (111) in (13a) and *still* (100) in (13b), entail the positive polarity sentence without aspectual adverbial. Those having an adverbial with negative A-value, i.e. *not yet* (010) in (14a) and *not anymore* (001) in (14b), entail the elementary negative polarity sentence.

A second type of static temporal reasoning relates to the internal negation of aspectual adverbs. A polarity reversal can be neutralized, if the original verbal predicate, e.g. *sleep* in (13-14) is simultaneously substituted by its contradictory predicate *be awake*, yielding an equivalence relation between *still* and *not yet* in (15), and between *already* and *not anymore* in (16).

- (15) a. John is not yet asleep  
        $\Leftrightarrow$  John is still awake  
       b. John is still asleep  
        $\Leftrightarrow$  John is not yet awake
- (16) a. John is already asleep  
        $\Leftrightarrow$  John is not awake anymore  
       b. John is not asleep anymore  
        $\Leftrightarrow$  John is already awake

### 2.3 Dynamic temporal reasoning

Static and dynamic temporal reasoning differ in that the latter crucially requires the update in information states to include the transition of the temporal reference point to a later one. The general pattern used for this type of reasoning takes as its first premiss the description with an aspectual adverb of a state holding at the first temporal reference point. The second premiss, presented later, indicates that a A-polarity transition took place at a later temporal reference point. The conclusion must contain a different aspectual adverbial describing the resulting state. Consider the dynamic inference pattern in (17).

- (17) a. John was still asleep.  
       b. John woke up.  
       c.  $\models$  John was not asleep anymore.

In order to account for the validity of (17) we need to distinguish between information which is modified or updated from one information state to the next, and information which remains stable across information states. In the 3-D representation the question is which parameters change their values from *still* in (17a) to *not anymore* in (17c). The second premiss in (17b), introducing a polarity transition, obviously switches C from 0 (i.e. prospectively looking towards a future falling asleep) to 1 (i.e. retrospectively looking back upon a realized falling asleep). From the constraints in (10-12) we know that as soon as the value for one parameter is reversed, the value of one (and only one) of the other two parameters must be reversed as well. In this case, the reversal of the C-parameter correlates with the A-parameter for the actual polarity. The value of the B-parameter, however, must be kept constant. In other words, temporal reasoning can only concern one single polarity transition consisting of adjacent and opposite polarities. The temporal inference in (17), reversing the A- and C-values while preserving the B-value, is schematically represented in (18):

- |         |                    |       |
|---------|--------------------|-------|
|         |                    | A B C |
| (18) a. | still asleep       | 1 0 0 |
| b.      | wake up            | 1/0   |
| c.      | not asleep anymore | 0 0 1 |

The examples in (19) illustrate the other two combinatorial possibilities of changing two values,

while preserving the third in temporal reasoning, both yielding invalid patterns.

- |      |                                    |       |
|------|------------------------------------|-------|
| (19) |                                    | A B C |
| a.   | John was not yet asleep.           | 0 1 0 |
| b.   | John fell asleep                   | 0/1   |
| c.   | $\neq$ John was still asleep       | 1 0 0 |
| c'.  | $\neq$ John was not asleep anymore | 0 0 1 |

Although in (19c) the A-value of the actual polarity is reversed with *still*, the prospectivity of the C-parameter is not changed accordingly. Instead, the B-transition of beginning is replaced by that of finishing, hence jumping forward, as it were, too far within the event for a valid inference. An even bigger jump forward occurs in (19c'): although the C-value is switched to retrospectivity, the actual polarity of the A-parameter is not, while the B-parameter is switched from beginning to finishing. As a consequence, two A-polarity transitions are crossed in one move, resulting in an invalid inference. If (19c') were not a conclusion based on an inference, but rather added as new information, it would cause the polarity in A to be reversed again, and switch the B-dimension to the endpoint (waking up), and adjusting accordingly the C-dimension to retrospective. This constitutes a perfectly acceptable dynamic update after (19 a + b). This is an important illustration of how the 3-D calculus models the difference between inferred information and new information used for an update, conflated in other systems of dynamic temporal semantics (e.g. DRT). Another invalid inference on the basis of the two premisses in (19a-b) is given in (20):

- |      |                                 |       |
|------|---------------------------------|-------|
| (20) |                                 | A B C |
| a.   | John was not yet asleep.        | 0 1 0 |
| b.   | John fell asleep                | 0/1   |
| c.   | $\neq$ John was already asleep. | 1 1 1 |

Strictly speaking the inference in (20c) runs perfectly parallel to that in (17-18): A and C are reversed, whereas B remains constant. However, the retrospective character of *already* conflict with the prospective character of (20a) and the presuppositions of (20b), all three of which concern the polarity of John's falling asleep. Presupposition accommodation apparently succumbs to dynamic updates of factual information in temporal inferences.

## 3. Adverbs of aspectual focus

### 3.1 The 5-D representation

Within the 3-D polarity system in section 2, the two adverbs *not yet* and *still not* in (21) would both be assigned 010, as the two adverbs *not anymore* and *no longer* in (22), both getting 001.

- (21) a. John was not yet reading.  
       b. John was STILL not reading.
- (22) a. John was not reading anymore.  
       b. John was no LONGER reading.

The focus dimension which distinguishes *STILL not* in (21b) from *not yet* in (21a) introduces the focus meaning SLOWER THAN EXPECTED, that cannot be represented in the 3-D polarity system. Similarly, the focus meaning FASTER THAN EXPECTED, which

distinguishes *no LONGER* in (22b) from *not anymore* in (22a) remains unaccounted for. Therefore, two new polarity dimensions are added to the grid in (23) and (24), each capturing the focus meaning of expected alternatives.

(23) polarity dimension D:  
evaluation of speed

D = 1 positive focus

course of events is earlier/faster than expected

D = 0 negative focus

course of events is later/slower than expected

(24) polarity dimension E: expected alternative is counterfactual

E = 1 primary focus

expected polarity is opposite to the actual polarity in A

E = 0 secondary focus

expected polarity is identical to the actual polarity in A

The meaning of the focus adverbs in (21b) and (22b) is captured in terms of a 5-D system, whereas their counterparts in (21a) and (22a) only get assigned a three-dimensional bit-string. The simple and focus assignments to aspectual adverbs are integrated in the table in (25):

(25)

	5-D POLARITY GRID	A	B	C	D	E
(4a)	John is asleep	1	-	-	-	-
(4b)	John is not asleep	0	-	-	-	-
(1a)	John is not yet asleep	0	1	0	-	-
(1b)	John is already asleep	1	1	1	-	-
(1c)	John is still asleep	1	0	0	-	-
(1d)	John is not asleep anymore	0	0	1	-	-
(2a)	John is STILL not asleep	0	1	0	0	1
(26a)	John is already almost asleep	0	1	0	1	0
(2b)	John is ALREADY asleep	1	1	1	1	1
(26b)	John is finally asleep	1	1	1	0	0
(2c)	John is STILL asleep	1	0	0	0	1
(26c)	John is already almost awake	1	0	0	1	0
(2d)	John is already NO LONGER asleep	0	0	1	1	1
(26d)	John is finally awake	0	0	1	0	0

The English aspectual focus adverbs form a quite richly lexicalized system, though other natural languages may constitute even richer lexicalized aspectual systems (cf. Smessaert (1999a)). If the polarity the speaker expected matches the A polarity, the speaker's evaluation of the speed of the action is expressed lexically, by using *already almost* if it is faster than expected (D=1), and *finally* if it is slower than expected (D=0). To convey counterfactual speaker's expectations conflicting in A and D, a focus adverb with prosodic marking must be used.

- (26) a. John is already almost asleep  
b. John is finally asleep  
c. John is already almost awake  
d. John is finally awake.

To illustrate the assignments of 01010 to *already almost* and 00100 to *finally* P' their paraphrases are decomposed in (27a-b):

- (27) a. already almost asleep

not sleeping (A=0)

start sleeping (B=1)

in future (C=0)

faster than expected (D=1)

expecting awake (E=0)

b. finally awake

not sleeping (A=0)

end sleeping (B=0)

in the past (C=1)

slower than expected (D=0)

expecting awake (E=0)

The table in (25) shows that the two focus parameters, D and E, are logically independent: all four combinatory binary assignments to DE -- i.e. 00, 01, 10 and 11 -- are realized. If the values for DE are composed with the C-parameter, however, only four of the eight logical CDE combinations turn out to be available. Interestingly, the constraints formulated in terms of convergent (11 or 00) versus divergent (01 or

10) polarities in the analogous case with 3-D ABC in (10-12) can be applied to the 5-D grid as well.

Consider the entailments in (28) to (30):

(28) [ (DE = convergent) => (C = 1) ]

& [ (DE = divergent) => (C = 0) ]

(29) [ (CE = convergent) => (D = 1) ]

& [ (CE = divergent) => (D = 0) ]

(30) [ (CD = convergent) => (E = 1) ]

& [ (CD = divergent) => (E = 0) ]

The key entailments here are those in (28), since they can be conflated with the ones in (10) to yield the 5-D constraints in (31): (31)

[(ABconvergent)=>(C=1)=>(DE convergent)]

[(AB divergent) => (C=0) => (DE divergent)]

The fact that only eight out of the thirty-two logical possibilities ( $2^5 = 32$ ) for a 5-D representation are available in (25) is the result of multiplying the ABC-restrictions in (10) with the CDE-restrictions in (28). The pivotal role of the C-parameter of speaker's perspective (i.e. prospectivity versus retrospectivity) in formulating these restrictions will be confirmed by its role in accounting for dynamic temporal reasoning in section 3.3. Although the entailments in (31) still reveal a certain redundancy in the 5-D polarity grid, since three binary parameters suffice to distinguish eight expressions, it is, once again, not a configuration of primary versus secondary parameters, but rather a matter of mutual predictability: given the assignment of any combination of three parameters, other than ABC or CDE, the value of the fourth and fifth parameter can be predicted. This may be regarded as a certain amount of 'semantic redundancy' in ordinary language signals, which safeguards human informational exchanges for misunderstandings and alleviates the hearer's information processing load.

### 3.2 Static temporal reasoning

As was already demonstrated with the simple adverbs in the first section, the key advantage of the polarity representation of the meaning of aspectual adverbs is that it allows a straightforward account of temporal inferences. With the static inferences, which concern one single context, the most trivial examples are those whose validity depends on the preservation of the A-polarity. The examples given in (32) and (33) are the focus counterparts of the simple inferences in (12) and (13) and the lexicalization of *not asleep* as *awake*:

(32) a. John is already almost awake

=> John is asleep

b. John is STILL asleep

=> John is asleep

(33) a. John is STILL not asleep

=> John is not asleep

b. John is already awake

=> John is not asleep

The sentences containing a focus adverbial with A = 1, such as *already almost not-P (awake)* (10010) in (32a) and *STILL* (10001) in (32b), entail the positive polarity sentence without aspectual adverbial (adverbial elimination). Those having an adverbial with A = 0, such as *STILL not* (01001) in (33a) and *already not-P*

(00111) in (34b), entail the elementary negative polarity sentence.

The original inferences from ABC to A in (12-13) could also be paraphrased informally as "ignore the last two parameters, but preserve everything else". The same instruction can be applied to the 5-D representation: in addition to the inferences from ABCDE to A in (32-33), a second type of inferences reduces ABCDE to ABC, i.e. from a focus adverbial to a simple aspectual adverbial. In other words, eliminating the focus parameters DE, but preserving the ABC values yields a valid inference, as is illustrated in (34) and (35) below.

(34) a. John is already almost awake

=> John is still asleep

b. John is STILL asleep

=> John is still asleep

(35) a. John is STILL not asleep

=> John is not yet asleep

b. John is already awake

=> John is not asleep anymore

Both (34a) and (34b) preserve the ABC values in the 5-D representation, 10010 and 10001 respectively, while reducing to the 3-D representation of *STILL*, 100. Similarly, the 010 assignment of *not yet* in (35a) is preserved in the 5-D of *STILL not*, i.e. 01001, whereas the 001 of *not anymore* is preserved in the 00111 assignment of *already not-P*. The inference in (36a), which is trivial, and that in (36b), which yields a focus conflict, do preserve in both cases the ABC values of 111 are preserved, but indicate that the meta-logical constraints of non-triviality and consistent expectations should already rule them out from the valid patterns.

(36) a. John is ALREADY asleep

=> John is already asleep

b. John is finally asleep

≠ John is already asleep

The mechanism of internal negation naturally extends to the domain of focus adverbs, where the AB values are switched, but the CDE-parameters are preserved. Consider the equivalences in (37) and (38) where the predicate-substitution neutralizes the internal negation on the adverbs.

(37) a. John is STILL not asleep

⇔ John is STILL awake

b. John is STILL asleep

⇔ John is STILL not awake

(38) a. John is already almost asleep

⇔ John is already almost no longer awake

b. John is already almost no longer asleep

⇔ John is already almost awake

Aspectual adverbs may not freely be

composed in ordinary English, as the complex *already almost no longer P* is far less natural than its equivalent *already almost not-P* in (38 a, b).

### 3.3 Dynamic temporal reasoning

In dynamic temporal reasoning the crucial question is what information is modified or updated in going from one information state to the next, and what information is stable across information states. Consider the valid inference pattern in (39), where the first premiss

contains a focus adverbial, the second premiss induces a polarity transition in C, and the conclusion describes

- (39) a. John was still not asleep.  
b. John fell asleep.  
c. John was finally asleep.

As was observed with the dynamic inferences in (17) and (19), the A polarity transition in (39b) also causes a switch of the C-value from 0 (prospectivity/future) to 1 (retrospectivity/past). The constraints in (31) furthermore require that either the D- or the E-parameter is reversed, but not both. Since the D-

the resulting state with a different focus adverbial

	A	B	C	D	E
0	1	0	0	1	
0/1					
1	1	1	0	0	

parameter (evaluation of speed) is unrelated to the A polarity, whereas the E-parameter is related to the A polarity (counterfactual expectation), it is obviously the latter that is reversed along with the A- and C-values. The set of validity conditions are summarized in (40):

(40)	A dynamic temporal inference with focus adverbials is valid if and only if	
	1. the C-value is switched from 0 to 1:	C = perspective
	2. the A- and E-values are reversed:	A = actual polarity E = (counter)factualty of expectation
	3. the B- and D-values are preserved:	B = polarity transition D = expectation/evaluation

Consider the inference in (41) which differs from (39) in two respects: it relates to the polarity transition of

finishing, instead of beginning (B= 0), and it has faster, instead of slower, evaluation of speed (D=1).

		A	B	C	D	E
(41)	a.	John was already almost awake.	1	0	0	1
	b.	John woke up.	1/0			
	c.	John was already no longer asleep.	0	0	1	1

According to the constraints in (28)-(31) the reversal of the C-value needs to be combined with that of either A or B (but not both), as well as with the reversal of either D or E (but again not both). This means that the valid pattern of (41), which reverses the three ACE-values, is only one out of four combinatorial

possibilities, the other three being ACD, BCE and BCD. The first two of these only deviate from the valid ACE configuration in one dimension, whereas the latter deviates in two dimensions. The inferences in (42) illustrate the ACD and BCE pattern

- (42) a. John was STILL not asleep.  
b. John fell asleep.  
c. ≠ John was ALREADY asleep.  
c'. ≠ John was finally awake.

0	1	0	0	1
0/1				
1	1	1	1	1(ACD)
0	0	1	0	0(BCE)

With *already* in (42c) A and C are properly reversed, but D (speed) is reversed, instead of E. As a consequence, the original negative evaluation associated with *STILL not*, i.e. *LATER THAN EXPECTED*, is incorrectly turned into the positive evaluation associated with *ALREADY*. However, this discrepancy with respect to the E-parameter is definitely not as bad as the one with the A-parameter in (42c') with *finally not-P*. Although in this case the negative the D-

parameter is preserved, switching B instead of A crosses two polarity transitions in one step, i.e. from being awake before falling asleep all the way into being awake after subsequently waking up. The invalid inference pattern in (43), which deviates from the valid ACE configuration both in A and E, combines the problems of (42c) and (42c'): the slow speed evaluation is not maintained and two polarity transitions are crossed simultaneously.

- (43) a. John was still not asleep.  
b. John fell asleep.  
c. ≠ John was already NO LONGER asleep.

0	1	0	0	1
0/1				
0	0	1	1	1(BCD)

The basic dynamic pattern of (39) can get a number of static extensions, as illustrated in (44):

- (44) a. John was STILL not asleep.  
b. John fell asleep.  
c. John was finally asleep.  
d. John was finally no longer awake.  
d'. John was already asleep.  
e. John was no longer awake.

0	1	0	0	1	
0/1					
1	1	1	0	0	(ACE)
0	0	1	0	0	(AB + P)
1	1	1			(keep ABC)
0	0	1			(AB + P or keep ABC)

The chain of valid temporal reasoning demonstrates that the conclusion of the dynamic reasoning in (44c) can function as the top of a lattice structure, which represents the valid static reasoning patterns. The focus construction in (44d) then represents the middle node on the left side, where the dynamic reversal of the ACE-values is followed by the static reversal of the AB-values in combination with the substitution of the

opposite predicate. Hence, switching the adverbial BCE-values and negating the predicate yields a perfectly valid dynamic inference. The sentence in (44d'), on the other hand, corresponds to the middle node on the right side: after the ACE-reversal one reduces the 5-D to the 3-D level, preserving the ABC-values. Finally, the sentence in (44e) constitutes the bottom of the lattice structure. It is either the result of

reducing the focus in (44d) to a simple aspectual form, or else the result of reversing the AB-values and the predicate of the simple form in (44d').

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