Event-calculus semantics of Polish aspect

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Cóż on robił *przez ten rok? Wszystko, albo prawie wszystko.*
A cóż zrobił*? Nic, albo prawie nic.*

What was he doing *during that year? Everything, or almost everything.*
And what has he done*? Nothing, or almost nothing.*

(following Herzen)

Contents

1 Introduction

Aspect and tense are natural languages' principal devices for expressing temporal relationships. Aspect is particularly important in languages which have grammaticalised it, such as the Slavic languages, among them – Polish. Usually it is said (by linguists [9], [28], [37]) that while tense expresses the location in time of some occurrence in question, aspect carries the speaker's subjective temporal perspective on it. But usually aspect is used (by native speakers [25]; cf. 2.1) to indicate some objective temporal information about the occurence, such as whether it has been completed. These views seem to be as correct as they are incompatible. Matters are not made easier by the complicated morphology of the Polish verb, which obscures possible explanations.

This work's purpose is to develop a semantics of the Polish aspect in the framework of van Lambalgen and Hamm's [33] event calculus. It may be hoped to relieve the discomforting situation just mentioned. Besides, it can be expected – as always when a formal semantics is developed for a fragment of a natural language – that the phenomenon at hand, viz. aspect, will be elucidated, and the theory used, viz. event calculus, will be vindicated by a successful application. In particular, e.g. arguments in favour of dividing the Polish verbs into Aktionsarten (cf. 2.2.2) and for treating the notion of planning as underlying the semantics of aspect (cf. 5.3) will be given.

The layout is as follows:

- In Chapter 2 the data are described, namely in 2.1 the basic informations about the Polish verbal aspect are given, while in 2.2 a more systematic treatment is introduced, following Młynarczyk [42].

- In Chapter 3 we review, rather critically, several attempts at providing a semantics for Polish aspect. In particular, we argue that the most promising for explaining the data as well as cognitively grounded approach is the one offered by the event calculus.

- Accordingly, Chapter 4 is devoted to introducing the event calculus formally, following [33].

- The gist of the thesis is to be found in Chapter 5, where the formal apparatus is applied to the data. The semantics thus developed in 5.2 is summarised in 5.3, along with the main conclusions of the work. Concrete examples of computations doable in the calculus are discussed in 5.4.

- Chapter 6 recapitulates the outline and the main results of the thesis.

2 Polish verbal aspect

Our topic not being philosophical, we shall not do unwisely by introducing the explanadum first. Hence, in 2.1 the data will be described from a possibly unbiased perspective – which, being thus atheoretical, might appear rather confusing. However, purposefully so, since indeed the data seem prima facie quite bewildering, both to the linguist and to the native speaker. The confusion will be relieved in 2.2 by introducing Młynarczyk's [42] aspectual classification of Polish verbs, which not only clarifies the data, but also provides the canvas for our further semantic investigations.

Preliminary remarks are in order here. Firstly, no general definition of aspect or of aspectual values will be attempted in this work. Such definitions are notoriously difficult to formulate; some can be found in Comrie's [9] textbook – along with a general introduction to aspect – and in [28]. It can be hoped, though, that this work will, by investigating their particular workings, shed some light these general notions. Secondly, *verbal* aspect is discussed in this chapter, since it is a phenomenon grammaticalised in Polish (as in other Slavic languages) on the lexical level. This perspective will be sustained throughout, but not without a possibility of extending to the sentential level (cf. 3.3).

Moreover, we will translate the Polish past tense into *either* English Simple Past or Present Perfect, as will appear stylistically more adequate. However, while Present Perfect will seem more adequate in some translations (e.g. to suggest the completion of an activity), it will *never* be intended as stressing the reference to the present time – as it normally does in English. In other words, the translations given in Perfect have to be understood as unfaithful insofar the Polish originals (in the past tense) involve no intrinsic reference to the present time. For more details about tenses, see 5.1.

2.1 The linguistic data

The principal aspectual opposition of perfective and imperfective will be described first, hinting at the problems with accounting for it at the simple morphosyntactic or lexical-semantic level. Secondly we will consider the status of the other aspectual value grammaticalised in Polish, that is, the habitual. We will end with some remarks on tense and markedness that will be needed later on. For more details on Polish grammar, historico-linguistic data and historical details on the study of aspect, [42] can be consulted. A recent major study, albeit in Polish, is [8].

2.1.1 Perfective and imperfective

The aspectual values of perfectivity and imperfectivity are ubiquitous in Polish, since each verb of that language can be ascribed one of them. Imperfectives can take any of the three tenses available in Polish, namely past, present and future; perfectives cannot take the present tense. Let us consider an imperfective in the past tense:

(1) *czytałem* ('I have been, I was reading')

Now, it seems that the intuition of a theoretically unbiased native speaker is that an imperfective normally has its perfective equivalent; that is to say, Polish verbs come in imperfecitve-perfective pairs. Usually, the perfective is formed by adding one of a number of prefixes that stem from prepositions. Thus of (1) one would prima facie say that its perfective form is:

(2) *przeczytałem* ('I have read')

where *prze-* – stemming from *przez*, 'across, through' – indicates that reading has been completed.

However, the perfectivising prefix need not be semantically empty, as it is in the above example; to the contrary, it may contribute new information. For instance, in some contexts the completion of the process of reading referred to by *czytałem* might be, to name a few possibilites:

(3) *odczytałem* ('I have read (aloud)', 'I have figured out by reading')

(4) *wyczytałem* ('I have read out (e.g. a name from a list etc.)', 'I have learned (a piece of trivia) by reading')

(5) *sczytałem* ('I have read off (e.g. a code from an object etc.)')

A school grammarian would answer that these are perfective forms of other verbs than (1), namely of the imperfectives *odczytywałem*, *wyczytywałem* and *sczytywałem*, respectively. These, though, are morphologically similar to another form corresponding to (1), namely:

(6) *czytywałem* ('I used to read (from time to time)')

the habitual; see 2.1.2.

Moreover, prefixation is not the only means of perfectivisation. In some cases, a suffix like *-ną-*, which has no meaning on its own, is used for deriving the perfective, for instance:

(7) *kopałem* ('I was, I have been kicking')

(8) *kopnąłem* ('I have kicked (once)')

But also the other way round:

(9) *zapytałem* ('I have asked (about something)')

(10) *zapytywałem* ('I was, I have been asking (about something)')

some imperfectives arise from perfectives by suffixation (e.g. *-wa-* and a vowel change) similar to that by which the habitual (6) can be derived by from the perfective (1).

Summing up, the aspectual distinction in Polish is not a syntactic one, because it does not account for a regularity in the morphology of the verb. Prefixation may give rise to a perfective, but also add some meaning beyond changing the aspectual value; suffixation can give rise to a perfective, but also to a habitual. Slavic scholars may then deliberate, whether some particular pre- or suffixes do give rise to 'genuine' aspectual pairs, while others change the meaning [11]. That, however is unavoidably arbitrary, since one can define some particularly well-behaved subclass of verbs to be 'genuine', but that will not be much of an explanation of the aspectual system. Hence the received view is that, in spite of the intuition of pairing, the perfective and imperfective forms are generally distinct lexical items.

To the contrary, the aspectual distinction is clearly a semantical one; indeed, a seventh-grade textbook says:

> We distinguish imperfective and perfective verbs. Imperfective verbs denote the duration of an activity or a state in the present, the past or the future. ... Perfective verbs denote the completion of an activity or of a state in the past or in the future. They occur in two tenses: the past and the future. [25, pp. 70–71]

(To avoid confusing the young reader, 'states' mean not the Aktionsart of states here, but rather activities performed by inanimate agents.) Thus other Slavists would try to explain the aspectual system by pondering the subtleties of lexical semantics [7]. But this approach is not much more promising, because there is no overt regularity in the meanings either. The prefixes do have a semantic 'flavour' inherited from the prepositions they originated from, but it is extremely vague. Sometimes it is so weak that the prefix is semantically empty, and adding it only perfectivises the verb (as in *czytałem*, *przeczytałem*) – and sometimes it does alter the meaning (as in *czytałem*, *wyczytałem*)[1]. But the alteration may be very slight and not obvious even for native speakers. For instance, what is the difference between *pocałować* and *ucałować* (both 'to have kissed', but the latter is of slightly higher register); is it the same as between *pokochać* and *ukochać* (both 'to have started loving', but again they differ in some shade of meaning)? To attempt explaining the aspectual system by investigating such questions would be a Sisiphus' task.

Therefore neither morphology nor lexical semantics alone can systematise the Polish aspectual system so as to account for the intuition of aspectual pairing. Indeed, on both approaches we would be forced to regard an imperfective and a corresponding perfective as distinct items. But that would be unsatisfactory, because there undoubtedly is a systematic connection between the meanings of corresponding perfectives and imperfectives – and to account for it is an objective of this work. For that, we need another approach to systematising the aspectual system; it seems that one such approach is the aspectual classification proposed by Młynarczyk [42] (cf. 2.2).

2.1.2 Habitual

From some, but not all, Polish imperfectives a habitual form can be derived by the formant *-yw-* or *-iw-*; for instance, corresponding to (1):

(6) *czytywałem* ('I used to read (from time to time)')

These habituals always have an iterative reading – unlike, for instance, the English habitual 'used to ...'. Not all imperfectives have corresponding habituals; ones that are unlikely to have an iterative reading, for instance *palić się*, 'to be burning' do not. Nor are there any habitual perfectives – unlike, for instance, in Bulgarian [9, 1.2.1]). Therefore in terms of school grammar habituals are a subclass of imperfectives. Yet on the whole, restricting the discussion of Polish aspect to the perfective-imperfective opposition and neglecting the habitual forms is not likely to be misleading or losing generality. Thus since this restriction significantly simplifies the data, we will follow Młynarczyk [42] in assuming it.

[1] Such perfectives with added meaning are called 'Aktionsartal' by some Slavists; cf. [11], [42].

However, any imperfective, regardless of whether there is a corresponding grammatical habitual, can have an iterative or habitual reading, for instance:

(11) Samochody to nie Ruscy kradną, tylko robią to właśnie
cars$_{acc}$ this not Russians steal$^{ipfv}_{3.pl.}$ but do$^{ipfv}_{3.pl.}$ this just
Polacy.
Poles

It's not the Russians who steal cars, indeed Poles do it.[2]

quite like e.g. the English Simple tenses can, as the translation evinces (cf. [10, p. 39]). Ones like *palić się* mentioned above, though, only acquire the iterative reading when coerced by an adverb like 'usually' etc. Again, for clarity of presentation we will ignore these readings throghout, even though in principle they could be incorporated in our semantics. In particular, in 5.2.6 we will discuss the few perfectives, such as *pozabijać*, 'to kill several times', that have only the iterative reading – thus seeming to be derived from the iterative readings of the corresponding imperfectives.

2.1.3 Markedness and tense

In the opposition of imperfectivity and perfectivity, the latter is clearly the marked element (thus the linguistic communis opinio [42, p. 46], [9, 6.1], as well as speaker intuitions). One consequence of this is that an imperfective's being true does not determine the truth value of the corresponding perfective, while a perfective usually cannot be true when the imperfective is false, e.g.:

(12) * Wypili, chociaż nie pili.
drunk$^{ep\text{-}pfv}_{3.pl.}$ though not drunk$^{ipfv}_{3.pl.}$

They have drunk up, even though they haven't been drinking.

Indeed, a perfective can always be replaced by an imperfective – the meaning may be less explicit, but it will not be contradicted; but not conversely.

[2] In glosses, the verbs' aspect is given in superscript; in subscript, person and number is given. The tense is given by the tense of the English verb or when that would be ambiguous, in the subscript. Apart from that only nouns' cases other than the nominative are given. The following abbreviations are used: *perfectives*, depending on the formant (cf. 2.2.2): ep-pfv – empty-prefix; mp-pfv – morphonological-change; *po*-pfv – delimitative-po-, sup-pfv – suppletive (cf. 2.2.3); *imperfectives*: ipfv, or: sec-ipfv – secondary imperfective; hab – a habitual (cf. 2.1.2); *cases*: acc – accusative; gen – genetive; dat – dative; loc – locative; instr – instrumental. The example (11) is from K. Staszewski.

Hence (2) cannot mean ‘I have been reading’, but (1) could mean ‘I have read’ – and indeed in absence of evidence to the contrary it will be thus understood (as in (25)). This default inference from imperfective to perfective takes place with accomplishment verbs and will be explained in 5.2.4.

Moreover, note that since there are no grammaticalised relative tenses in Polish (apart from seldom-used relics of pluperfect), the three absolute tenses sometimes are used in their stead. Thus the past perfective can sometimes be assigned the rôle fulfilled in English by Past Perfect; past imperfective – Past Perfect Continuous; future perfective – Future Perfect; and future imperfective – Future Perfect Continuous. This can be signalled by temporal adverbs or the ordering of information in discourse, or left to be inferred via world knowledge.

2.2 The aspectual classification

Here we will summarise Młynarczyk’s aspectual classification of Polish verbs [42], suggesting some alterations. To begin with, pairing tests (2.2.1) allow to establish which verbs form aspectual pairs – or, strictly speaking, tuples, since sometimes to one imperfective two or three perfectives correspond. A test can formulated to apply to almost all Polish verbs, suggesting that there are four morphologically distinct methods of perfectivisation – two types of prefixation and two of suffixation. By considering, which verbs can take which methods, the classification emerges, yielding five classes of verbs (2.2.2) – which will be the basis of the semantics we shall develop further on. The exceptions to the classification can be reasonably explained away (2.2.3).

2.2.1 Aspectual pairing tests

One way of testing whether a perfective corresponds to an imperfective in the sense that they belong to the same aspectual tuple is the secondary imperfectivisation test [42, p. 116]. A perfective is said to pass it if and only if there is a *unique* way of imperfectivising it while retaining the single-episode reading; then it belongs in the same aspectual tuple with the resulting imperfective. For instance the perfective *przeczytać*, ‘to have read’ can only be imperfectivised to *czytać*, ‘to be reading’, so these two belong in the same aspectual tuple. (It is essential here that we neglect the iterative readings.)

However, this was a simple example, because the only other obvious candidate form, **przeczytywać*, is clearly wrong to any competent speaker[3]. Now consider (4), in the infinitive: *wyczytać*, 'to read out (etc.)'; it can clearly be imperfectivised to *wyczytywać*, and indeed these forms belong to the same aspectual tuple. But why not imperfectivise *wyczytać* to *czytać*, 'to be, to have been reading'? After all, whenever one has read something out, one has been reading out as well as just reading. The fact that *czytać* belongs to another aspectual tuple does not affect the test; *wyczytać* fails it.

Generalising from this (not untypical) example, it seems that if the imperfective already has a non-empty prefix, the intuitively corresponding perfective will fail the test, since it could also be imperfectivised into an imperfective without the prefix. Of course this depends on what do we mean by 'imperfectivising' and 'unique'; but it seems that in order for this test to work properly, these terms would have to be defined so as to beg the question. In other words, the test is inadequate unless we understand these terms as to rule out the alternative way of imperfectivisation. But the above example shows that the latter is very natural, so ruling it out would be rather arbitrary.

One way to avoid this difficulty is to stipulate that the derived imperfective should have the same lexical meaning as the perfective (modulo aspect, of course) [42, p. 51]. Incidentally, this indicates, what is meant by *secondary* imperfectivisation, as can be seen from Table 1. Then *wyczytać* passes the test in tuple with *wyczytywać*, and *czytać* does not stand in the way – as it did previously – because it is considered to have different lexical meaning.

primary impfv.	perfective	secondary impfv.
czytać, 'to be reading'	*przeczytać*, 'to have read'	**przeczytywać*
czytać, 'to be reading'	*poczytać*, 'to have been reading a bit'	**poczytywać*
	wyczytać, 'to have figured out by reading'	*wyczytywać*, 'to be figuring...'

Table 1: Primary and secondary imperfectivisation

However, while this additional proviso renders the test adequate, it also relies on lexical intuitions heavily. Consider *poczytać*: according to the above, it has the same lexical meaning (modulo aspect) as *czytać* – while

[3]Though in some peculiar circumstances it might be used in spite of its incorrectness – cf. 3.2.2.

wyczytać does not. Now, whether this is true depends on what one means by 'modulo aspect', of course. Given the aspectual classification that is being described here, it in fact is. But a priori it is difficult to think of an intuitive reason for treating *poczytać* as an aspectual variant of *czytać* rather than differing in lexical meaning. To assume there is such a reason is to assume the classification – and thus beg the question again.

This obstacle would dissolve if we could test whether an imperfective and a perfective have the same lexical meaning (modulo aspect) in some operational way – rather than intuitively or by assumption. Now, this seems to be possible by the historical present test, proposed by Maslov [37, p. 53][4]. Namely, the two aspectual forms have the same lexical meaning if translating the perfective's past tense into the historical present will yield the imperfective. Translation is meant to be as faithful as possible, that is minimising the loss of meaning. Of course this still does rely on speakers' meaning intuitions, but gives a systematic, operational criterion for testing them. In other words, while it is not obvious, whether *poczytać* has the same lexical meaning as *czytać*, it is clear that the most faithful way of rendering the past *poczytałem*, 'I have been reading a bit' into the historical present is *czytam*, 'I am reading'.

To sum up, the secondary imperfectivisation test is either inadequate – without the stipulation on lexical-meaning identity, or, with it – begging the question. The Maslov test, which can be seen as its operationalised variant avoids these problems. Nevertheless, notwithstanding the previous one's methodological deficiencies, both tests do give the same results for Polish verbs, that is classify almost all of them into aspectual tuples in a peculiar way, which we will discuss next.

2.2.2 The classification arises

In the aspectual tuples obtained by the pairing test, four systematic ways of perfectivisation, called 'formants' (cf. [42, p. 9]), can be distinguished:

- the (semantically) empty prefix, that is any from a group of prefixes like *u-*, *z-*, *po-*, *na-*, *prze-* etc. used to contribute no other meaning apart from perfectivisation (ep);
- the semelfactive suffix *-ną-*;
- morphonological change, that is vowel change and/or removing a suffix from the imperfective, e.g. the *-yw-* suffix (mp);[5]

[4] Reprinted from [36].

[5] From a philological point of view, morphonological change is an imperfectivising

- the delimitative (use of the) prefix *po-*, that is such that apart from perfectivising induces an 'a-bit' – meaning either duration *longer* than usual, or, to the contrary, *shorter*. We assume that the previous is the semantic meaning and the latter results by pragmatic effects. We take the English expression 'a bit' as *ambiguous* between 'quite a bit' for the previous meaning and 'only a bit' for the latter. See 5.2.4.

Now the verbs can be segregated according to which formants can they be subject to. ('The verbs' meaning almost all Polish verbs; the exceptions are discussed in 2.2.3.) This yields five classes, as shown in Table 2, where 'yes' means that verbs of given class can be subject to given formant. This classification, although driven by verbal morphology, turns out to carve at semantic joints:

- Class_1 imperfectives denote either states (e.g. *lubić*, 'to be liking') or gradual transitions (e.g. *chudnąć*, 'to be getting thinner'); perfectives denote either incepted states (*polubić*, 'to have started liking') or completed transitions (*schudnąć*, 'to have gotten thinner').

- Class_2 imperfectives denote strict, that is, intransitive activities (e.g. *wisieć*, 'to be hanging'); perfectives denote activities that have been terminated after going on a bit (*powisieć*, 'to have been hanging a bit').

- Class_3 imperfectives denote ongoing and yet not completed accomplishments (e.g. *pisać*, 'to be writing'); perfectives formed with the delimitative *po-* denote accomplishments that have not been in fact accomplished, but terminated beforehand (*popisać*, 'to have been writing a bit'); empty-prefix perfectives denote completed accomplishments (*napisać*, 'to have written').

- Class_4 imperfectives denote semelfactive activities, that is activities that can be broken down into minimal instances (e.g. *kopać*, 'to be kicking'[6], consists of single kicks). Perfectives formed by *-ną-* denote such minimal instances (*kopnąć*, 'to have kicked once'); empty-prefix perfectives denote activities completed by iteration of minimal instances (*skopać*, 'to have beaten by kicking'); finally, delimitative-*po-* perfectives denote activities terminated after some minimal instances, but before completion of the activity (*pokopać*, 'to have been kicking a bit').

formant, since the perfective is suffixed to obtain the imperfective. We treat it as a perfectivising formant for the sake of uniformity, though.

[6] There is also a Class_3 verb *kopać*, 'to be digging'.

	ep	*po-*	*-ną-*	mp	e.g.
Class_1	yes				*wierzyć* ('to be believing')
Class_2		yes			*siedzieć* ('to be sitting')
Class_3	yes	yes			*czytać* ('to be reading')
Class_4	yes	yes	yes		*pukać* ('to be knocking')
Class_5				yes	*kupić* ('to buy')

Table 2: Aspectual classes according to formant applicability

- Class_5 perfectives denote achievements (e.g. *zabić*, 'to kill'), and imperfectives achievements ongoing in the sense of still being in the preparatory phase that will lead to the achievement proper (*zabijać*, 'to be killing').

By applying the relevant formants, in total fifteen types of verbs can be obtained – thus exhaustively systematising the Polish aspectual system. Significantly, this emergent classification turns out to be semantic: the fifteen verb types correspond to different types of occurrences given in Table 3. These types resemble Vendler's [66][7] classification of verbs with respect to their temporal schemata, taken up by Moens and Steedman [43] as 'aspectual classes' and – following van Lambalgen and Hamm [33, p. 85] – can be called *Aktionsarten*.[8]

Now, Class_1 as defined above encompasses two distinct Aktionsarten, those of states and of gradual transitions. This seems to be a discomforting exception in a classification that otherwise pairs verb classes with Aktionsarten. Młynarczyk's [42, 4.5.1] argument in favour of defining Class_1 thus is that the distinction between inchoative and non-inchoative (usages of the) empty prefixes is not a formal one, in the sense that it relies on the speakers' meaning intuitions rather than on morphology. Hence, she argues, splitting Class_1 would deprive the classification of its virtue of being a natural semantic pattern emergent from pure morphology. Resorting to semantic intuitions in order to form a semantic pattern would lower the methodological standard.

[7] See mainly Ch. 4, reprinted from [65].

[8] Accordingly we change the terminology used in [42] for consistency with [33, p. 88]. Beware also that sometimes 'Aktionsart' is meant quite differently – in opposition to aspect. Thus e.g. Verkuyl: 'For lexical characterisation of V, without taking into account its arguments, the term *Aktionsart* is available, for the grammaticalisation the term *aspect* is used' [69, p. 98]. However, 'Aktionsart' was first introduced by Argell [1] for the very purpose of studying Polish verbal aspect.

Class	Aspect and formant	Aktionsart	Example
$1s$	impfv	state	*wierzyć* 'to be believing'
$1s$	pfv, ep	inception of an ongoing state	*uwierzyć* 'to have started believing'
$1t$	impfv	transition	*grubnąć* 'to be growing fat(ter)'
$1t$	pfv, ep	completed transition	*zgrubnąć* 'to have grown fat'
2	impfv	activity	*siedzieć* 'to be sitting'
2	pfv, *po-*	terminated activity	*posiedzieć* 'to have been sitting a bit'
3	impfv	ongoing accomplishment	*czytać* 'to be reading'
3	pfv, ep	accomplishment	*przeczytać* 'to have read'
3	pfv, *po-*	terminated accomplishment	*poczytać* 'to have been reading a bit'
4	impfv	semelfactive activity	*pukać* 'to be knocking'
4	pfv, ep	completed semelfactive	*zapukać* 'to have knocked'
4	pfv, *po-*	non-minimal semelfactive	*popukać* 'to have been knocking a bit'
4	pfv, *-ną-*	minimal semelfactive	*puknąć* 'to have knocked once'
5	pfv, mp	achievement	*kupić* 'to have bought'
5	impfv	ongoing achievement	*kupować* 'to be buying'

Table 3: Aktionsarten according to aspect and aspectual class

However, as we have just mentioned above, the classification does relay on some semantic intuitions anyway. Firstly, the secondary imperfectivisation test, which is indispensable in order to form the classification, depends on judging whether there is a single way or several ways of imperefectivising a verb. That is an intuitive judgement, for it involves assessing what forms are admissible. For instance, *podbijać* ('to be conquering' etc.[9]) can be derived from *podbić*, but **pobijać* cannot be derived from *pobić* ('to have beaten'). One also has to distinguish imperfectives from iteratives, e.g. *bijać*, 'to beat sometimes'.

Furthermore and more importantly, distinguishing the delimitative and empty usages of *po-* is essential for the classification. Namely, it is necessary in order to distinguish between Class_2 and Class_1; in the previous, all verbs take the delimitative *po-*, but in the latter some take the empty *po-*. For instance, *pokochać*, 'to have started loving', is a Class_{1s} perfective, while *posiedzieć*, 'to have been sitting a bit' is a Class_2 one. Such judgements are also intuitive.

Therefore, some semantic intuitions of native speakers are required in order to construct the classification. Then why banish the distinction between Class_{1t}, containing transition verbs and Class_{1s}, containing state

[9]Namely: 'to be placing something (a stamp, a heel) by hitting or nailing', 'to be validating (a document) by stamping', 'to be suddenly raising (a price, a bid)', 'to be juggling (a ball upwards)', ?'to be giving somebody a black eye'.

verbs? The intuitive distinction between inchoative and non-inchoative empty prefixes, distinguishing these two classes, seems to be of a similar methodological status as the intuitions mentioned above. Thus, since the distinction is semantically interesting, we will not hesitate to use it.

Hence it seems that what is needed is a semantics for aspect that could account for this classification, by defining the various Aktionsarten. In having emerged from rather concrete data: morphology and but a few simple speakers' intuitions, it would have the virtue of being grounded in the linguistic data rather than arbitrarily constructed.

2.2.3 Exceptions

There are some verbs that elude the classification, nevertheless not invalidating it insofar as they are explainable as exceptions. To begin with, modal verbs in Polish have in fact no aspect; grammarians classify them as imperfectiva tantum, but for morphological rather than semantic reasons. Thus modals fall out of scope of the classification.

Secondly, there are several suppletive pairs, that is aspectual tuples consisting of morphologically unrelated verbs, as in *brać*, 'to be taking' and *wziąć*, 'to have taken'. Since the classification is driven by morphology, these verbs fall out of its scope as well. However, semantically they behave just like regular aspectual tuples, and in principle could be ascribed to aspectual classes according to meaning. Thus suppletive pairs do not violate the classification either.

Thirdly, habituals are entirely ignored by the classification, which can be seen as a disadvantage, since they appear to exhibit some aspectual regularity both in terms of morphology and of meaning. Nevertheless, it is neglecting them that has made the picture clear enough for introducing the classification at hand. Extending it to cover habituals as well seems a task rather promising, but requiring further descriptive work – in want of which we are forced to neglect the semantics of the habitual as well. This, however, is admissible insofar as the Polish habitual is of rather small importance, as has been pointed out in 2.1.2. Perhaps more discomforting is that Młynarczyk neglects not only habituals, but all verbs having a multiple-episode reading. In 5.2.6 we will argue that this is not necessary for some non-habitual perfectives having the iterative reading.

Finally and somewhat more importantly, there seem to be a few imperfectives that can be perfectivised in two distinct ways, using various empty prefixes[10]. For instance, consider the examples in Table 4, which

[10]Moreover, some verbs seem to admit re-imperfectivisation, eg.: *planować*, 'to be

imperfective		perfective	
tyć	'to be growing fatter'	*utyć, przytyć*	'to have grown fatter'
reperować	'to be repairing'	*zreperować, nareperować*	'to have repaired'
całować	'to be kissing'	*pocałować, ucałować*	'to have kissed'

Table 4: Some putative exceptions

could be thought to contradict the classification. However, in some such cases the speaker intuition is not very reliable insofar as on second thoughts one of the perfectives turns out to correspond to a different imperfective; for instance, *ucałować* seems to correspond to a rather unusual, but admissible imperfective *ucałowywać*, 'to be kissing'. One could at first confuse *ucałować* to be an empty-prefix perfective of *całować*, because the difference of meaning between *ucałowywać* and *całować* is very elusive[11].

Yet in the remaining cases there indeed are two synonymous empty-prefix perfectives corresponding to one imperfective. It comes as no surprise when the origin of empty prefixes is considered. Namely, verbal prefixes stem from prepositions and even having become empty, that is, having lost their specific meaning content they can can evoke associations with the original prepositions. Thus while e.g. *utyć* and *przytyć* are fully interchangeable in all contexts, it may be stylistically preferable to use the latter in:

(13) Aleksander przytył pięć kilo.
Alexander put-on$_{3.sg.}^{ep\text{-}pfv}$ five kilos$_{acc}$
Alexander has put on five kilograms.

because adding a specific number of kilograms evokes *przy*, 'at, towards' rather than *u*, 'at, of (possessive)'. Similarly, it can be the case that the alternative empty prefixes stem from different varieties of the language; for instance, *zreperować* is the prescriptively more correct form, while for some speakers *nareperować* may be more natural.

But note that in spite of there being alternative ones, there still is a unique way of imperfectivising the perfectives forming aspectual pairs. It does make the secondary *perfectivisation* test unfeasible, but in fact that test

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planning' perfectivises to *zaplanować*, 'to have planned', which perhaps can be re-imperfectivised to ?*zaplanowywać* ([42, p. 116]). The latter sounds admissible, but it is by no means clear what it means; most plausibly, it has an iterative meaning, and thus falls outside the scope of the classification. Otherwise it might be understood as what we call an illegal secondary perfective (see 3.2.2).

[11] The prefix *po-* in *pocałować* is empty – that is the default reading, regardless of a conjecture that a delimitative reading might also be possible; cf. (62).

is redundant; its justification is of philological rather than semantic nature ([42, p. 119]), hence it can be discarded altogether. However, this does not contradict the classification as based on the secondary *imperfectivisation* test – or the Maslov test. Nor do the other exceptions mentioned above genuinely violate the classification; so on the whole there seem to be no reasons to mistrust it.

3 Which semantics for aspect?

Since the classification introduced above turns out to be essentially semantic, a semantic groundwork for it is needed. Its task would be to define the semantic types – Aktionsarten – yielded by the classification. To fulfil this task with merit, the semantics would have to introduce the Aktionsarten formally and naturally, in the sense that they should follow from the workings of the formalism rather than be additionally stipulated upon it. In other words, the formalism should give an elegant answer to the question: what must semantics be like in order for the Aktionsarten to appear in morphology?

This requirement is not only of æsthetic, but also of methodological nature. That there is some connection between the morphology of a language and its semantics seems not too extravagant an assumption; it has been phrased by Jackendoff:

> The *Grammatical Constraint* says that one should prefer a semantic theory that explains otherwise arbitrary generalizations about the syntax and the lexicon. [23, p. 13]

One such generalisation is the presence of Aktionsarten in the Polish verbal system. Thus our requirement is but a special case of the Grammatical Constraint, which is justified in its own right (e.g. as indispensable for language aquisition; cf. [23, 1.5]).[12]

The purpose of this chapter is to justify the choice of the event calculus as our framework by showing that it fulfils the requirement just mentioned, while the alternative approaches do not. Thus first we will briefly discuss the tense-logic approach originally proposed by Młynarczyk, pointing out its inadequacy. Next and rather crucially, in 3.2, we

[12]Besides, the requirement can be seen as exemplifying a principle of conservation of empirical justification: since, at the lexical level, the Aktionsarten are justified by morphological data, it will be commendable to retain them at the semantic level.

will argue in favour of the event-calculus approach adopted here, adding to the arguments about its cognitive plausibility from [33] some evidence from Polish. Finally, for the sake of completeness, we will have a look at the widespread approach to aspectuality in terms of quantification and argue why it is inadequate for our purposes.

3.1 Tense logic approach

To provide a semantic groudwork for her classification, Młynarczyk [42, 5.3] offers a Priorean [51] semantics, with $\mathfrak{M} = \langle \mathbb{R}, <, E \rangle$, where E is the set of eventualities understood as triples of type, temporal profile and culmination. A unique type is ascribed to each aspectual tuple. Temporal profile is a real interval (for Class_4 a series of intervals), culmination either $\varnothing$ or the singleton of the interval's endpoint. Thus Class_1 as well as Class_2 verbs are represented by eventualities of the form:

(14) $\langle verb, [a, b], \varnothing \rangle$

while for Class_4 there can be more intervals included; for Class_3 and Class_5 the eventualities are of the form:

(15) $\langle verb, [a, b), \{b\} \rangle$

Next, for each Aktionsart (to use our terminology), satisfaction is defined. For imperfectives of all classes, we have:

(16) $\mathfrak{M}, t \models verb$ iff there is an eventuality of type $verb$ s.t. $t \in [a, b]$;

and for perfectives,

(17) $\mathfrak{M}, t \models verb$ iff there is an appropriate eventuality of type $verb$ s.t. $b < t$, where b is the conclusion of $verb$.

The 'appropriateness' of an eventuality is defined for some Classes as an informal requirement as to the nature of the eventuality. For instance, for a Class_4 perfective *po-* verb, the condition is: 'the eventuality is a non-minimal Class_4 eventuality'.

This may seem to be adequate in the sense of being correct; but by no means so in the sense of explaining the classification's underlying semantics. There is no explanation of what is common to the meaning of the verbs in a class. Even though eventualities are defined separately for each class, their structure does not differ much (or at all, e.g. between Class_1 and Class_2). If at all, the meanings specific to particular Aktionsarten are distinguished by stipulating 'appropriateness' informally and artificially.

Moreover, matters are pushed down to the informal lexical level. In order to know, whether $\mathfrak{M}, t \models verb$, we must check the $verb$'s type, which amounts to locating it in the lexicon. Only having established the most specific, lexical component of the verb's meaning, do we look at the more general, structural components: the temporal profile and 'appropriateness' for the given Aktionsart. Hence the foremost objective of semantics for Polish aspect is frustrated: the aspectual classification's semantic foundations do not follow from the formalism in the sense required by us.

Furthermore, this approach is incomplete in lacking means to capture causal relations among occurrences, or to accommodate for tenses, temporal modifiers, not to mention coercion. An attempt to relieve some of these shortcomings is [6], where a compositional semantics using Davidsonian [12] events is introduced over the Priorean structure described above. For instance, for a Class_4 delimitative-*po-* perfective *popukać*, 'to have been knocking for a bit', it gives the representation:

(18) $\lambda y \lambda s \exists e(\text{PUKAĆ}(e) \wedge \neg \text{MINIMAL}(e) \wedge \text{AGENT}(e, y) \wedge \text{CONCLUSION}(e, s))$

By combining with representations for other constituents and applying some rules provided for tense, the meaning of Polish sentences can be thus calculated.

However, this offers no improvement as far as capturing the generalisations about the meaning of Aktionsarten is considered. Using special predicates like $\text{MINIMAL}(e)$ to distinguish the types of eventualities is merely rewriting the 'appropriateness' stipulations symbolically. Perhaps the deficiency could be remedied if such predicates were defined in some uniform way, exhibiting the semantic grounding of the division into Aktionsarten. But that is not done; indeed, they remain undefined. That deficiency is a specific case of what van Lambalgen and Hamm observed generally:

> ...we object to the use of a Davidsonian event argument together with predicates corresponding to thematic rôles, because this device is neither capable of representing the structure inherent in events, nor of the different perspectives on events. [33, p.75]

Therefore neither the bare Priorean approach nor its Davidsonian augumentation can satisfy our requirement.[13] That is, they shed no light on where the semantic distinction into Aktionsarten uncovered by the aspectual classification of Polish verbs comes from. It seems that in order

[13] Another Davidsonian approach is [5].

for any elucidation to be expected, we would have to turn to a formalism explicitly treating the structure behind Aktionsarten – such as the event calculus.

3.2 Why event calculus?

What must our minds be like for tense and aspect to make sense? The event calculus as a semantics of natural language is an attempt to tackle this question. Thus the basic claims are that the way temporal relations are coded in language reflects the human cognitive representation of time – and that this representation can be modelled in the event calculus [33, p. 9]. That this is indeed so, will be argued in 3.2.1 (basing on [33, Part 1]), followed by some specific evidence from Polish. Another feature of the calculus – namely the algorithmic approach to meaning along with stressing non-monotonicity and coercion rather than compositionality – will be discussed in 3.2.3.

However, to note a general objection first, the question posed above may be seen as too bold. Certainly language requires some underlying cognitive structures; but should semantics speculate about them? Some would rather have it first work with (more) abstract models, which should in principle have empirical significance, but need not be based on more data that some linguistic examples. So for instance ter Meulen introduces her book on tense and aspect:

> This book is the result of purely theoretical investigations. ... The results of this theoretical research are certainly claimed to have empirical signifiacance and hence explanatory and predictive power within the generative linguistic research program of universal grammar. ... The abstract semantic principles governing tense and aspect constrain the set of possible languages considerably... [38, pp. ix–x]

(cf. also [38, pp. 119–120]). But that approach also must make bold assumptions about some cognitive structures ultimately underlying the universal grammar – except it does not attempt modelling them directly. So, although on different levels, speculations are required in both paradigms.

Nevertheless, this is not a place to argue about paradigms' relative merits. The best we can do is to adopt one, quoting a general principle underlying the above question, Jackendoff's *Cognitive Constraint*:

> There must be levels of mental representation at which information conveyed by language is compatible with information

> from other peripherial systems such as vision ... If there were no such levels, it would be impossible to use language to report sensory input. [23, p. 16]

which leads to a specific claim directly justifying our work. Namely, one product of the human cognitive capabilites that language must be compatible with is the representation of time; whence van Lambalgen and Hamm write[14]:

> ... we claim that the particular way in which temporal relations are coded in language reflects the human cognitive representation of time; moreover, we claim that the intricate patterns of linguistic encoding of time can only be fully understood if the mental construction of time is taken into account. [33, p. 9]

One such intricate pattern is aspect. As will be seen in the following, one way of accounting for the mental construction of time is the event calculus. To put it tersely, we want a cognitively plausible semantics of aspect, and this section is intended to show why the chosen formalism is cognitively plausible.

3.2.1 Time and planning

The event calculus will be formally introduced in Chapter 4; for now it shall suffice to mention that its lineage lies in robotics, where its ancestors were explicitly intended to deal with planning. The principal entities it employs are events and so-called fluents, constructed from events, but temporally extended. Its axioms allow for expressing the connections between events and fluents that amount to planning. Since, however, human plans are inherently prone to failure, the event calculus is non-monotonic, so that these connections may be severed by further information.

To begin with, let us briefly review the psychological data on planning cited in [33, Ch.Ch. 1-2]. Trabasso and Stein [64] show that a child's developing sense of time is connected with its ability to think in terms of plans and goals. They conclude that our thinking about time, consisting in mental integration of past, present and future in working memory, depends on our capability of planning. Moreover, as Michon [40], [39] argues, the reason we have a conscious experience of time at all is to tune ourselves to the sequentially ordered environment we live in. But in the longer perspective, goal-oriented, pre-planned action is necessary for such

[14] Though they do not refer to Jackendoff explicitly.

tuning. Indeed, such longer perspective is only available to humans, not to other animals, who are unable of thinking about the past and the future, as Suddendorf and Corbalis [61] claim.

Therefore it seems plausible to assume that human cognitive representation of time is based on plans and goals. Since the event calculus captures them well, it can be considered cognitively plausible. Furthermore, there is direct linguistic evidence that plans have to be incorporated in any adequate semantics of tense and aspect. For instance, in English the future tense can be expressed with *will*, *be going to*, Simple Present or Present Progressive. These constructions are not all available in every context; it turns out that it depends on whether the event in question is viewed as a goal to be acheived and whether it is certain to happen [33, pp. 35–36; Ch. 8]. Some other examples come from the French Passé Simple and Imparfait and English Perfect [33, Ch. 3], [45], [46]; we will consider some Polish data.

3.2.2 Evidence from Polish

One piece of evidence from Polish concerns future markers as well; namely in narrative discourse, as when telling a story in the historical present, *chcieć* ('want to') is used as the future marker, instead of the regular future tense.[15] Two other ones we want to discuss are illegal secondary imperfectivisation and purely intentional readings of some imperfectives.

The first phenomenon, which may also be dubbed re-imperfictivisation is the following. As shown in 2.2.1, normally secondary imperfectivisation derives the imperfective from a perfective of meaning related to, but different from that of the original imperfective (cf. Table 1). Thus no aspectual tuple contains more than one imperfective. However, sometimes this can be violated: for instance, the imperfective **zbudowywać* – derived from the perfective *zbudować*, 'to have built', which derives from *budować*, 'to be building' – means 'to be building with the intention of completing'. Despite being marked as substandard, such forms seem to be fairly understandable among competent speakers (and perhaps natural among children who already speak the language, but have not yet been taught the correctness rules). The intended, but not yet achieved completion of a goal is the gist of these forms' meaning – which is a clear instance of planning.

Secondly, Class_5 and some readings of Class_3 imperfectives can have a purely intentional reading. These verbs describe a phase preparatory to

[15] This claim is based on several observations, remaining to be confirmed with a systematic study.

some goal – but the preparatory phase may consist in pure intention, for instance:

(19) Maciej zakładał nową partię, lecz w końcu jej nie
Matthew founded$^{\text{ipfv}}_{\text{3.sg.}}$ new party$_{\text{acc}}$ but in end her$_{\text{gen}}$ not
założył.
founded$^{\text{mp-pfv}}_{\text{3.sg.}}$

Matthew was founding a new political party, but eventually he did not found it.[16]

(20) Lechosław oświadczał się Miriam, ale wobec sprzeciwu
Lechosław proposed$^{\text{ipfv}}_{\text{3.sg.}}$ refl Miriam$_{\text{dat}}$ but towards objection$_{\text{gen}}$
rodziny się rozmyślił.
family$_{\text{gen}}$ refl changed-mind$^{\text{mp-pfv}}_{\text{3.sg.}}$

Lechosław was about to propose (lit. 'has been proposing') to Miriam, but given the family's objection he changed his mind.

The subjects might have not actually done anything to realise their goals; merely having had the intention to have done so suffices to use the imperfective. Another interesting example is:

(21) Upili się, chociaż się nie upijali.
got-drunk$^{\text{mp-pfv}}_{\text{3.pl.}}$ refl though refl not got-drunk$^{\text{ipfv}}_{\text{3.pl.}}$

They have gotten drunk, even though they haven't been getting drunk.

which prima facie could be thought unacceptable just like (12); but in fact it appears plausible – since there is an inherently intentional component in the process of getting drunk.[17] Bogusławski [8, p. 140] cites a similar sentence overheard in a crowded bus:

(22) Nie wychodzę, ale wyjdę.
not get-off$^{\text{ipfv}}_{\text{1.sg.}}$ but get-off$^{\text{mp-pfv}}_{\text{1.sg.future}}$

I wasn't going to get off (lit. 'I'm not getting off'), but I will.

meaning that the speaker will get off in spite of not having intended that. Neither of these examples could be accounted for in a purely temporal framework not involving plans.

[16] For a discussion of a similar sentence (due to Landman [34]) as an example of accomplishment cf. [33, p. 163].

[17] Some speakers find (21) doubtful, on the grounds that for them, getting drunk is independent of one's will, so not intentional. But they admit that if it was intentional, (21) would be acceptable.

3.2.3 Meaning as computation

In the event calculus the meanings of linguistic items are coded as programs consisting of conditional clauses, as will be explained in 4.3.1. Thus these programs are plans, and can be thought of as algorithms and as scenarios:

> ...if semantics wants to make contact with the huge psycholinguistic literature on language comprehension and production, it had better become computational. We propose to identify the *sense* of an expression with the algorithm that computes the expression's denotation. [33, p. 55]

The algorithmic approach to meaning, first proposed by Tichý [62], [63], has recently been developed by Moschovakis [44] and taken up by van Lambalgen and Hamm [32], [33].[18] All these authors point out that it is a particularly adequate reconstruction of Fregean [18] sense and denotation. Frege meant the former as the method of deriving the latter – so algorithm and its value seem quite natural candidates here, certainly more so than possible worlds.

That being a merit in itself, it also opens the connection with psycholinguistics, which, as mentioned above, has long been using the algorithmic notion of meaning (e.g. [41]). In particular, programs (that is, scenarios – cf. 4.3.1) can be thought of as plans in the AI or cognitive-science sense of the word (cf. [54, Ch. 4], [47]) – mental representations of linguistic meanings as well as of world knowledge.[19] A unified treatment of these two is another advantage, since it easily accounts for the contribution of world knowledge and the ordering of information in discourse (e.g. coercion, cf. [33, Ch. 11]) to the interpretation of natural-language expressions – which is a difficulty for purely compositional approaches. That can be formalised in the event calculus due to its non-monotonicity, also enabled by the programming approach (as will be seen in 4.2.1).

3.3 Quantificational approaches

A comprehensive account of aspectuality has been proposed by Verkuyl [67], [68], [69], endeavouring to explain the intricate interaction between

[18] Though Moschovakis does not refer to Tichý – whose work is being continued as the Transparent Intensional Logic, e.g. [20].

[19] It can be added that, as Zacks and Tversky [71] observed, humans resort to goals and plans when encoding events in memory ([33, Ch. 3]) – and quite so in the event calculus: to define an event, a program specifying a relevant plan can be given.

temporal and atemporal components of meaning. It treats aspectuality quite generally as the properties of sentences that serve to express boundedness, duration, repetition etc. These properties arise compositionally from both temporal and atemporal information submitted by the sentence's constituents. In investigating how that happens, the theory turns mainly to generalised quantifiers and ponders on problems posed by sentences like:

(23) Three men carried the five pianos on which Zimmermann and Argerich played Cage's '4′33″' in four minutes for three hours every other day one week each year.

The atemporal information is contributed by NPs; they can be ascribed the feature [±SQA], standing for specified vs. unspecified quantity. VPs, on the other hand, contribute temporal information and can be ascribed the feature [±ADD TO], standing for dynamicity vs. stativity. By combining the two features, the sentence's aspectuality is compositionally derived, yielding three types of eventualities, as shown in Table 5 (from [68, p. 67]). Verkuyl calls the aspectuality corresponding to event 'terminativity', as opposed to 'durativity' in the other cases.

	[−ADD TO]	[+ADD TO]
[−SQA]	state	process
[+SQA]	state	event

Table 5: Verkuyl's features and eventuality types

This approach has been mainly applied to Dutch, English and (by Krifka [31]) to German. As far as Slavic languages go, their grammaticalised verbal aspect contributing towards thus understood aspectuality is claimed to be an essentially quantificational phenomenon. In particular, the perfective is argued [69, Ch. 5] to correspond to the Germanic determinate article in imposing a [+SQA] interpretation on the direct object. The theory has been applied to Czech by Filip [16], [17] and to Russian by Schoorlemmer [57], [58], successfully dealing with the perfective, but for the imperfective turning out to be a failure (cf. [42, p. 69]).

Polish aspect being quite similar to Czech and not very different from Russian (cf. [9], [42], [8]), we should expect a similar outcome – which seems to be an argument against using the Verkuylian approach.[20] More-

[20] Piñón [49] analysed the perfective *przeczytać*, 'to have read' in a Krifkesque style – but that is too fragmentary a result to undermine our scepticism. Also see below for a methodological objection.

over, Młynarczyk [42, pp. 100–107] gives a number of convincing counterexamples, showing [−SQA] perfectives, as in:

(24) Pokończył seminaria, kursy, fakultety – ale wciąż nie
ended$^{\textit{po}\text{-pfv}}_{3.sg.}$ seminars$_{acc}$ courses$_{acc}$ faculties$_{acc}$ – but still not
wie nic, niestety.
know$^{ipfv}_{3.sg.}$ nothing alas

He has finished seminars, courses, faculties – yet still he knows nothing, alas.

which by no means implies that he should have finished *all* the (contextually relevant) seminars etc., or a specified number of them. On the other hand, [+SQA] imperfectives are also possible, as in:

(25) Wiem, jak się kończy „Effi Briest", czytałem.
know$^{ipfv}_{1.sg.}$ how refl ends 'Effi Briest' read$^{ipfv}_{1.sg.past}$

I know how 'Effi Briest' ends, I've read it (lit.: 'I've been reading').

which is a case of the default perfective reading of a grammatical imperfective (cf. 2.1.3). Thus while Polish verbal aspect can have quantificational effects, the Verkuylian approach does not give a satisfactory account of that.

Furthermore, to base a theory on the definite vs. indefinite vs. bare noun distinction in languages lacking (as Slavic languages do) overt articles is a petitio principii. In order for the theory to hold, the distinction must be interpreted into the data, so to speak. That involves a peril of a bias towards theory, which seems to lurk for instance in Piñón's [49] argument that Polish perfectives cannot take bare plurals as arguments. According to him in:

(26) Wódka zmroziła się w zamrażalniku.
vodka froze$^{mp\text{-}pfv}_{3.sg.}$ refl in freezer$_{loc}$

(The) vodka has cooled in the freezer.

a Pole will interpret the direct argument definitely, not as a bare noun. Perhaps; this is quite obscure for a native speaker intuition.[21] But Piñón avoids mentioning ambiguous cases like (24) or:

[21] Note also that quite to the contrary, a perfective can be used in a context enforcing the bare-noun interpretation, for instance:

W zamrażalniku wódka zmrozi się.
in freezer$_{loc}$ vodka freeze$^{mp\text{-}pfv}_{3.sg.future}$ refl

In the freezer, vodka will freeze.

expressing a regularity allowing no definite reading of the noun.

(27) Wypróżnił butelki.
emptied$_{3.sg.}^{mp\text{-}pfv}$ bottles$_{acc}$
He has emptied bottles.

with no hint whatsoever as to the bottles' definiteness or not.[22] Similarly, some Polish data quoted by Verkuyl [68, pp. 137–138] seems to be overinterpreted. On the whole, it is difficult not to be suspicious about the the quantificational approach's claims on Slavic verbal aspect, given how the relevant data had been treated to yield them.

Moreover, Verkuyl [68], [69] repeatedly bashes Vendler [65] for having introduced what we call Aktionsarten and thus suggested that aspectual properties were inherent in verbs:

> The compositional approach . . . is in conflict with the idea of aspectual classes, such as Vendler's popular verb classes.. . . This classification is non-linguistic, as it concerns situational categories . . . In my view, Vendler's classification runs afoul of the evidence emerging from the linguistic tradition in the first half of this century that aspect is essentially a non-lexical property of the sentence structure, both in non-Slavic and Slavic languages. Yet many semanticists use it as part of their aspectual theory. The two things cannot be married: if aspect formation is a process at the structural [i.e., sentential – P.L.] level it is hard to see how a lexical division can be maintained. [68, pp. 3–4]

Yet as we have seen in 2.2, there is evidence emerging from Polish morphology to the effect that Aktionsarten are actually present at the lexico-semantic level. Trusting morphology rather than tradition, we want to account for them; hence in order not to run the risks of an impossible marriage we will have to ignore the sentential level.[23]

To sum up, even though the quantificational approach to aspectuality stresses some interesting phenomena, it does not give a good account of the Slavic verbal aspect. In particular, it is ill-suited to deal with our focus of interest – the semantics of Aktionsarten. On a more general level, its main merit, compositionality, can be supplanted by coercion, as is done

[22] Incidentally, Piñón's [49] second set of data comprises accomplishment perfectives, which cannot take durative adverbial. But that is exactly because they are accomplishments; cf. [66, p. 101].

[23] Not entirely, because by coercion the Aktionsart of a sentence can be established in event calculus. Coercion fares beter than compositionality in this case, since it allows to conveniently incorporate nonlinguistic contextual information. [33, pp. 169–171]

in event calculus, gaining advantages such as non-monotonicity and cognitive plausibility (cf. 3.2). Conversely, it seems possible to deal with the quanificational phenomena, especially incremental theme, within event calculus; some suggestions will be given in 5.3.[24]

[24] Let us mention three accounts of aspect we have not discussed here: ter Meulen's [38] also emphasises quantification, albeit in a different formalism; Klein's [28] is in another vein, but restricted to Germanic languages; Bogusławski's [8] gives a detailed description of the Polish data, but no formal theory.

4 Event calculus

Before presenting the semantics of aspect in the event calculus, the calculus itself must be briefly introduced. It originates from the work in AI by Kowalski and Sergot [30]. In [33], van Lambalgen and Hamm developed Shanahan's [59] version of the calculus, applying it to natural-language semantics. While following them closely, we will omit many details, remaining within the basics necessary for our purpose. For a complete account, the interested reader may consult their [33] or [22]; another informal account is available in [45, pp. 72–81].

We will first introduce the formal system EC, being the basis of the event calculus. Next, in 4.2, the class of its models will be restricted to minimal ones. This will be done by the means of constraint logic programming and yield some desirable properties such as non-monotonicity. Strictly speaking, in order to express that restriction a *constraint language* over EC is needed; we will not define that language formally. In all, the system we call the *event calculus* consists of EC restricted to minimal models plus two auxiliary languages: the constraint language and L_0 introduced in 4.1.2 below. Finally, the tools the event calculus offers for the semantics of natural language will be presented 4.3.

4.1 The formal system EC

We will first describe the syntax of the language EC and next a way of constructing models for it. The latter will involve a technique called Feferman coding, providing the entities to construct the models from.

4.1.1 Syntax

To begin with, assume a many-sorted first-order logic, with the following sorts:

- individuals, e.g. pieces of furniture, people, rhinoceroses etc.;

- real numbers, i.e. the structure $\langle \mathbb{R}, <, +, \cdot, 0, 1 \rangle$, one purpose of which is to represent time;
- properties, called *fluents*, that can hold of some individuals over some temporal interval, e.g. snoring, being-sleepy, dreaming-of etc.;
- real variables that can be arguments of fluents thought of as functions, such as dimensions or values ascribed to adjectives on a scalar interpretation, e.g. the degree of sleepiness;
- event types, the instantiations (tokens) of which mark the inception and termination of a fluent as well as represent events, e.g. an explosion, a single snore etc.

Note that for simplicity we will usually omit the arguments for a fluent's or event's agent, patient etc., sometimes also the real arguments. Now, writing e for a variable ranging over events, f for one ranging over fluents and t – over time points, the following distinguished predicates are introduced, along with their intended interpretations:

- $Initially(f)$, meaning that f holds at 'time 0' – that is, holds already at the beginning of the time scope in consideration;
- $Happens(e, t)$: straightforwardly enough, a token event e happens at t;
- $Initiates(e, f, t)$ and $Terminates(e, f, t)$: the event e happening at t can, respectively, start or end the interval at which f holds – which provides for instantaneous change;
- $Trajectory(f_1, t, f_2(x), d)$: provides for continuous change, where f_1 is a force and $f_2(x)$ a result of the force being exerted, so that if f_1 holds from t until $t + d$, at which point $f_2(x)$ will hold;
- $Releases(e, f, t)$ is used to connect the two above sorts of change, as will be seen from Axiom 5 below;
- $Clipped(t_1, f, t_2)$ means that between t and t' there is some event terminating or releasing f;
- $Declipped(t_1, f, t_2)$ means, similarly, that between t and t' there is some event initiating or releasing f;
- $HoldsAt(f, t)$ is, finally, a truth predicate: f is true at t.

An immediate objection is that admitting a truth predicate in a first-order logic leads to antinomies by Tarski's limitation theorem. However, that can be remedied by means of partial models (along with some additional axioms). Since the formal details can be found in [33, Ch. 6], here we will neglect this objection as well as the remedying stipulations.

In order to codify the distinguished predicates' meanings sketched above, the following axioms are added:

Axiom 1. $Initially(f) \rightarrow HoldsAt(f, 0)$

Axiom 2. $HoldsAt(f, r) \wedge r < t \wedge \neg \exists s < r HoldsAt(f, s) \wedge \neg Clipped(r, f, t) \rightarrow HoldsAt(f, t)$

Axiom 3. $Happens(e, t) \wedge Initiates(e, f, t) \wedge t < t' \wedge \neg Clipped(t, f, t') \rightarrow HoldsAt(f, t')$

Axiom 4. $Happens(e, t) \wedge Initiates(e, f_1, t) \wedge t < t' \wedge t' = t + d \wedge Trajectory(f_1, t, f_2, d) \wedge \neg Clipped(t, f_1, t') \rightarrow HoldsAt(f_2, t')$

Axiom 5. $Happens(e, s) \wedge t < s < t' \wedge (Terminates(e, f, s) \vee Releases(e, f, s)) \rightarrow Clipped(t, f, t')$

4.1.2 Semantics

To provide a model for EC, we interpret fluents as finite sets of disjoint real intervals of the form $[0, b]$ or $(a, b]$ such that at a an event initiating the fluent f at hand occurs, and at b the first (after a) event terminating f does. Thus for each f there are two event types – for events initiating and terminating f – interpreted as sets of pairs (f, t), where t-s are the instants at which the tokens of such type occur. The distinguished predicates can be interpreted accordingly (details for a fragment of EC can be found in [33, pp. 47–48]).

Somewhat surprisingly neither this interpretation nor EC itself does require events to be punctual. In fact, they can be extended in time and distinguished not by their structure, but by the rôles they play in the event calculus (cf. [33, p. 69]). If the event e initiating the fluent f is temporally extended, then f starts holding at the first instant t such that $Happens(e, t) \wedge Initiates(e, t)$, even if these predicates might keep holding for some interval immediately afterwards. This follows from the completion (in the sense of Definition 2 below) of Axiom 3; an analogous fact holds for $Terminates$ as well. Temporally extended events will prove useful in accounting for some perfectives; cf. 5.2.

Indeed, this kind of model has it that both fluents and events are, so to speak, of the same stuff – being both in fact nominalised VPs. The event calculus performs the computations on these nominalisations – rather than, for instance, on event-arguments á la Davidson (cf. [33, p. 75]). Thus the temporal structure of the VP is built in the fluent, which allows to represent the aspectual properties of a VP in more detail (than, e.g., in [6] – see 3.1). Moreover, it allows for easily converting events to fluents and vice versa, which is helpful not only for representing nominalisation (in the linguistic sense), but coercion and aspect as well.

The formalism behind this is Feferman coding, originating in [15, §9] and applied in [22] and [33, pp. 76–77]. Let L_0 be a first-order language with $\mathbb{R}$, $+$ and $\cdot$, and let $\mathfrak{M}_0$ be its model. It is possible to define a Gödel numbering of the formulas of L_0 in it. It is furthermore possible in L_0 to define a binary *pairing operation* $(\, , \,)$ with two corresponding projection operations π_1, π_2 such that $\pi_1(x, y) = x$ and $\pi_2(x, y) = y$. This in turn allows for, firstly, defining tuples $(\tau_1, \ldots, \tau_k)$ recursively: $(\tau_1) = \tau$ and $(\tau_1, \ldots, \tau_{k+1}) = ((\tau_1, \ldots, \tau_k), \tau_{k+1})$. Secondly, then the corresponding projection operations are generally π^k_i, where $1 \leq i \leq k$, such that: $\pi^k_i(x_1, \ldots, x_k) = x_i$.

Then for φ being a formula of L_0 let $\ulcorner\varphi\urcorner$ be its Gödel number in $\mathfrak{M}_0$ or, interchangeably, the numeral in L_0 denoting that number. If φ has free variables among $x_1, \ldots, x_k, y_1, \ldots, y_n$, then the operation $(\ulcorner\varphi\urcorner, y_1, \ldots, y_n)$ abstracts the $x_1, \ldots, x_k$, treating $y_1, \ldots, y_n$ as parameters; hence:

Definition 1. $\varphi[\hat{x}_1, \ldots, \hat{x}_k, y_1, \ldots, y_n] = (\ulcorner\varphi\urcorner, y_1, \ldots, y_n)$.

In particular, for $k = 1$ we have $\varphi[\hat{x}, y_1, \ldots, y_n] = \{x|\varphi(x, y_1, \ldots, y_n)\}$.

Now, since EC can be contained in L_0, the coding can be applied to its formulas. Thus from a formula $\varphi(x_1, \ldots, x_n, t)$ of EC, formalising some VP, a fluent can be constructed as $\varphi[x_1, \ldots, x_n, \hat{t}]$ and similarly an event type as $\exists t(\varphi[x_1, \ldots, x_n, t])$. However, while these are set-like objects, e.g. $\varphi[x_1, \ldots, x_n, \hat{t}] = \{t|\varphi(x_1, \ldots, x_n, t)\}$, they may be intensional in the sense that among them co-extensionality does not entail identity. The entites thus constructed can now be used as a universe for models of EC.

4.2 Minimal models

However, the kind of models just sketched do not preclude unintended interpretations, because they do not prevent events initiating and terminating fluents from cropping up arbitrarily. Thus if we stipulate that f starts at a and ends at b, it may not ensure that $HoldsAt(f, t)$ will be true exactly in $(a, b]$; some events can crop up in the meantime, terminating f

and incepting it again. Now, this reminds of the frame problem in AI – and indeed, the same solution is helpful, namely the closed-world assumption has to be made: 'nothing changes, unless there is explicit evidence that it does' [22].

For that purpose, we restrict the class of EC's models to minimal ones, that is such that contain only the events, fluents and relations indispensable for rendering EC along with whatever theory we want to assert in it true. This prevents e.g. unintended initiations and terminations from cropping up: once a fluent starts, it holds until terminated and no longer. Formally, there are several ways of restricting the class of models to minimal ones (cf. e.g. [35]); one is circumscription, used in [22]. In [33, Ch. 5], however, constraint logic programming is advocated, since it has the advantages of cognitive plausibility discussed in 3.2. Furthermore, it restricts EC to a decidable fragment.

We will follow [33, Ch. 13], which can be consulted for the details, in introducing logic programming (cf. e.g. [13]). To begin with, in 4.2.1 its simplest version will be sketched, augmented in the following two sections: first to deal with negative evidence and then to extend to predicate logic. Thus constraint logic programming, strong enough to deal with EC, will be reached. Finally, in 4.2.4, we will mention some properties of minimal models that will be useful later on.

4.2.1 Simple logic programming

Beginning with *simple* logic programming we will be limited to propositional logic and positive clauses. Briefly speaking, it restricts syntax to *positive clauses* of the form $\varphi \to q$, where φ is the *body* consisting of a conjunction of propositional variables, or possibly empty. A conjunction of positive clauses is a *positive program*. Moreover, a *query* (or a *goal*) is a finite sequence of atomic formulas $?p_1, \ldots, p_n$; the *empty query* is $\perp$.

Then one derivation rule is used, namely *resolution*, which takes a positive program $p_1, \ldots, p_n \to q$ and a query $?q$ and yields the query $p_1, \ldots, p_n$. Resolution is complete in the sense that for any positive program P and atomic formula q, $P \models q$ iff the empty query can be derived from $?q$ using P. If the latter is the case, the derivation is said to be *successful*. By *derivation* for $?\varphi$ we mean, of course, repeatedly applying resolution to obtain the empty query from the initial goal $?\varphi$. For complex goals this can involve resolving sub-goals first, so it is in order to talk of derivation *trees*.

This much being settled, the restriction to minimal models can now be introduced. Namely, we restrict the class of models of a program P to such which satisfy the completion of P:

Definition 2. The *completion* of a positive program P, written $comp(P)$, is obtained by the following syntactic procedure:

(i) for every q, take all clauses $\varphi_i \rightarrow q$ and form the expression $\bigvee_i \varphi_i \rightarrow q$;

(ii) if q does not occur as a head, add the clause $\perp \rightarrow q$;

(iii) replace the implications by equivalences;

(iv) the conjunction of the sentences thus obtained is the $comp(P)$.

The non-monotonic consequence relation $\mid\approx$ can then be defined thus: $P \mid\approx \varphi$ iff $comp(P) \models \varphi$. (For a direct characterisation of the class of models in question, see [33, p. 229].) Completion realises the closed-world assumption by allowing to draw negative conclusions: if $P \not\models \varphi$, then $P \mid\approx \neg\varphi$.

4.2.2 Negation as failure

However, simple logic programming does not allow for negative *evidence*, that is negative formulas in the body of a clause. That has to be remedied, since $\neg Clipped$ occurs in the antecedents of Axioms 2-4. Thus let us redefine:

Definition 3. A *simple body* is a formula of the form $L_1 \wedge \cdots \wedge L_n$, where each L_i is a *literal*, that is an atomic formula, a negation thereof, $\top$ or $\perp$. If φ and ψ are simple bodies, then $\varphi \wedge \psi$ is a *body*, and so are $\neg\varphi$ and $\neg\psi$. A formula of the form $\varphi \rightarrow q$, with φ being a body, is a *normal clause*. A conjunction of finitely many such clauses is a *normal program*.

Definition 4. A *general query* is a finite sentence $?L_1, \ldots, L_n$, where each L_i is a literal.

and add the following inference rule of *negation as (finite) failure*. Given a normal program P and a general query containing a negative literal $\neg q$, we start a derivation for the query $?q$. If it gives a finite derivation tree not having the empty clause at one of its end nodes, then the query q *fails finitely*. Then we can erase $\neg q$ from the original query. If, though, the derivation for $?q$ succeeds finitely, then $\neg q$ fails, whence the original query fails too. (Note that this rule runs the risk of looping computations, e.g. for the program $P = \{\neg q \rightarrow q\}$). But this risk will be eliminated by defining a canonical form for programs in 4.3.1.)

Once this is added, the semantics sketched above for simple logic programming becomes insufficient, allowing for contradictions under some circumstances (cf. [33, p. 231]). These being undesirable, the semantics

p	1	0	u	1	1	0	0	u	u
q	1	0	u	0	u	1	u	1	0
$\neg p$	0	1	u	0	0	1	1	u	u
$p \wedge q$	1	0	u	0	u	0	0	u	0
$p \vee q$	1	0	u	1	1	1	u	1	u
$p \to q$	1	1	u	0	u	1	1	1	u
$p \leftrightarrow q$	1	1	u	0	u	0	u	u	u

Table 6: Kleene three-valued connectives

has to be upgraded to that of a three-valued Kleene [27] logic, with the set of truth values $\{u, 0, 1\}$ such that $u \leq 0$ and $u \leq 1$. Intuitively, u is the undetermined truth value, which may turn to 1 or 0 as the computation progresses. The connectives are shown in Table 6.

Now, assuming P to be a normal logic program, we can define the consequence operator T_P^3 and models for P:

Definition 5. A *three-valued model* is an assignment of the truth values 0, 1, u to the set of propositional letters. For $\mathfrak{M}$, $\mathfrak{N}$ models, write $\mathfrak{M} \leq \mathfrak{N}$ iff for every propositional letter p its truth value in $\mathfrak{M}$ is equal or smaller than in $\mathfrak{N}$.

Definition 6. Given a three-valued model $\mathfrak{M}$, $T_P^3(\mathfrak{M})$ is the model determined by, for an atomic formula p:
(i) $T_P^3(\mathfrak{M})(q) = 1$ iff in P there is a clause $\varphi \to q$ such that $\mathfrak{M} \models \varphi$;
(ii) $T_P^3(\mathfrak{M})(q) = 0$ iff for all clauses $\varphi \to q$ in P, $\mathfrak{M} \models \neg\varphi$.
For formulas constructed using $\neg$, $\wedge$ and $\vee$, the operator T_P^3 behaves according to Table 6.

Theorem 7. $\mathfrak{M} \leq \mathfrak{N}$ implies $T_P^3(\mathfrak{M}) \leq T_P^3(\mathfrak{N})$.

Theorem 8. $\mathfrak{M}$ is a model of $comp(P)$ iff it is a fixed point of T_P^3. The least fixed point of T_P^3 exists and can be reached in finitely many steps. It will be called the *minimal model* of P.

If all three-valued models satisfy $comp(P)$, write $comp(P) \models_3 \varphi$, then the non-monotonic consequence with negation as failure obtains: $P \mathrel{|\!\!\approx}_3 \varphi$. Its logic is sound and complete:

Theorem 9. For a normal program P and atomic formula q:
(i) there is a successful derivation from $?q$ iff $P \mathrel{|\!\!\approx}_3 q$;
(ii) the query $?q$ fails finitely iff $P \mathrel{|\!\!\approx}_3 \neg q$.

4.2.3 Constraint logic programming

The above is still limited to propositional logic; now we will make the extension to first-order predicate logic. Literals will contain variables, which we will tacitly assume to be universally quantified. Thus we must replace the definitions of resolution and derivation from 4.2.1 as well as the Definition 4 of (general) query thus:

Definition 10. Let P be a normal program. A *query* is a finite formula of the form $?L_1, \ldots, L_k, E_1, \ldots, E_m$ where L_i are literals and E_j equations between terms. Let $?L_1, \ldots, L_k, E_1, \ldots, E_m$ be a query and $L_i(t_1, \ldots t_l)$ a positive literal such that the clause $K_1 \wedge \cdots \wedge K_n \rightarrow L_i(x_1, \ldots x_l)$ is in P. Then resolution yields the new query: $?\, L_1,\ \ldots,\ L_{i-1},\ K_1,\ \ldots,\ K_n,\ L_{i+1},\ \ldots,\ L_k,\ x_1 = t_1, \ldots,\ x_l = t_l,\ E_1, \ldots,\ E_m$. A derivation is *successful* if its last line consists only of equations between terms.

Importantly, constraint logic programming is sound:

Theorem 11. Let the normal program P be given. If a derivation from $?\varphi(y_1, \ldots y_v)$ ends successfully with a set of equations which jointly imply $y_1 = s_1, \ldots, y_v = s_v$, then $P \mathrel{|}\!\!\approx_3 \varphi(s_1, \ldots, s_v)$.

4.2.4 Inertia

The closed-world assumption can be though of as a principle of *inertia*, positive: 'whatever goes on, does so until explicitly stopped' and negative: 'nothing starts unless explicitly started'. Moreover, not only future, or right-hand inertia – but past, or left-hand inertia is possible as well. Thus in minimal models four kinds of inertia obtain; assuming universal quantification:

(28) $Happens(e,t) \wedge Initiates(e,f,t) \wedge t < t' \wedge \neg Clipped(t,f,t') \rightarrow HoldsAt(t',f)$;

(29) $Happens(e,t) \wedge Initiates(e,f,t) \wedge t > t' \wedge \neg Declipped(t',f,t) \rightarrow \neg HoldsAt(t',f)$;

(30) $Happens(e,t) \wedge Terminates(e,f,t) \wedge t > t' \wedge \neg Clipped(t,f,t') \rightarrow HoldsAt(t',f)$;

(31) $Happens(e,t) \wedge Terminates(e,f,t) \wedge t < t' \wedge \neg Declipped(t',f,t) \rightarrow \neg HoldsAt(t',f)$.

If a theory contains only one event happening and initiating or terminating a given f, then the f is neither clipped nor declipped apart from that one instance, and the consequents of the relevant two inertia laws hold.

That will be the case for micro-theories – that is, scenarios as defined in 4.3.1 – representing the (lexical) meaning of a single verb; once we add further discourse, the f may be clipped or declipped – which will be an instance of non-monotonic cancellation.

However, the sets of initiating and terminating events must not be dense. Loosely speaking, this means that cancellation cannot occur 'immediately' after (or before) the event initiating (or terminating) f. Hence corresponding to the four laws of inertia, the consequents of which may be cancelled by clipping or declipping, there are four laws of *least inertia* stating what cannot be thus cancelled:

(32) $Happens(e,t) \wedge Initiates(e,f,t) \rightarrow \exists t' > t\ (HoldsAt(f,t') \wedge \neg Clipped(t,f,t'))$;

(33) $Happens(e,t) \wedge Initiates(e,f,t) \rightarrow \exists t' < t\ (\neg HoldsAt(f,t') \wedge \neg Clipped(t',f,t))$;

(34) $Happens(e,t) \wedge Terminates(e,f,t) \rightarrow \exists t' < t\ (HoldsAt(f,t') \wedge \neg Declipped(t',f,t))$;

(35) $Happens(e,t) \wedge Terminates(e,f,t) \rightarrow \exists t' > t\ (\neg HoldsAt(f,t') \wedge \neg Declipped(t,f,t'))$.

Both (28–31) and (32–35) are properties of minimal models; the latter are not as straightforward as the previous, nevertheless, this being a basic and informal presentation, we omit the proofs.

4.3 Application to natural language

In order to apply the event calculus to the semantics of natural language, we must be able to formalise the meanings of natural-language expressions in it; for that purpose, *scenarios* will be introduced. Next, since our purpose is to explicate the meaning shared by verbs in an aspectual class – the meaning of an Aktionsart – we will need ways of making semantic generalisations, which will be found in *eventualities* as well as scenarios along with *integrity constraints*.

4.3.1 Scenarios

The meaning of a natural-language expression can be captured in EC by a scenario, that is a micro-theory consisting of EC-propositions that will axiomatise the interpretation of some EC-expression (e.g. a fluent) to mimic that meaning. For computational reasons (cf. [33, p. 49]) it is useful define a standard format for these micro-theories as a kind of programs, whose bodies are *settings*[25]:

Definition 12 (setting). A setting $\sigma(t)$ at time t is a first-order formula consisting of
(i) literals of the form $(\neg)HoldsAt(f,t)$ for the fixed t and any f,
(ii) identities between fluent- and between event-terms, and
(iii) formulas in the language of $\langle \mathbb{R}, <, +, \cdot, 0, 1\rangle$.

Definition 13 (scenario). A scenario S is a conjunction of propositions of the form:
(i) $Initially(f)$,
(ii) $\sigma(t) \rightarrow Initiates(e,f,t)$,
(iii) $\sigma(t) \rightarrow Terminates(e,f,t)$,
(iv) $\sigma(t) \rightarrow Happens(e,t)$,
(v) $\sigma(t) \rightarrow Releases(e,f,t)$,
(vi) $\sigma(f_1, f_2, t, d) \rightarrow Trajectory(f_1, t, f_2, d)$
where $\sigma(t)$ (more generally, $\sigma(f_1, f_2, t, d)$) are (possibly various) settings at a fixed t.

All temporal variables in settings and scenarios are assumed to be bound by universal quantification (cf. 4.2.3).

4.3.2 Eventualities

In order to capture the differences between Aktionsarten, we will now introduce eventualities (the term comes from Bach [3]). To begin with, considering the various syntactic rôles a verb can play in a scenario, we can distinguish four kinds of variables:

- f_1 which may be the first argument of $Trajectory$, but not the third one, nor that of $Releases$ – and accordingly represents an activity;
- f_2 which may, conversely, be the argument of $Releases$ and the third, but not the first of $Trajectory$ – and represents a change some object is undergoing;
- e representing a canonical culmination event (incepting f_3) or, should that be wanting, an otherwise relevant event such as that of termination (terminating f_1)[26];

[25] In [33, p. 49] the term 'state' is used, but the name 'setting' avoids its ambiguity.

[26] In adding events other than those of culmination here (and in adding a third value

- f_3 which may occur in the same places as f_2 and represents a consequent state that is brought about by the occurrence in question.

Usually, when $Trajectory$ holds, f_2 will be its third argument taken as parametrised $f(x)$ – that is, the degree of change – while f_3 will be the same argument taken as constant $f(c)$ where c is a constant representing the change's point of completion.

Then eventualities can be defined as quadruples of the form $\langle f_1, f_2, e, f_3 \rangle$. Writing $+$ or $-$ to indicate whether the consecutive elements of the quadruple have to be present in the scenario clauses representing the verb's meaning, we can determine the Aktionsart of the verb:

eventuality	Aktionsart
$\langle -, -, -, + \rangle$	state
$\langle +, -, -, - \rangle$	strict activity
$\langle +, +, -, - \rangle$	transitive activity
$\langle +, +, +, + \rangle$	accomplishment
$\langle -, -, +, + \rangle$	achievement
$\langle -, -, +, - \rangle$	point

Table 7: Eventualities and Aktionsarten

This table (taken from [33, p. 88]) gives the usual Aktionsarten, but we will see that other combinations also come in play. It has to be remembered, though, that an Aktionsart is ascribed to a verb as nothing more than a default one to be found in the verb's lexical entry. Various contexts can coerce a verb into Aktionsarten other than the default one (cf. [33, Ch. 11]).

Moreover, apart from $+$ and $-$, we will use $\mp$, meaning that the element in question is required by the verb's scenario clauses, but *can be cancelled* non-monotonically by further linguistic items (or pieces of world knowledge) added to the scenario. Thus $+$ will be restricted to meaning that not only is the element required, but furthermore *cannot* be cancelled – that is, cancelling it would render the piece of discourse represented by the scenario self-contradictory.

for the slots in eventuality quadruples, below) we depart from [33]. This is because while there eventualities corresponding are a guide to assigning the clauses for the VPs of a given Aktionsart – here we will proceed in the opposite direction: first establish the scenario clauses for a given verb class, and from those the relevant eventuality. The changes allow to encode a bit more information in the eventualities.

4.3.3 Integrity constraints

A notion taken from database theory, an integrity constraint says that if the states of the database fulfill a given condition (possibly empty), they must also fulfill a given obligation (cf. [29], [33, pp. 101–103]). For instance, the road sign 'bikes only' can be understood as the following integrity constraint:

(36) *If* $?HoldsAt(drive(x, here), now)$ *succeeds, then* $?HoldsAt(cyclist(x), now)$ *succeeds,*

while a promise made by Blücher to Wellington could have introduced the following constraint:

(37) $?Happens(arrive(prussians, waterloo), 18.6.1815)$ *succeeds.*

Then the definition, restricted for the positive case (though it can be generalised with negation as finite failure), is:

Definition 14 (integrity constraint). Let R be a time constant in the constraint language, φ and ψ formulas of EC. An integrity constraint is a statement of the form: *If* $?\varphi$ *succeeds, then* $\psi(R)$ *succeeds*, with possibly $?\varphi$ being the empty query. This means that if $?\varphi$ succeeds in a scenario S, then $?\psi(R)$ must be made to succeed as well.

Hence first it has to be attempted to resolve $?\varphi$ using the scenario, i.e. a program, S. If that fails (finitely), the program S has to be extended to S', by adding some new clauses – for instance, pieces of world knowledge – until $?\varphi$ is successfully resolved.

Integrity constraints are particularly useful when the meaning of an expression picks some entity – an individual, point in time etc. –, which cannot be accounted for by the scenario clauses, because they are universally quantified. Moreover, they are what finally determines the interpretation. The minimal model of a scenario (cf. Theorem 8) remains general: the interpretations of particular fluents and events are only defined up to parameter, expressing general causal or semantic relationships. To fix them to some particular (finite sets of) intervals, integrity constraints must be added to the scenario. For instance, if S is a scenario describing an international crisis, triggered by $shoot(x, y)$, we can fix it thus:

(38) $?Happens(shoot(gavrilo, franz),\ 28.6.1914)$ *succeeds,*

Then the general model of S becomes the model of a particular crisis in the summer of 1914.

5 Event-calculus semantics for aspect

The gist of the thesis – endeavouring to apply the event calculus introduced in Chapter 4 to Polish aspect described in Chapter 2, on the motivation given in Chapter 3 – is this chapter. It will begin with a preliminary discussion of Polish tenses in view of their intimate connection with aspect. The crucial part will be 5.2, where we will investigate the meaning shared by the verbs of particular Aktionsarten yielded by the aspectual classification. The results of that investigation will be summarised in 5.3, where also conclusions will be drawn pertaining to the general characterisation of aspect, Polish aspectual system and further applications of our approach. Finally, in 5.4 we will give a few examples of actual computations using the machinery from Chapter 4 and the results from 5.2.

5.1 Tense

As discussed in 2.1.3 above, a Polish imperfective can take the present, past or future tense – and a perfective either future or past, the unmarked defaults being the present imperfective and the past perfective. Thus it seems that aspect is intrinsically connected to tense (thus van Lambalgen and Hamm [33, p. 106] contra Comrie [10]). That indeed will be seen in the definitions of tenses, as well as in their application in 5.2.

In the definitions, we will use Reichenbach's [53] reference time (as in [33, Ch. 8] and e.g. [26]). It is a marker for the time or situation being talked about, which must be available to the speakers in order for them to be able to engage in temporal discourse. In general, the reference time can be distinct from the time the occurrence spoken of took place ('event time'). The paradigmatic example of that is the English Perfect – where the reference time is identical with the utterance time, while the event time lies in the past. However, since the three Polish tenses are absolute, we will simply use the reference time as identical with the event time.

Thus let $R, R_1 \dots R_n$ be real constants of the constraint language, and let now be another one. These constants are available independently of scenarios, because the latter model lexical meaning (which can then be combined with world knowledge, cancelled by other lexical items etc.) – while the previous model, so to speak, temporal consciousness. By that we mean knowing the answers to: 'what time is it now?' (now) and 'what time is being referred to?' (R_i).

Definition 15 (tenses for imperfectives). For an imperfective VP represented by the fluent f, the present tense is given by the integrity constraint
(i) $?HoldsAt(f, R),\ R = now$ *succeeds*;
the past tense by
(ii) $?HoldsAt(f, R),\ R < now$ *succeeds*;
and the future tense by
(iii) $?HoldsAt(f, R),\ R > now$ *succeeds*.

Thus defined past tense includes the past use of (morphologically) present imperfectives, i.e. the historical present as well.

Definition 16 (tenses for perfectives). For a perfective VP represented by the event e or by the fluent f with e as the third element of the corresponding eventuality, the past tense is given by the integrity constraint:
(i) $?Happens(e, R),\ R \leq now$ *succeeds*;
and the future tense by
(ii) $?Happens(e, R),\ R > now$ *succeeds*.

These definitions assume that for all perfectives the third slot of the eventuality is filled, while no imperfective is represented by an event; in 5.2 that will be seen to be the case. The constants $R, R_1 \ldots R_n$ are not indispensable for the above definitions. We have nevertheless introduced them, since in general they allow for representing relative temporal relations induced by the order of information in discourse (cf. 5.4) or by world knowledge (cf. [33, Ch.Ch. 8-9]), for instance the double rôle of the perfective mentioned in 2.1.3.[27]

Moreover, given the laws of inertia, if the sign $\leq$ in Definition 16 is not to reduce to $<$, the constant now must be a non-punctual interval, which might seem surprising at the first glance. However, as psychologists – from James [24] to recent empirical researchers [55], [50] – have argued,

[27]Note that our treatment of tense is ancillary to the discussion of aspect in 5.2; accordingly, by no means do we claim it to be complete and exhaustive. Still, the Polish tense system does seem simple enough for this treatment to be adequate. For instance, the future tense does not exhibit any complexities comparable to those of its English counterpart (cf. [33, pp. 116–130]).

what humans perceive as 'now' is in fact an interval several seconds long (cf. [33, pp. 11–12]). Therefore the temporally extended now is in fact cognitively plausible.[28]

Finally, discussing the semantics of particular Aktionsarten we will abstract from the tense of the verb, aiming at capturing the meaning contribution of the Aktionsart and aspect. However, integrity constraints with $Happens$ or $HoldsAt$ need to be related to now. Therefore we will write $R \lesseqgtr now$ in these, meaning that when used in a concrete scenario, the constraint should include the tense information by replacing $\lesseqgtr$ with another sign according to Definitions 15–16.

5.2 Semantics of the Aktionsarten

Here the meaning specific to each of the Aktionsarten mentioned in Table 3 will be explicated by stating what scenario clauses or integrity constraints must be added when introducing a VP of a given Aktionsart. From this, the eventuality corresponding to the given Aktionsart in the sense of 4.3.2 will follow. When the imperfective's meaning is obvious, to be plainly represented by

(39) $?HoldsAt(f, R), R \lesseqgtr now$ *succeeds*,

with R being the reference time in the sense of Definition 15, we will not mention that. Nor – as settled in 2.1.2 – will we discuss the iterative and habitual readings that all, or almost all, imperfectives can take or be coerced into (quite like the habitual reading of English Simple Present). Furthermore, we will not take any passives into consideration.

Finally, apart from the tense definitions from 5.1, one technical assumption needs to be made: we must ensure that whenever an object is mentioned in a scenario, it has a unique name throughout. In particular, fluents that are causally related should have the same arguments in the proper places. For instance, if Julia is the direct object of one VP and the subject of another VP, that may be significant for the scenario and should be preserved in the formalism. This can be done by an integrity constraint, assuming that ${x_1}^{f_1}, \ldots, {x_n}^{f_1} = \bar{x}^{f_1}$ are the agent arguments of f_1, $\bar{x}^{f_3}$ of f_3 and $\bar{y}^{f_2}$ the patient arguments of f_2; then:

(40) $?\ \bar{x}^{f_1} = \bar{y}^{f_2} = \bar{x}^{f_3}$ *succeeds*

[28] Logically as well, since it is possible to define instants in terms of intervals rather than the other way round; see [33, Ch. 2], [70], [21].

ensures that all these are e.g. Julia. Similar consistency-of-arguments assumptions are, despite triviality, indispensable also elsewhere, e.g. ensuring that a f_2 of $Trajectory$ takes one value only for any t (cf. [33, p. 91]). Henceforth we will assume consistency of arguments tacitly, mutatis mutandis for whatever fluent or event arguments that will be relevant.

5.2.1 Class$_{1t}$: transitions

Recall that by a transition we mean a gradual appearance (or disappearance) of some property (cf. [4]), as in *grubnąć, zgrubnąć* – 'to be growing, to have grown fat(ter)', *zielenić się, zazielenić się* – 'to be becoming, to have become green(er)' etc.[29] Let us conceive it as a function $f_2(x)$ of the property represented by the variable x growing[30] in time, where g is the function describing the growth (i.e. $g\colon t \mapsto x$). Then, assuming b to have been the initial value of the property before the transition started, we have the clause:

(41) $HoldsAt(f_2(x), t) \wedge x \geq b \rightarrow Trajectory(f_1, t, f_2(x + g(d)), d)$

so as long as the transition is ongoing, the imperfective, represented by f_1, obtains.

Now, a culmination point would occur at $t + d$, initiating the resulting state (being fat, green etc.). But the perfective obtains once the transition has progressed to any arbitrary extent, regardless of whether it has already ended or not. That is to say, Class$_{1t}$ verbs are atelic (cf. Aristotle [2, Θ 6, 1048b]): once one has started growing fat, one has already grown fat – even though the transition might well go on further. Hence if we want to use the culmination point to initiate the resulting state, we have to extend it over the entire f_1. Fortunately, that is doable, because in the event calculus events can be temporally extended:

(42) $HoldsAt(f_1, t) \rightarrow Happens(e, t)$

(43) $Initiates(e, f_3, t)$

Defined thus, e includes the canonical culmination point as its endpoint, but is not restricted to it; compare (70–71). Hence completed transitions – corresponding to Class$_{1t}$ perfectives – are $\langle +, -, +, + \rangle$, while ongoing transitions – for Class$_{1t}$ imperfectives – are $\langle +, \mp, \mp, - \rangle$.

[29] The comparative in the English translations of these verbs is optional; see (49).

[30] For simplicity we will assume that a transition is always an increase of some property, even if it is a negative one, e.g. stupidity, poorness or thinness. One could have decreasing transitions for these on similar lines, but that would call for defining the pairing between positive and negative properties.

An objection could be raised that f_1 should be identical with f_2. After all, transitions (in the active voice) are never driven by an external force; indeed, they could more properly be called 'transmutations'. Accordingly, Class_{1t} verbs are never transitive and often must be accompanied by the reflexive pronoun, e.g. *starzeć się*, 'to age', *zielenić się*, 'to grow green'. Thus it is queer to postulate a force driving the change, yet distinct from it. Nevertheless, on a closer scrutiny there always is such a force, as ergative alternation evinces. For instance, in:

(44) Julia się zarumieniła. Czyżby miała się czego wstydzić?
Julia refl $\text{blushed}^{\text{ep-pfv}}_{\text{3.sg.}}$. whether $\text{had}_{\text{3.sg.}}$ refl what $\text{shame}_{\text{infinitive}}$
Julia blushed. Did she have anything to be ashamed of?

it is what allows to infer from a transition taking place that there must have been a cause.[31] The cause must relate to f_1, but need not *directly* influence $f_2(x)$: shame causes blushing, but it does not directly influence the hue of Julia's skin. Thus it makes good sense to have distinct f_1 and f_2.

Furthermore, that e should be present, but not restricted to the culmination point can be seen from the following examples. Firstly, it does not have to be fixed at any specific value of x (as a canonical culmination point would); for instance, *mądrzeć*, 'to be growing wiser' perfectivises to *zmądrzeć* 'to have grown wiser' without meaning any specific punctual metanoia. Nevertheless, the event must be there not merely for a technical, but for a semantic reason as well. That can be seen from nominalisation: the noun *mądrzenie*, '(the process of) growing wise' derives from the fluent $f_2(x)$ – but *zmądrzenie*, '(the event of) having grown wise', derives from the event e.

Secondly, the e ending the perfective can be taken punctually, but also unpunctually, stretching over the entire f_1, as the above construction allows. This is where the widespread definition of the perfective as ignoring the 'internal temporal structure' (e.g. [9, pp. 3, 16], [37, p. 5], [28, p. 16]) of the occurence is indeed right. However, the perfective can also be used to *explicate* the internal temporal structure; compare:

(45) Aleksander grubnął od dawna, aż wreszcie
Alexander $\text{got-fatter}^{\text{ipfv}}_{\text{3.sg.}}$ from long-ago until finally
zgrubnął.
$\text{get-fatter}^{\text{ep-pfv}}_{\text{3.sg.}}$

[31] It seems that in order to argue that, nevertheless, sometimes no cause is available one would not only have to be on bad terms with the principle of causality, but also forced to endorse something like the Heideggerian '*man*'.

Alexander has been getting fatter for a long time, until finally he became fat.

(46) Przez ostatnią kadencję Aleksander zgrubnął.
through last term_{acc} Alexander $\text{got-fatter}^{\text{ep-pfv}}_{\text{3.sg.}}$
During his last term in office, Alexander got fatter.

In (45) we have a fluent f_1 for the imperfective *grubnął* concluding with the punctual event e for the perfective *zgrubnął*, which reveals the temporal structure of a transition viewed, as it were, as an accomplishment. In (46), to the contrary, the fluent is co-extensional with the event, neglecting the temporal structure.

These two readings of the perfective are in fact available regardless of the Aktionsart. It will be seen that all perfectives' representations involve an event (be it culminating, initiating or terminating), and when they also involve a fluent, the event can be taken to extend over the duration of the fluent. So even though we will not repeat the argument in the following sections, in principle it can be applied to verbs discussed there as well. That the fluent and the event refer to the same occurence is due to Feferman coding (cf. 4.1.2).

Returning to Class_{1t} verbs, having no culmination point is why they cannot give rise to the imperfective paradox[32]. Conversely, verbs that can, must not be Class_{1t}, which gives a criterion for distinguishing the latter; for example, a Class_{1t} verb in:

(47) * Aleksander grubnął, ale nie zgrubnął.
Alexander $\text{got-fatter}^{\text{ipfv}}_{\text{3.sg.}}$ but not $\text{got-fatter}^{\text{ep-pfv}}_{\text{3.sg.}}$
Alexander has been growing fatter, but he hasn't grown fatter.

Sentences like this might be considered acceptable, but only when understood as being analytically false in order to carry some implicature by violating the Gricean [19] maxim of quality, e.g. that the transition has progressed, but to a small degree only. To the contrary, opposed a Class_3 verb in:

[32]The paradox, first discussed by Dowty [14], is as follows. Accomplishments (so Class_3 verbs) consist in striving towards an objective. Were there no objective, the occurence could not be considered an accomplishment. Yet when the objective is eliminated by some further discourse (as in (48)), the (imperfective of the) accomplishment verb can nevertheless be used. This causes problems to some theories, but not for the present one; see [33, pp. 156–157] for a discussion and references.

(48) Mieczysław reformował gospodarkę, ale jej nie
Mieczysław reformed$^{\text{ipfv}}_{\text{3.sg.}}$ economy$_{\text{acc}}$ but her$_{\text{gen}}$ not
zreformował. Było to już niemożliwe.
reformed$^{\text{ep-pfv}}_{\text{3.sg.}}$. was it already impossible

Mieczysław has been reforming the economy, but he has not reformed it completely. That was no longer possible.

or in (19) does give rise to the imperfective paradox. The reason for that can be seen in connection with (hierarchical) planning: in (48) or (19) the activity's successful conclusion depends on having attained some partial goals, which may fail. In (47) the transition is simple, not requiring any subordinate goals, not even that it should reach some treshold.

This criterion is useful, because otherwise in order to assign a verb to, for instance, either Class$_{1t}$ or Class$_3$, one would have to decide whether it may or may not take the delimitative *po-* prefix, which can often not be obvious. Indeed, it is a case where speaker intuitions are of little help, because they can be mixed with rules of prescriptive grammar. For instance, it seems to be a reasonable prediction to rule out **pogrubnąć*, '*to be growing fat a bit' (Class$_{1t}$) and to accept *poreformować*, 'to be reforming a bit' (Class$_3$), even if the latter is dubious from the prescriptive point of view.

Moreover, apparently f_3 might hold both before and after the transition, thus violating least inertia, as in:

(49) Andrzej zawsze był mądry, ale po wizycie w Klewkach
Andrew always was$_{\text{3.sg.}}$ wise but after visit$_{\text{loc}}$ in Klewki$_{\text{loc}}$
jeszcze zmądrzał.
yet got-wiser$^{\text{ep-pfv}}_{\text{3.sg.}}$

Andrew has always been wise, but after the visit to Klewki he grew even wiser.

However, such an interpretation would be based on equivocating two different states of being wise in different degrees – and thus incorrect. That is to say, f_3, 'being wiser' does not hold before the transition; some other fluent of 'being (somewhat less) wise' does. Hence the inertia of f_3 accounts for the intuitive inference from 'he has grown wiser' to 'he had been *less wise* beforehand'. Normally, by the pragmatic quantity principle (cf. [19]), 'less wise' would be taken to be the same as 'unwise' (and conversely, 'wiser' the same as 'wise'), which is the source of the normally innocuous equivocation. But in (49) this inference is cancelled by the explicit addition of 'he was wise beforehand', thus rendering the equivocation incorrect.

5.2.2 Class$_{1s}$: states

States are verbs[33] such as *chorować*, 'to be being sick' or *martwić się*, 'to be worrying', *nienawidzić*, 'to be hating' or *wierzyć*, 'to be believing'. Let a state f_3 be incepted by the event e; we need an initiating event:

(50) $Initiates(e, f_3, t)$

(51) $?Happens(e, R), R \lesseqgtr now$ *succeeds*.

Then a Class$_{1s}$ perfective holds once e has occurred. The corresponding imperfective holds whenever f_3 holds (although if it had held since time 0, it may also hold despite that the perfective does not). Thus, incepted and ongoing states – corresponding to Class$_{1s}$ perfectives – are $\langle -, -, +, + \rangle$. The imperfectives are $\langle -, -, -, + \rangle$ – or, for that matter, $\langle +, -, -, - \rangle$ since the distinction between states and activities is relative to the scenario [33, p. 88].

The negative past and positive future inertia entailed by (51) account for the meaning of a punctual inception of a state that had not obtained before:

(52) Nie wierzył, ale gdy tylko ujrzał – uwierzył.
not believed$^{\text{ipfv}}_{\text{3.sg.}}$ but when only saw$^{\text{sup-pfv}}_{\text{3.sg.}}$ – believed$^{\text{ep-pfv}}_{\text{3.sg.}}$

He had not believed, but as soon as he saw – he started to believe.

(53) * Wierzył już od dawna, ale gdy tylko ujrzał
believed$^{\text{ipfv}}_{\text{3.sg.}}$ already from long-ago$_{\text{gen}}$ but when only saw$^{\text{sup-pfv}}_{\text{3.sg.}}$
– uwierzył.
– believed$^{\text{ep-pfv}}_{\text{3.sg.}}$

He had already been believing for a long time, but as soon as he saw – he started to believe.

It generally distinguishes states from transitions (compare (53) with (49)), explaining why we do not need any prior fluent f_1, as well. Furthermore, (53) is ruled out due to least inertia – *uwierzył*, 'has started believing' requires that immediately beforehand he had not been believing, that is least negative past inertia. Of course, this is not to say that f_3 could not have held at any time beforehand; in general, inertia can be overridden. For instance in:

[33] As elsewhere, we make a mental shortcut by dubbing the verbs 'states', while in fact verbs *refer* to states, or perhaps even not to states, but to properties or relations giving rise to states. But we need not be philosophically meticulous.

(54) Dawno przestał wierzyć. Ale gdy poznał
long-ago stopped$_{3.sg.}^{\text{mp-pfv}}$ believe$_{\text{infinitive}}$ but when met$_{3.sg.}^{\text{mp-pfv}}$
Paulinę, uwierzył znów.
Paulina$_{\text{acc}}$ believe$_{3.sg.}^{\text{ep-pfv}}$ again

He had stopped believing long ago. But when he met Paulina, he started to believe again.

the information added in the second sentence amounts to extending the scenario with conditions overriding the default 'inert' inference that he does not believe now.

Finally, note that if there is a Class$_{1s}$ perfective at all, it is temporally co-extensional with the corresponding imperfective. (There can be no perfective if the imperfective holds since time 0, that is – the state is ongoing in spite of not having been incepted.) But for instance:

(55) Po wojnie Leszek uwierzył w komunizm. Ale w 1956
after war Leszek believed$_{3.sg.}^{\text{ep-pfv}}$ in communism$_{\text{acc}}$. but in 1956
stracił wiarę i dziś jest liberałem.
lost$_{3.sg.}^{\text{ep-pfv}}$ faith$_{\text{acc}}$ and today is$_{3.sg.}$ liberal$_{\text{instr}}$

After the war Leszek started to believe in communism. But in 1956 he lost faith and today he is a liberal.

entails that now the past perfective *uwierzył*, 'started to believe' is true, but the present imperfective *wierzy*, 'is believing' is false; does that not contradict co-extensionality? Not really, because of the difference of tenses: the past perfective understood as pluperfect ('had started believing') is co-extensional with the past imperfective *wierzył*, 'has been believing'; the present imperfective is co-extensional with the past perfective understood as present perfect (cf. 2.1.3). Therefore in fact (55)'s past perfective should be read as a pluperfect one, while the inferred imperfective is present; hence the contradiction between them does not violate the co-extensionality of aspects in Class$_{1s}$.

5.2.3 Class$_2$: strict activities

The verbs found in this class denote strict, that is intransitive, activities (in [42] called 'processes') that have no natural culmination point. In the perfective they are meant to be terminated after having held for a while; no culmination point is involved. Thus: *siedzieć*, 'to be sitting' and *posiedzieć*, 'to have been sitting a bit'; *narzekać*, 'to be complaining' and *ponarzekać*, 'to have been complaining a bit'. So given an activity f_1 we need a termination point:

(56) $Terminates(e, f_1, t)$

(57) $?Happens(e, R), R \lesseqgtr now$ *succeeds*

where f_1 has been holding for a bit in the sense of Definition 18 below; formally, this requirement is an integrity constraint as well. Therefore terminated activities – for Class$_2$ perfectives – are $\langle +, -, +, - \rangle$; we put a plus for e, even though it is not a canonical culmination point, but rather a termination point – yet it is implied in the meaning of the perfective. The corresponding imperfectives are $\langle +, -, -, - \rangle$.

The least inertia applying to f_1 is important here. If an imperfective verb is in the past tense, then there is a default – perhaps pragmatic – inference that an event terminating it has occurred. It can be cancelled, e.g. in:

(58) Jan siedział pod lipą i wciąż tam siedzi.
John sat$^{\text{ipfv}}_{\text{3.sg.}}$ under linden$_{\text{instr}}$ and still there sit$^{\text{ipfv}}_{\text{3.sg.}}$
John was sitting under the linden and he is still sitting there.

had it not been for the second clause, we could infer that John is not sitting anymore. However, not so for a Class$_2$ perfective:

(59) * Jan posiedział pod lipą i wciąż tam siedzi.
John sat$^{\textit{po}\text{-pfv}}_{\text{3.sg.}}$ under linden$_{\text{instr}}$ and still there sit$^{\text{ipfv}}_{\text{3.sg.}}$
John has been sitting under the linden a bit and he is still sitting there.

The default inference cannot be simply cancelled, even though it can be non-monotonically overridden by later occurrences:

(60) Jan posiedział pod lipą, wstał i znowu usiadł.
John sat$^{\textit{po}\text{-pfv}}_{\text{3.sg.}}$ under linden$_{\text{instr}}$ got-up$^{\text{mp-pfv}}_{\text{3.sg.}}$ and again sat$^{\text{ep-pfv}}_{\text{3.sg.}}$
John has been sitting under the linden a bit, he got up and sat down again.

Still, it is necessary for the use of a Class$_2$ perfective that the opposite of the original activity obtained at some point, which is what we obtain by least negative future inertia of f_1.

Moreover, we insist that the activities in Class$_2$ are intransitive. Transitive ones – even though Młynarczyk [42, p. 129] assigns some here: *całować*, 'to be kissing', *chłonąć*, 'to be absorbing', *lizać*, 'to be licking' – must belong to Class$_3$, because they admit both delimitative and empty *po-*, for instance:

(61) Kiedy zgasło światło, pocałowali się.
when went-off$^{\text{ep-pfv}}_{\text{3.sg.}}$ light kissed$^{\text{ep-pfv}}_{\text{3.pl.}}$ refl
After the light had gone off, they kissed.

(62) Kiedy zgasło światło, pocałowali się chwilę.
when went-off$^{\text{ep-pfv}}_{\text{3.sg.}}$ light kissed$^{\textit{po}\text{-pfv}}_{\text{3.pl.}}$ refl moment$_{\text{acc}}$
After the light had gone off, they would kiss (lit. were kissing) for a moment.

which allows us to restrict Class$_2$ to strict activities. Of course coercion may be possible either way. For example, even though we assign *narzekać*, 'to be complaining' to Class$_2$, because it has no empty-prefix perfective equivalent, it still may be coerced into transitivity by adding an argument, say *narzekać na rząd*, 'to be complaining about the government'. Conversely, a transitive activity like *czytać*, 'to read', when used without an argument has an intransitive reading.

Having thus cleared the ground, let us pass on to an essential property of Class$_2$ perfectives. As already mentioned, their meaning entails that the activity – f_1 – has been going on for a while before the termination. For instance:

(63) * Jan posiedział, ale od razu wstał.
John sat$^{\textit{po}\text{-pfv}}_{\text{3.sg.}}$ but from once$_{\text{gen}}$ got-up$^{\text{mp-pfv}}_{\text{3.sg.}}$
John had been sitting a bit, but he got up immediately.

One might think that this is ruled out by the least inertia requirement. However, recall that this requirement is satisfied by any, arbitrarily short interval at which f_1 holds, so it does not rule (63) out, nor does it rule the following correct example out:

(64) Jan usiadł, ale od razu wstał.
John sat-down$^{\text{ep-pfv}}_{\text{3.sg.}}$ but from once$_{\text{gen}}$ got-up$^{\text{mp-pfv}}_{\text{3.sg.}}$
John had sat down, but got up immediately.[34]

Here the duration of f_1 may indeed be arbitrarily minimal, yet undoubtedly nonzero. Class$_2$ perfectives, to the contrary, entail that the duration was, so to speak, *of the usual order*. Thus let us define:

[34] *Usiadł*, 'has sat down' is a Class$_5$ perfective, to which the imperfective *siadać*, 'to be sitting down' in the sense of 'to be getting into a sitting position' rather than 'to be being in a sitting position' (*siedzieć*) corresponds.

Definition 17 (Usual duration). Take a perfective VP denoting a nonculminated[35] activity, represented by f_{VP}. Let S be the scenario expressing the paradigmatic script for that VP. Let both f_{VP} and a complementary fluent f'_{VP} such that $\forall t(HoldsAt(f_{VP}, t) \leftrightarrow \neg HoldsAt(f'_{VP}, t))$ be included in S. Let S be fixed to a particular finite set of intervals by some integrity constraints I.

Take the class of S's minimal models in which I hold. Let $\mathbf{F}_{VP}$ be the set of the fluents f_{VP} taken from these models. Then $\mathbf{D}_{VP}$, the set of the lengths of the intervals the fluents f_{VP} consist of: $\mathbf{D}_{VP} = \{\bar{b} \mid \exists f \; b \in f \wedge f \in \mathbf{F}_{VP}\}$ is the range of VP's usual duration.

Hence let us write $\bar{t} \approx \mathbf{D}_{VP}$, for 'the duration $\bar{t}$ is of the order of the VP's usual duration' iff $\exists b = \bar{t} \, b \in \mathbf{D}_{VP}$. Let us write $\bar{t} \gtrnapprox \mathbf{D}_{VP}$, for 'the duration $\bar{t}$ is greater than the order of the VP's usual duration' iff $\forall b \in \mathbf{D}_{VP} \, \bar{t} > b$; and similarly for $\lnapprox$, $\lesssim$ and $\gtrsim$.

An example might elucidate this definition somewhat; take the scenario for the paradigmatic script for crossing the bridge (a particular one of given length l – say, the Magere Brug). Thus f_{VP} is the fluent $crossing$, which is related to $distance(x)$ by a $Trajectory$:

(65) $HoldsAt(distance(x), t) \rightarrow Trajectory(crossing, t, distance(x+g(d)), d)$;

generally, the scenario is similar to that given in [33, p. 50]. Importantly, g is a function of time (presumably linear; cf. 5.2.1), describing the progress of the crossing. So if I will fix the event initiating $crossing$ at some particular time t_1, and the minimal models will be such at which the crossing proceeds ordinarily (e.g., the Magere Brug is not opened while being crossed etc.), then g will yield $distance(l)$ at $t_1 + d$. Hence d will be the usual duration; but since there may be several equally good ways of crossing the bridge ordinarily, there may be several distinct minimal models and thus different $d_1, \ldots d_n$. These will constitute the set $\mathbf{D}_{crossing}$.

Of course not every verb is to be represented by a fluent being an argument of a $Trajectory$; indeed, Class_2 verbs are not. For those $\mathbf{D}_{VP}$ cannot be obtained so straightforwardly as in the above example. But it seems reasonable to expect that all verbs having usual duration are ultimately related to some $Trajectory$, even if indirectly. For instance, the usual duration of sleeping derives from some bodily processes involving dynamic change, so a $Trajectory$. In any case, the above definition does not require explicating such indirect connections (cf. (66) below).

Few more remarks are in order here. The notion of paradigmatic *script*, taken from cognitive science (cf. [54, Ch. 3]), describes the VP's

[35] Including, but not limited to nonculminating.

paradigmatic instance: what goals, actors, occurrences etc. does it usually involve, in what order and taking how long. It essentially depends on explaining human cognitive abilities in terms of planning (cf. [47]). To invoke this notion is innocuous insofar scripts are believed to be a part of our cognitive equipment, and thus readily available when we are computing meaning.

Furthermore, to see why usual duration is associated with an entire VP rather than just the verb, compare the usual duration of the VP *posiedzieć w pracy*, 'to be sitting (staying) at work a bit' with that of *posiedzieć w więzieniu*, 'to be sitting (staying) in prison a bit'. The complementary fluents are necessary to ensure that not only does f_{VP} not prematurely terminate – which follows by inertia of the minimal model (cf. 4.2) –, but does not unduly persist either – then f'_{VP} would be prematurely terminated.

Now the condition mentioned above that the activity described by f_1 of a Class$_2$ perfective has been going on for a bit can be put straightforwardly as[36]:

Definition 18 (Going on a bit). The fluent f terminated at t' has been going on a bit iff the following integrity constraint holds: *If* $?(HoldsAt(f,t') \wedge Happens(e',t') \wedge Terminates(e',f,t')) \wedge (((Happens(e,t) \wedge Initiates(e,f,t)) \vee (Initially(f) \wedge t' = 0)) \wedge \neg Clipped(t',f,t))$ *succeeds, then* $?(t - t') \gtrsim \mathbf{D}_f$ *succeeds.*

Let us consider another example with usual duration defined rather precisely, even though with no relation to a $Trajectory$:

(66) Posłuchał „Verklärte Nacht" pod von Karajanem.
listened$^{po\text{-pfv}}_{3.sg.}$ 'Verklärte Nacht' under von Karajan$_{\text{instr}}$
He was listening to 'Verklärte Nacht', conducted by von Karajan, for (just \ quite) a bit.

For the corresponding imperfective VP *słuchał...*, 'he was listening...'n, world knowledge (namely knowledge of the recording [56]) gives us that $29'55'' \in \mathbf{D}_{ipfv}$. This seems the most plausible candidate for usual duration; yet should it turn out incompatible with the rest of the scenario, we can look for other elements of $\mathbf{D}_{ipfv}$.

By Definition 18, the fluent of listening has been holding for longer than $29'55''$, so the subject has listened to more than the entire piece. Is this the right interpretation? Yes, insofar given no further context (66) may have that meaning (cf. 2.2.2). However, if there was in the context some

[36]This does not allow for verbs with an infinite usual duration – but even if there were such verbs, they plainly could not be Class$_2$ perfectives.

suggestion of a relatively short time (a temporal adverb etc.), then (66) would be understood quite oppositely, as meaning that he has listened to just a part of the piece. This would exclude the above interpretation, but also yield a piece of world knowledge suggesting another usual duration, shorter than $29'55''$. The above reasoning can be repeated for the shorter duration. On that interpretation no conclusions as to the objective duration of listening can be drawn (since it is longer than shorter than $29'55''$, which is not particularly informative). However, it carries the subjective-shortness meaning, which is the adequate interpretation.

Finally, one objection to this approach to usual duration could be that it is an ad hoc device, designed merely to explain examples like (63–64), a peculiarity of Class$_2$. To the contrary, firstly, it will be useful for Clas$_3$ and Class$_4$, where the delimitative *po-* appears as well. Secondly, it can help in accounting for other phenomena as well, for instance the inherent temporal meaning of some lexical items.

For example, compare the Class$_2$ verb *stać*, *postać*, 'to be standing, to have been standing a bit' with the Class$_5$ verb *przestać (godzinę)*, *przestawać (godzinę)*, 'to have been, to be standing (for an hour)'[37]. Usually, the latter's meaning inherently implies that the period of standing was long, while *postać* implies that it was rather short and *stać* is neutral (Comrie [9, p. 17] gives this example for Russian). However, that implicature may concern either the objective duration or the subjective impression of it.

Now, $\bar{t}$ is the same in both cases, but the usual duration of *przestać* is greater than that of *postać* (that is to say, $\mathrm{median}(\mathbf{D}_{\textit{przestać}}) > \mathrm{median}(\mathbf{D}_{\textit{postać}})$), and for the imperfective *stać* $\mathbf{D}$ is undefined. Then for some duration $\bar{t}$, $\mathbf{D}_{\textit{postać}} \approx \bar{t}$ and $\mathbf{D}_{\textit{przestać}} \gnsim \bar{t}$, so *postać* used of that duration is true and means an objectively short standing; *przestać* used of the same duration is literally false, hence bearing a quality implicature that the standing was subjectively long. To take an example, in this manner we can account for

(67) Postałem parę minut na mrozie.
stood$^{\textit{po}\text{-pfv}}_{\text{1.sg.}}$ couple minutes$_{\text{gen}}$ on frost$_{\text{loc}}$
I have been standing in the cold for a *few* minutes.

meaning that the standing was objectively short (since a few minutes are within the usual duration of *postać na mrozie*), while

(68) Przestalem parę minut na mrozie.
prze-stood$^{\text{mp-pfv}}_{\text{1.sg.}}$ couple minutes$_{\text{gen}}$ on frost$_{\text{loc}}$

[37] The temporal qualifier is needed to distinguish this verb from the habitual *przestawać*, 'to be standing for some time every now and then'. There also is a homographic verb *przestać*, *przestawać*, 'to have stopped, to be stopping'.

I have been standing *in the cold* for a few minutes.

means that the stay was subjectively long (since a few minutes are less than the usual duration of *przestać na mrozie*).

5.2.4 Class$_3$: accomplishments

An accomplishment is a transitive activity f_1 producing a progressing change f_2 and culminating with the canonical culmination point e, thus incepting the resulting state f_3. The imperfective, for instance *czytać*, 'to be reading', *budować*, 'to be building', *myć*, 'to be washing', denotes a dynamic change and is accordingly interpreted as f_1 in $Trajectory$, where f_2 is the change corresponding to the passive, e.g. *być czytanym*, 'to be being read' etc. Hence for a Class$_3$ imperfective we have:

(69) $HoldsAt(f_2(x), t) \rightarrow Trajectory(f_1, t, f_2(x + g(d)), d)$

(70) $Initiates(e, f_2(c), t)$

(71) $HoldsAt(f_1, t) \wedge HoldsAt(f_2(c), t) \rightarrow Happens(e, t)$

The latter two clauses define e to be the canonical culmination point (cf. [33, p. 90]). Now, for the empty-prefix perfective – like *przeczytać*, 'to have read', *zbudować*, 'to have built', *umyć*, 'to have (completely) washed' – the culmination point must be reached:

(72) $?Happens(e, R), R \lesseqgtr now$ *succeeds*.

On the other hand, a terminated accomplishment is one that does not reach the canonical culmination point, but rather terminates with some e' beforehand. Thus for a Class$_3$ delimitative-*po-* perfective – like *poczytać*, *pobudować*, *pomyć*, 'to have been reading, building, washing a bit' – (69) must hold, but additionally a terminating event happens:

(73) $Terminates(e', f_1)$

(74) $?Happens(e', R) \wedge (Trajectory(f_1, t, f_2(x + g(d)), d) \rightarrow R \leq t + d), R \lesseqgtr now$ *succeeds*

where f_1 has been holding a bit (in the sense of definition 18). Thus accomplishments – corresponding to Class$_3$ empty-prefix perfectives – are $\langle +, +, +, + \rangle$; terminated accomplishments – Class$_3$ delimitative-*po-* perfectives – are $\langle +, +, +, - \rangle$. Imperfectives of Class$_3$ are transitive activities, $\langle +, +, \mp, - \rangle$.

Note that by least inertia f_1 must cease after the culmination at least for a moment, which accounts for examples like:

(75) * Przeczytałem „Sein und Zeit" i wciąż je czytam.
read$^{\text{ep-pfv}}_{\text{1.sg.}}$ 'Sein und Zeit' and still it$_{\text{acc}}$ read$^{\text{ipfv}}_{\text{1.sg.}}$
I have read 'Sein und Zeit' and I am still reading it.

but of course in general inertia can be non-monotonically cancelled:

(76) Przeczytałem „Der logische Aufbau" i znów ją czytam.
read$^{\text{ep-pfv}}_{\text{1.sg.}}$ 'Der logische Aufbau' and again her$_{\text{acc}}$ read$^{\text{ipfv}}_{\text{1.sg.}}$
I have read 'Der logische Aufbau' and I am reading it again.

Least inertia can also be seen in the resulting state f_3 (which can be directly referred to by a perfective passive, consisting of *być*, 'to be' or *zostać*, 'to become' and an adjective derived from the empty-prefix perfective). For instance, *została wypita*, 'has become drunk-up' in the following examples:

(77) Popili wódki, ale nie została ona wypita.
drunk$^{\textit{po}\text{-pfv}}_{\text{3.pl.}}$ vodka$_{\text{gen}}$ but not became$^{\text{mp-pfv}}_{\text{3.sg.}}$ she drunk-up
They have been drinking the vodka a bit, but it hasn't been drunk up.

(78) * Wypili wódkę, ale nie została ona wypita.
drunk$^{\text{ep-pfv}}_{\text{3.pl.}}$ vodka$_{\text{acc}}$ but not became$^{\text{mp-pfv}}_{\text{3.sg.}}$ she drunk-up
They have drunk the vodka up, but it hasn't been drunk up.

The delimitative-*po-* perfective in (77) does not (have to) entail the inception of f_3 (nor does the imperfective), but the empty-prefix perfective in (78) does, thus enforcing least inertia contradicted by the second clause.[38]

Nevertheless, the termination point can be premature, but does not have to. For instance, when *wypili*, 'they have drunk up' is true and it is also true that the drinking took a bit, then *popili*, 'they have been drinking a bit' is true as well, even though the termination was not premature. Only when there is no evidence to the contrary, using the delimitative-*po-* perfective instead of the empty-prefix serves to implicate (by the maxim of quantity) that the termination has been premature, as in:

(79) Wieczorem poczytałem „Materializm subiektywny".
evening$_{\text{instr}}$ read$^{\textit{po}\text{-pfv}}_{\text{1.sg.}}$ 'materialism$_{\text{acc}}$ subjective'
In the evening I was reading 'Subjective materialism' a bit.

[38]It is interesting to observe that the delimitative-*po-* requires the direct object to appear not in the accusative, as usually, but in the (structural) genitive (cf. [52, 5.1]). If in (78) the accusative *wódkę* were replaced with the genitive *wódki*, the sentence would be correct and synonymous (modulo stylistic subtleties) with (77). This may indicate some impact of aspect on the NP, as discussed in the quantificational approach (cf. 3.3).

which clearly implicates that I haven't finished the book then.

Finally, the imperfective being represented by a $Trajectory$, it entails that should there be no information to the contrary, the culmination point will be reached and the perfective hold as well. (Should there subsequently be such information, the perfective will fail, as in (48), by non-monotonicity.) This explains the default inference from the imperfective to the perfective, mentioned in 2.1.3 and seen in (25). Indeed, since the imperfective is unmarked and provides – by that inference – the same information as the marked perfective, it is in accord with the maxim of quantity to use the previous instead of the latter, which is exactly what Polish speakers tend to do.

5.2.5 Class$_4$: semelfactive activities

By semelfactive activities we understand activities that consist of a series of unit instances, like *kichać*, 'to be sneezing', *pukać*, 'to be knocking', *kopać*, 'to be kicking', *machać*, 'to be waving' and so on. Recall that to each of such imperfectives three perfectives correspond: the semelfactive, the delimitative-*po-* perfective and the empty-prefix perfective. Importantly, the activity may hold not only during the instances, but between them as well: sneezing overarches, so to speak, some unit-sneezes and the time between them. The Aktionsart of the instances is that of point, thus we represent them by events rather than fluents (cf. Table 7); normally, a sneeze is not taken to have temporal extension.[39] Thus the activity f_1 overarches the individual instances e_i in the following sense:

Definition 19 (overarching). Take event type e_i, that is $\exists t(e_i[x,t])$ and by Feferman coding convert it to a fluent f_i, that is $f_i[x,\hat{t}]$. Next, for every two token events $e_i(t)$, $e_i(t')$, if $|t-t'| \ll \frac{1}{2}\mathbf{D}_{f_1}$, then add the interval $(t,t']$ to f_i. Call the resulting fluent f; it overarches the event type e_i, write $e_i \sqsubset f$.

Note that overarching is intrinsic, that is, thanks to Feferman coding (cf. 4.1.2) a fluent cannot accidentally overarch an unrelated event type – and extensional, that is, if the instances occur often enough, the activity holds automatically. But two sneezes separated by a long pause (longer than half the usual duration of sneezing) do not qualify as one activity of sneezing together. Finally, since this definition cannot cause looping computations, formulas of the form $e_i \sqsubset f_1$ can be added to settings in the sense of Definition 12.

[39]Yet if one wants to treat it as extended, as e.g. Bogusławski [8, pp. 12–17] would, the event calculus allows it.

Thus for a Class$_4$ imperfective apart from the usual $HoldsAt$ we need overarching:

(80) $e_i \sqsubset f_1$

(81) $?HoldsAt(f_1, R), R \lesseqgtr now$ *succeeds*

and for a empty-prefix perfective additionally a usual termination point:

(82) $Terminates(e_i, f_1, t)$

(83) $?Happens(e_i, R), R \lesseqgtr now$ *succeeds*.

The latter condition holds also for the delimitative-*po-* perfective, except that f_1 must have been going on for a bit in the sense of Definition 18 – which enforces that there must have been more than one minimal instances. On the other hand, the *-ną-* perfective explicitly requires that the activity be restricted to a single minimal instance, simply:

(84) $?Happens(e_i, R), R \lesseqgtr now$ *succeeds*

instead of (80–81). Therefore Class$_4$ imperfectives are $\langle +, -, -, - \rangle$, while perfectives are either $\langle +, -, +, - \rangle$ or $\langle -, -, +, - \rangle$, with the second plus for the terminating event, even though it is not a canonical culmination point, as in Class$_2$.

Note that empty-prefix Class$_4$ perfectives may denote a fluent overarching several minimal instances, but also restricted to one, as in the semelfactive *-ną-*perfectives. That is to say, since fluents are interpreted as right-closed intervals (cf. 4.1), (80) can be satisfied by f_1 of point length, co-extensional with a token instance of e_i. This in fact agrees with the data, for example:

(85) Jęknął dwa razy i wyzionął ducha.
groaned$^{\text{mp-pfv}}_{\text{3.sg.}}$ two times and exhaled$^{\text{mp-pfv}}_{\text{3.sg.}}$ spirit$_{\text{acc}}$

(86) ? Zajęczał dwa razy i wyzionął ducha.
groaned$^{\text{ep-pfv}}_{\text{3.sg.}}$ two times and exhaled$^{\text{mp-pfv}}_{\text{3.sg.}}$ spirit$_{\text{acc}}$
He groaned twice and gave up his spirit.

Both examples have the same meaning; (86) is perhaps somewhat less elegant. However, assuming that there was no unusual hiatus in between the two groans, the same situation could be described by (86) without the specifier 'two times' – that is, with *zajęczał* overarching both instances. That can be accommodated by the two condition (80), with f_1 interpreted either so as to be co-extensional with e_i (for (86)) or as to overarch its two instances, beginning with the first and terminating with the other. So an empty-prefix Class$_4$ perfective is inherently ambiguous between the two readings, one synonymous with a *-ną-* and the other with a *po-* perfective.

5.2.6 Class$_5$: achievements

Finally, achievements are verbs such as *kupować*, 'to be buying', *zabijać*, 'to be killing', *strzelać*, 'to be shooting', *upijać się*, 'to be getting drunk' etc. Thus for the perfectives – *kupić*, 'to have bought' etc. – it suffices that:

(87) $Initiates(e, f_3, t)$

(88) $?Happens(e, R), R \lesseqgtr now$ *succeeds*.

But recall that while the perfectives, obtained by morphological change, denote achievements themselves, the imperfectives denote the preparatory processes leading to them. Thus, for a Class$_5$ imperfective (69) must hold – as for a Class$_3$ imperfective, an ongoing accomplishment – where at $d + t$ a canonical culmination point occurs, in the sense of (70–71), at which $x = c$, so that also $f_2(c) = f_3$. (And the remarks on the default perfective reading of imperfectives from 5.2.4 hold here as well.) Therefore Class$_5$ imperfectives are $\langle +, \mp, \mp, - \rangle$ and morphonological-change perfectives are $\langle -, -, +, + \rangle$.

However, the preparatory phase is not always possible for Class$_5$ verbs. This is why no $Trajectory$, but only (88) is required for the perfective, and can be seen (in a similar vein as Vendler's examples distinguishing accomplishments and achievements in English [66, p. 104]) in:

(89) Wystrzelił korek od szampana.
popped$^{\text{mp-pfv}}_{\text{3.sg.}}$ cork from champagne$_{\text{gen}}$
The champagne cork popped.

which does not entail that there had been any preparatory phase. In such cases the imperfective can be (though this seems to be a rare usage) taken to, so to speak, zoom in on the event normally taken to be punctual and treat it as an accomplishment:

(90) Dokładnie w chwili, kiedy wystrzeliwał korek od
exactly in moment$_{\text{instr}}$ when popped$^{\text{ipfv}}_{\text{3.sg.}}$ cork from
szampana, Konrad dźgnął księcia.
champagne$_{\text{gen}}$ Konrad stabbed$^{\text{mp-pfv}}_{\text{3.sg.}}$ prince$_{\text{acc}}$
Exactly at the moment when the champagne cork was popping, Konrad stabbed the prince.

This requires the original popping event to have been temporally extended and converts it into a fluent. It is also a clear case of the imperfective serving to reveal more temporal structure (cf. 5.2.1). The more so, since

(90) could be rephrased with the perfective *wystrzelił*, losing no meaning, only some stylistic elegance.

On the contrary, when there can be a preparatory phase (which, it seems, is determined by the script for the given VP), as in *kupować*, 'to be buying', the imperfective is normally taken to refer to it. A reading like in (90) might occur, though seldom. As usual, the imperfective can be cancelled before the culmination point is reached; the inertia effects take place like in Class$_3$.

However, even when the imperfective allows for a preparatory phase, the above setup allows for it being false and the perfective true. This accounts for examples like (21), repeated here:

(21) Upili się, chociaż się nie upijali.
got-drunk$^{\text{mp-pfv}}_{\text{3.pl.}}$ refl though refl not got-drunk$^{\text{ipfv}}_{\text{3.pl.}}$
They have gotten drunk, even though they haven't been getting drunk.

but is somewhat doubtful when the preparatory phase is a barely dispensable part of the script:

(91) ? Chociaż nic nie kupował, to kupił pół litra.
though nothing not bought$^{\text{ipfv}}_{\text{3.sg.}}$ this bought$^{\text{mp-pfv}}_{\text{3.sg.}}$ half$_{\text{acc}}$ litre$_{\text{gen}}$
Even though he hasn't been buying anything, he has bought a bottle of vodka.

This sound suspicious, but might be acceptable on the reading that he has not intended to buy anything, thus omitting the preparatory phase, but instantaneously and gratuitously he did buy the bottle. It is doubtful, though less so if the imperfective is stressed to give a contrastive focus. However, on the interpretation given above, the sentence is not self-contradictory.

Our explanation of such examples being doubtful is that they run afoul of some of the world knowledge contained in the VP's script. The perfective non-monotonically cancels the negation of the imperfective, so the bottle is bought. Yet the world knowledge contradicts the negation, yielding a pragmatic inference that the buying has been preparationless, hence gratuitous and instantaneous – unlike the imperfective would have it. This explanation holds for such doubtful Class$_5$ cases, but not in Class$_3$, where, the preparatory phase being built in the lexical meaning, similar examples are blatantly unacceptable, e.g.:

(92) * Chociaż nic nie budował, to zbudował dom.
though nothing not built$^{\text{ipfv}}_{\text{3.sg.}}$ this built$^{\text{ep-pfv}}_{\text{3.sg.}}$ house$_{\text{acc}}$

Even though he hasn't been building anything, he has built a house.

This sentence is self-contradictory; indeed the contradiction is so salient that it would require a very far-fetched implicature to save its felicity.

Finally, it seems that Class_5 imperfectives lend themselves to perfictivisation not only by means of morphonological change, but of the *po*-prefix as well. Młynarczyk [42] rules this out on the grounds that the resulting forms are inherently iterative. For instance *zabijać*, 'to be killing' becomes *pozabijać* 'to kill several times' and *kupować*, 'to be buying' becomes *pokupować*, 'to buy several times'. But since the prefix is clearly the delimitative-*po*-, it is the prefixed imperfective that must already carry the iterative reading (cf. 2.1.2); thus indeed these forms fall outside the scope of our work.[40]

Nevertheless, they resemble Class_4 delimitative-*po*- perfectives with an additional stipulation – representing the iterativity inherent in the original imperfective – that more than one instances of e_i, the perfective fulfilling (88) have taken place. Thus, assuming that f_i has been going on for a bit, (80–83) suffice for the forms at hand, which may thus be aptly dubbed Class_5 delimitative-*po*- perfectives. That f_i has been going on for a bit in the sense of Definition 18 entails that several tokens of e_i have occurred, because the script for the iterative reading imposes a long enough usual duration. This gives the required additional meaning of 'several times'. Thus the iterative readings could in principle be included in our framework.

5.3 Results and outlook

Summarising the previous section's results, Table 8 lists the Aktionsarten of Polish verbs with the corresponding eventualities. It can be seen that indeed, as claimed in 5.1, it is exactly the perfectives' eventualities that must contain an event. This allows us to describe the Maslov test more formally than in 2.2.1, as the following procedure. Take the scenario clauses corresponding to a (past) perfective; then:

- If these involve the fluent $f_2(x)$ (in the sense of 4.3.2), the (historical-present) imperfective corresponding to that fluent (i.e., formalised by $f[x, \hat{t}]$) is in tuple with the perfective. This is the case for Class_{1t} and Class_3.

[40] But consider examples like *pozabijać nudę*, lit. 'to kill boredom', which is clearly not iterative. Perhaps the distinction between habituals and single-episode readings is not so clear-cut.

- Otherwise, if they involve the fluent f_1, the imperfective corresponding to that fluent is in tuple with the perfective. This is the case for $Class_2$ and for delimitative-*po-* and empty-prefix perfectives of $Class_4$.

- Otherwise, take the event e of the perfective and convert it into the fluent f_e by Feferman coding (cf. 4.1.2). That fluent will correspond to the imperfective in tuple with the perfective. This is the case for $Class_5$ and for *-ną-* perfectives in $Class_4$.

The reference time R remains unchanged by this procedure, as a glance at Definitions (15–16) can explain. Of course in the third case $HoldsAt(f_e, R)$ replaces $Happens(e, R)$.

Now, in the first two cases, the imperfectives denote the processes resulting from or causing the events introduced by the perfectives' scenario clauses. Since these processes are also introduced by the perfectives' clauses, a scenario for the perfective always includes the scenario for the imperfective. In the last case, the obtained imperfectives have a 'zoomed-in' reading, like in (90). That is, they have the same temporal extension as the perfectives, but view it with more structure. Note that when a perfective's event is taken to extend over its fluent (cf. 5.2.1), the last case conflates with one of the previous cases.

Hence, in the third case aspect is restricted to a change of the subjective temporal perspective. In the first two cases it can additionally express an objective temporal meaning, but does not have to. For instance, in $Class_3$ the imperfective *czytał*, 'has been reading' can have the same temporal extension as the perfective *przeczytał*, 'has read', the difference lying in the subjective perspective – but goal-oriented rather than temporal perspective. But if *przeczytał* is taken to refer to the culmination itself, neglecting the prior course of reading, then there is an objective temporal perspective. Similarly, for $Class_2$ the perspective is partly temporal (since the duration is being assessed), but also bound with goals (since the basis for the assessment is the usual script).

Therefore it seems that (at least as far as Polish is concerned) aspect serves to express both the subjective and the objective perspectives on the temporal constituency of an occurrence, to a varying extent for different Aktionsarten. The objective perspective can comprise, on the one hand, completion, termination or inception of the occurrence; on the other, (comparative) duration in the sense of going on a bit. The latter, though, can also have a subjective interpretation (cf. 5.2.4). Now, firstly, the subjective temporal perspective is intrinsically connected with planning (as has

Class	Aspect and formant	Aktionsart	Eventuality
$1s$	impfv	state	$\langle -, -, -, + \rangle$
$1s$	pfv, ep	inception of an ongoing state	$\langle -, -, +, + \rangle$
$1t$	impfv	transition	$\langle +, \mp, \mp, - \rangle$
$1t$	pfv, ep	completed transition	$\langle +, -, +, + \rangle$
2	impfv	strict activity	$\langle +, -, -, - \rangle$
2	pfv, *po-*	terminated strict activity	$\langle +, -, +, - \rangle$
3	impfv	ongoing accomplishment	$\langle +, +, \mp, - \rangle$
3	pfv, ep	accomplishment	$\langle +, +, +, + \rangle$
3	pfv, *po-*	terminated accomplishment	$\langle +, +, +, - \rangle$
4	impfv	semelfactive activity	$\langle +, -, -, - \rangle$
4	pfv, ep	completed semelfactive act.	$\langle +, -, +, - \rangle$
4	pfv, *po-*	non-minimal semelfactive act.	$\langle +, -, +, - \rangle$
4	pfv, *-nąֹ-*	minimal semelfactive act.	$\langle -, -, +, - \rangle$
5	pfv, mp	achievement	$\langle -, -, +, + \rangle$
5	impfv	ongoing achievement	$\langle +, \mp, \mp, - \rangle$

Table 8: Evetualities corresponding to Polish verbs' Aktionsarten

been discussed in 3.2). Secondly, the notion of completion, termination or inception depends on that of planning quite obviously. Thirdly, comparative duration in the mentioned sense depends on planning via the notion of a paradigmatic script (cf. Definition 17). Therefore what unifies the two functions of aspect is the goal-oriented, or planning, perspective.[41]

The event calculus being expressly designed to deal with planning, we have treated both these functions. This seems to be an improvement over other approaches to aspect, which hitherto have been rather one-sided. Namely while the naïve native speaker notices the objective function only (cf. [25]), linguists tended to concentrate solely on the subjective function of aspect (cf. [9], [27], [37]). Taking the notion of planning to underlie aspect allows to reconcile the intuitions of both sides and – we think – allows to understand the semantics of aspect better.

That being the general conclusion, let us end with a few more specific remarks pointing to possible further research. Firstly, we have seen that the delimitative *po-* always relates to usual duration. Now, it seems that the habitual, which we have ignored above, is available for the same

[41] A similar contention about aspect and tense has been made by Steedman [60, p. 932], cf. [33, p. 84].

Classes as the delimitative *po-*, namely 2, 3 and 4. It could perhaps be accounted for by constructing the habitual's fluent from the instances of the regular imperfective's fluent (compare Definition 19 above and [33, p. 224]). Along with that the iterative readings of the regular imperfectives should be incorporated, which is in principle possible, as we have seen in 5.2.6.

Secondly, it is worthwhile noticing that the semantics presented above does not rule illegal secondary perfectivisation (cf. 3.2.2) out. Similarly to the zooming-in imperfectives for Class_5 (cf. (90)), we could define secondary imperfectives for the other classes. Some are used, in spite of their illegality:

(93) Kto może utrzymać łopatę czy miotłę, wykopuje rowy.
Who can hold_{inf} $\text{shovel}_{\text{acc}}$ or $\text{broom}_{\text{acc}}$, $\text{digs}^{\text{sec-ipfv}}_{\text{3.sg.}}$ $\text{ditches}_{\text{acc}}$
Whoever can handle a shovel or a broom, digs ditches (out).

where *wykopuje* is a secondary Class_4 imperfective; or for Class_{1t}:

(94) Nie mogę nosić tej bluzki bez stanika, bo mnie podrażnia.
Not $\text{can}_{\text{1.sg.}}$ wear_{inf} this $\text{blouse}_{\text{gen}}$ without bra_{gen}, because me $\text{irritates}^{\text{sec-ipfv}}_{\text{3.sg.}}$
I can't wear this blouse without a bra, because it irritates me.

One explanation can be that the morphological and semantic system licences such forms, but their plausibility depends on the scripts for particular VPs and world knowledge connected with those. It would be interesting to conduct a corpus study to find out whether this is indeed the case.[42]

Thirdly, to fend off an objection to the approach advocated here that might seem obvious from the linguistic quarters, we think that it can be easily extended to deal with the quantificational effects (cf. 3.3). The impact aspect has on the incremental theme can be described by defining the behaviour of f_2's real argument more explicitly and in detail. However, it would also have to consider the impact of iterativity – as in:

(95) ? Wypijał setkę.
$\text{drunk}^{\text{sec-ipfv}}_{\text{3.sg.}}$ $\text{hundred}_{\text{acc}}$
He was drinking (lit. drinking up) a shot of vodka.

[42] Example (93) is taken from the daily *Gazeta Wyborcza*, 4th October 2004, p. 12; (94), for which I am indebted to A., from a casual conversation. Also e.g. in a recent play by the author Jerzy Pilch two secondary imperfectives can be found: *zwęszać* and *zwietrzać*, both Class_3, meaning 'to smell, to sniff' [48, p. 89].

(96) Wypijał czwartą setkę.
drunk$^{\text{hab}}_{\text{3.sg.}}$ fourth hundred$_{\text{acc}}$
He was drinking (lit. drinking up) the fourth shot of vodka.

where the first *wypijał* is a secondary imperfective, while the second one is an iterative. Moreover, it would have to consider coercion, which can be dealt with in the present approach, unlike in the Verkuylian one – possibly helping to explain the counterexamples confusing the latter.

To sum up, we have obtained a characterisation of the Aktionsarten of Polish verbs as well as a more formal description of the Maslov test. This can be considered a semantic grounding for Młynarczyk's classification we have started with. However, the semantics we have developed licences some forms not included in that classification, suggesting that the aspectual system embraces not only the perfectives and (primary) imperfectives, but the habituals, iteratives and secondary imperfectives as well. To elaborate on that suggestion remains a task for the future. In any case, the principle underlying the system is that aspect serves to express the goal-oriented perspective on occurrences.

5.4 Examples of computations

Finally, we will show how the machinery developed above works in some typical, but interesting cases. One will be non-monotonic cancellation, where enriching a VP's scenario with further information cancels some default inference. Another is the use of an imperfective (fluent) as a temporal background for a perfective (event). At that point we will also illustrate how the order of events can be derived from a scenario. Finally, an example of changing the Aktionsart by coercion will be discussed.

5.4.1 Non-monotonic cancellation

Let us consider a Class$_3$ VP, that is an accomplishment: *czytać książkę*, *przeczytać książkę*, 'to be reading a book, to have read a book'.

(97) Czytałem książkę, ale mi przerwali.
read$^{\text{ipfv}}_{\text{3.sg.past}}$book$_{\text{acc}}$ but I$_{\text{dat}}$ interrupt$^{\text{mp-pfv}}_{\text{3.pl.}}$
I was reading a book, but I was interrupted.

Now let us follow 5.2.4 in constructing the scenario for (97), with $g(x)$ giving the number of pages read. Say that the book has 100 pages: $c = 100$; then for *czytałem*, 'I was reading', we have:

(98) $HoldsAt(read(x), t) \rightarrow Trajectory(reading, t, read(x + g(d)), d)$

(99) $Initiates(finish, read(100), t)$

(100) $(HoldsAt(reading, t) \wedge HoldsAt(read(100), t)) \rightarrow Happens(finish, t)$

Next, consulting Definition 16, to represent the meaning of *przerwali mi*, 'I was interrupted' and the past tense:

(101) $Terminates(interruption, reading, t')$

(102) *?* $HoldsAt(reading, R_1), Happens(interruption, R_2), R_2 \leq R_1 < now$ *succeeds*

We assume, rather uncontroversially, that $R_2 \leq R_1$ is inherent in the meaning of 'interrupt'. Note also that the integrity constraints are combined as (102) to ensure that the reference times remain consistent.

Now a query: have I read the book? – that is *?* $Happens(finish, t)$, $t \leq now$ – can be posed, initiating the derivation shown in Fig. 1. Had there been no cancellation, the derivation would continue (in a manner similar to that of the derivation for 'cross the street' in [33, pp. 72–74]) yielding the default conclusion that I have completed reading the book. Yet *przerwali mi* being there, Fig. 1 shows the actual derivation concluding in failure.

5.4.2 Imperfective as background

One typical use of the aspectual opposition is to use a temporally extended imperfective as a background for a punctual perfective – roughly corresponding to an implicit 'while', as in:

(103) Maszerowali. Wzeszło słońce.
marched$^{\text{ipfv}}_{\text{3.pl.}}$. rose$^{\text{mp-pfv}}_{\text{3.sg.}}$ sun
They were marching. The sun rose.

where it is meant that the sun rose while they were marching, i.e. they were doing so continuously before, during and after the sunrise. The order of the VPs is significant; here:

(104) Wzeszło słońce. Maszerowali.
rose$^{\text{mp-pfv}}_{\text{3.sg.}}$ sun. marched$^{\text{ipfv}}_{\text{3.pl.}}$
The sun rose. They were marching.

it is only said that after the sunrise, they were marching – no background effect. Of course that effect can be cancelled explicitly, e.g. by use of temporal adverbs. Moreover, a causal connection between the VPs can cancel it as well, for instance:

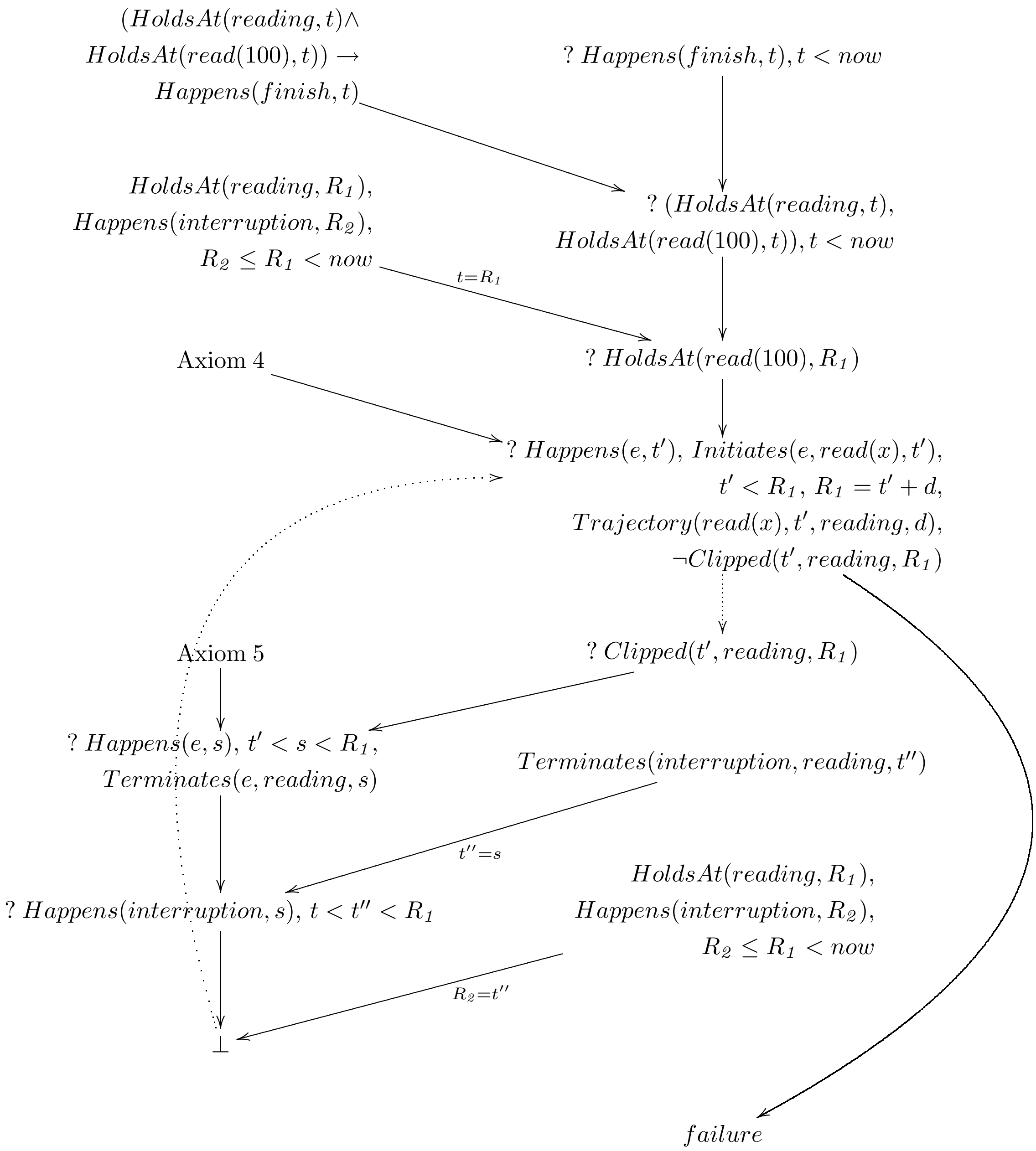

Figure 1: Derivation for (97).

(105) Maszerowali. Porucznik skręcił kostkę.
marched$^{\text{ipfv}}_{\text{3.pl.}}$. lieutenant sprained$^{\text{mp-pfv}}_{\text{3.sg.}}$ ankle$_{\text{acc}}$
They were marching. The lieutenant sprained his ankle.

(106) Maszerowali. Porucznik ruszył pierwszy.
marched$^{\text{ipfv}}_{\text{3.pl.}}$. lieutenant set-out$^{\text{mp-pfv}}_{\text{3.sg.}}$ first
They were marching. The lieutenant (had) set out first.

Therefore the background effect can be thought of as a particular case of the following simple rule. In absence of information to the contrary such as explicit temporal adverbs or temporal or causal information inherent in lexical meanings, for a sequence of VPs $VP_1 \dots VP_n$ in the past tense, they are to be ascribed reference times $R_1 \leq \cdots \leq R_n$. If for a given VP_i such information is present, then it is not necessary to ascribe reference time to VP_i in this way, since that very information should set its temporal location relative to other VP's reference times. As can be easily seen, this rule is general enough to hold for sequences of perfectives and of imperfectives as well.

Now, in (103) the first verb is of Class$_2$, the second of Class$_5$; according to the rule just formulated, the scenario will include:

(107) $?\,HoldsAt(marching, R), Happens(sunrise, R_1), R \leq R_1 \leq now$ *succeeds*

(108) $Initiates(sunrise, day, t)$

The background effect can be shown by the query $?\,HoldsAt(marching, t)$ succeeding regardless of whether $t \leq R$ or $t > R$; the derivation is given in Fig. 2. Note that in want of information as to the inception of the marching, we can add

(109) $Initially(marching)$

to the scenario.

On the other hand, the scenario for (106) includes (107) and (109) as well as

(110) $?\,Happens(set\text{-}out, R_2), R_2 < now$ *succeeds*

(111) $Initiates(set\text{-}out, marching, t)$

Note that in this case the temporal order is determined not by the order of utterances, but by the causal connection between the occurrences denoted by the verbs. Thus the query $?HoldsAt(marching, t)$ will conclude in requiring that $t > R_2$, as shown in Fig. 3 (cf. similar derivations in [45, Ch. 5]).

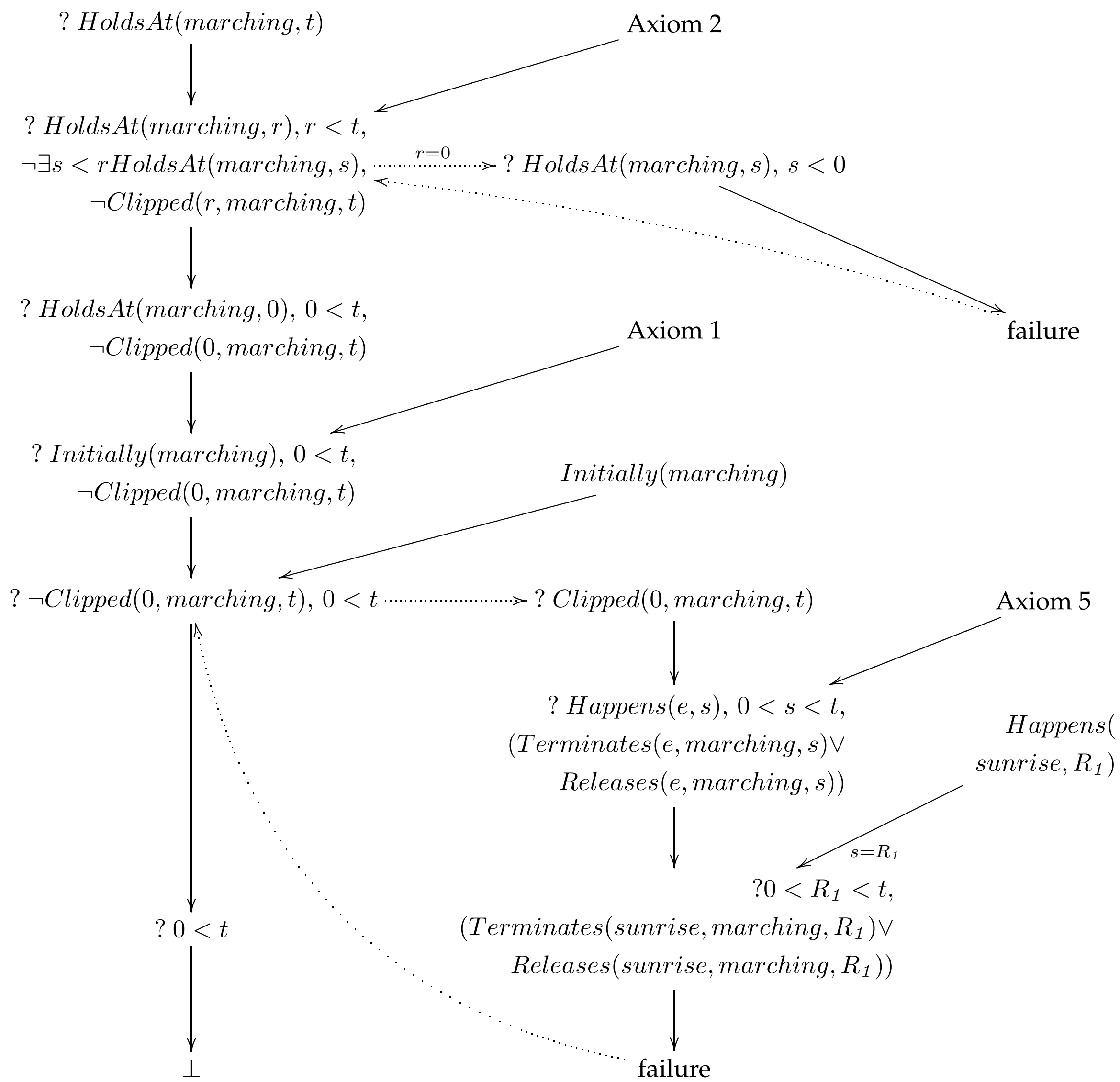

Figure 2: Derivation for (104).

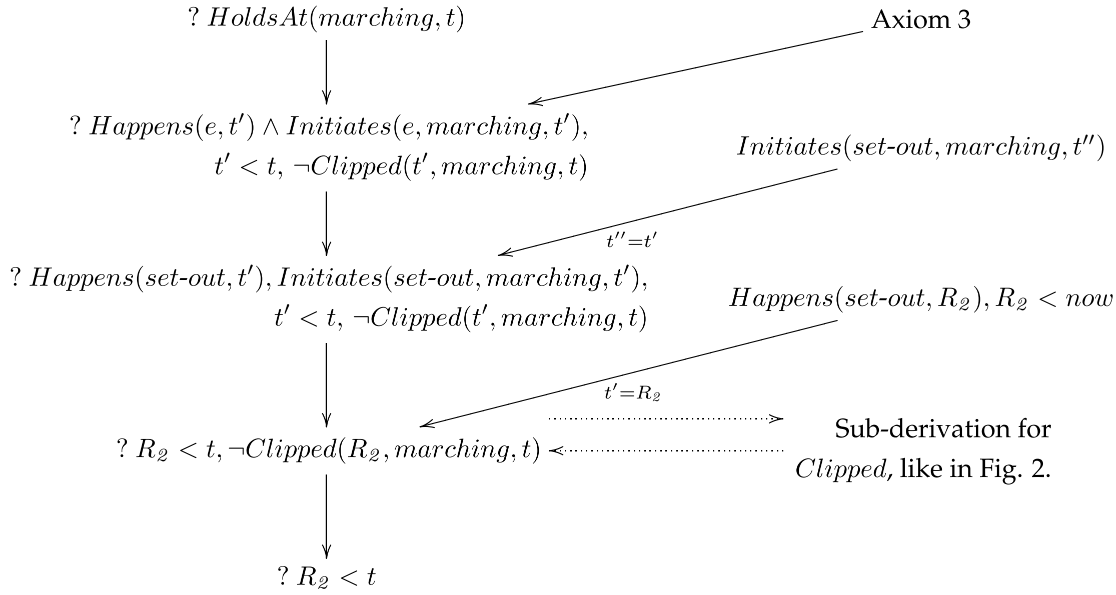

Figure 3: Derivation for (106).

5.4.3 Additive coercion

Let us consider a case of simple additive coercion (in the sense of [33, p. 171]), where a strict activity (i.e., a Class$_2$ verb) becomes transitive:

(112) Myślał o Julii.
thought$^{\text{ipfv}}_{\text{3.sg.}}$ about Julia$_{\text{loc}}$
He was thinking about Julia.

First, we define the fluent holding of the patient, for once writing the agent and patient arguments:

(113) $HoldsAt(think(he), t) \rightarrow HoldsAt(be\text{-}thought\text{-}of(julia), t)$

Of course (113) can only be added when the direct object $julia$ appears in the scenario (otherwise it would follow that whenever he thinks, he thinks of Julia, which admittedly may be true, but rather not a priori). Moreover, such *fluent definitions* may be added to a scenario – even though they are not allowed by Definition 13 – since they cannot induce looping computations as long as they are of the proper form [33, p. 49]:

Definition 20 (fluent definition). A definition of a fluent f takes the form $\varphi \rightarrow HoldsAt(f, t)$ where φ consists of $HoldsAt$ formulas only, and f does not occur in it. Similarly for a definition of an event, with $Happens$ and e instead of $HoldsAt$ and f.

This addition transforms our VP from $\langle +, -, -, - \rangle$, to $\langle +, +, -, - \rangle$. Thus it falls under none of the eventualities listed in Table 8. Indeed, it is by coercion that the Aktionsart of a sentence or a VP can differ from that of the constituent verb (cf. [33, p. 88]) – so the Aktionsarten available for VPs need not be restricted to those listed for verbs. Nevertheless, since thinking about somebody is an atelic transitive activity, it resembles Class$_{1t}$ except that it involves no gradual change. The eventuality $\langle +, +, -, - \rangle$ can be thought of as a special case of that Class's $\langle +, \mp, \mp, - \rangle$. Accordingly, we fix the scenario with the integrity constraints:

(114) $?HoldsAt(think(he), R), R < now$ *succeeds*

similar to those required in Class$_{1t}$. Now, corresponding to the passive: was Julia being thought of?, the query $?\ HoldsAt(be\text{-}thought\text{-}of(julia), R)$ can be posed – see Fig. 4.

However, consider whether the perfective *pomyślał o Julii*, 'has thought about Julia' holds. One could expect the prefix to be the delimitative *po-* here, as it is in Class$_2$ for bare *pomyślał*. But the coercion changed the VP's Aktionsart, and in fact the delimitative 'a-bit' reading sounds incorrect here. The intuitive reading is the empty-prefix one, again similarly as in Class$_{1t}$. (The 'a-bit' reading would require further coercion by an explicit adverb, e.g. 'for a moment'.) Thus the *po-* in *pomyślał o Julii* is the empty *po-*. Calling the corresponding fluent $have\text{-}thought\text{-}about(he, julia)$ (and the event initiating that state – a $thought$), its meaning is represented, like in Class$_{1t}$ (cf. 5.2.1), by:

(115) $HoldsAt(think(he), t) \rightarrow Happens(thought, t)$

(116) $Initiates(thought, have\text{-}thought\text{-}about(he, julia), t)$

Hence we can ask: $?\ HoldsAt(have\text{-}thought\text{-}about(he, julia), s)$, 'has he thought about Julia?' – see Fig. 5 – showing that $have\text{-}thought\text{-}about(he, julia)$ holds from the initiating event on.

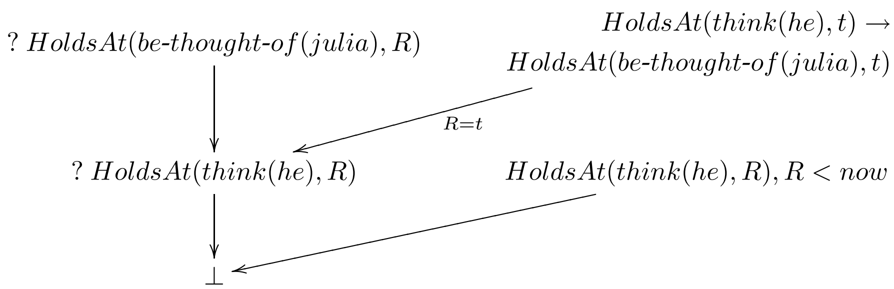

Figure 4: Derivation for (112), passive.

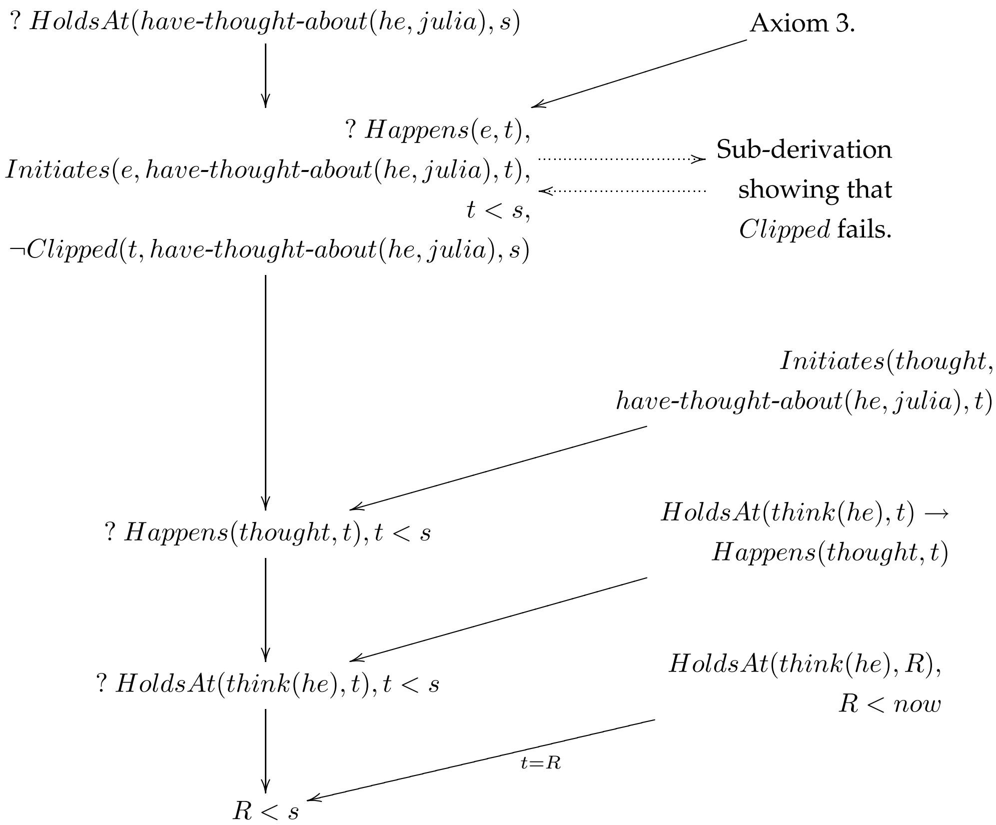

Figure 5: Derivation for (112), perfective.

6 Conclusion

Let us briefly summarise the thesis. Polish verbal aspect, described in Chapter 2, is a morphologically complex phenomenon, not lending itself to a consistent systematisation straightforwardly. However, such a systematisation is achieved by Młynarczyk's [42] classification of verbs according to the pre- and suffixes they can take (discussed in 2.2, with some criticism). The verbal classes it yields turn out to be Aktionsarten: transitions, states, strict activities, accomplishments, semelfactive activities and achievements.

Thus there is a semantic grounding for the Polish aspectual system; to explicate it in terms of formal semantics was the task of the thesis. In Chapter 3 we considered the possible approaches to that task, beginning in 3.1 by criticising the one based on tense logic and Davidsonian events. The Verkuylian [67], [68], [69] approach undoubtedly has its merits in relating aspect and quantification – nevertheless we argued in in 3.3 that it is inadequate for our purpose. To the contrary, we found the event calculus of van Lambalgen and Hamm [33] to suit it well, for reasons expounded in 3.2. In particular, we argued its non-monotonicity and connection with the notion of planning to be useful in accounting for aspect.

Accordingly, having introduced the event calculus formally in Chapter 4 and defined the Polish tenses in its terms in 5.1, we tackled the main task in 5.2. Namely, for each Aktionsart we discussed what must be included in the semantic contribution of a verb in its imperfective and perfective forms. We represented that contribution as the event-calculus formulas that are added to account for such a verb in a scenario representing the meaning of an expression it occurs in. Examples of such scenarios were given in extenso in 5.4, demonstrating some interesting features of this approach.

On the whole, we claim that the the event calculus provides a proper framework for describing the semantics of the Polish aspect. Even though we have neglected the habitual forms in this thesis, they could in principle be incorporated, as we argued in 5.3 and 5.2.6. We also believe that the quantificational effects of aspect (cf. 3.3) as well as various peculiarities of usage that render particular aspectual forms more adequate in specific contexts (cf. [8]) can be explained by the mechanisms available in the event calculus. Thus we hope that this work may instigate a treatment of aspect both elegant and true to data.

In particular, as we argued in 5.3, it shows how the two opposing concepts of aspect – as a subjective perspective on the temporal structure of an occurrence and as an objective report about its completion or duration – can be reconciled. We think that this is possible through the notion of planning, which underlies both these concepts; indeed, as van Lambalgen and Hamm [33] claim (cf. 3.2), it underlies temporal thinking in general. Thus we also hope that this treatment of aspect could be plausible not only linguistically, but cognitively as well.

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* * *

I affectionately dedicate this work to Dr. Stefan Wewiórski, my grandfather, on his eightieth birthday.

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