

UNDERSTANDING REPETITION IN NATURAL LANGUAGE INSTRUCTIONS – THE SEMANTICS OF EXTENT

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Introduction

Natural language instructions, though prevalent in many spheres of communication, have only recently begun to receive attention within computational linguistics[5]. Instructions are often accompanied by language intended to signal repetition of the action that they instruct. In order to develop a system that is able to understand instructions, with the goal of executing them, it is necessary to investigate what is meant by various types of repetition, and the different ways in which repetition can be expressed.

We focus on sentences that are instructing that some action is to be performed and that this action is to be performed more than once¹. There are two aspects to consider – scope (what part of the action that is instructed in the dialogue is to be repeated) and extent (how much repetition is to be done). This is illustrated by examples (1) and (2).

Place a chunk of rhubarb into each tart. (1)

Continue to layer in this way until all the fruit is used. (2)

The repetition in (1) has scope on *place a chunk of rhubarb (into a tart)* and extent *across all tarts*. (2) has scope over *layer in this way* and extent *until all the fruit used*. Within this framework of scope and extent that I have described only informally, I discuss the issue of extent in more detail².

Karlin [3], presents a semantic analysis of verbal modifiers in the domain of cooking tasks. Much of this is pertinent to an examination of extent, in particular the relation of different modifiers to the aspectual category of an event (according to Moens & Steedman [4]). This has formed an important starting point for my work in understanding instructions for repetition. However, there are aspects where a different approach to Karlin's is required, and some of these are discussed in the rest of this paper.

Semantics of verbal modifiers

In analysing the semantics of verbal modifiers, Karlin[3] identifies three kinds of modifiers, which are themselves divided further. The primary categorisations are

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¹This paper deals only with instructions, and uses the words sentence and instruction interchangeably.

²A central theme of my thesis is that both scope and extent must be accounted for in a full treatment of repetition, but a discussion of scope is outwith the scope of this paper.

- 1 The number of repetitions of an action.
- 2 The duration of an action.
- 3 The speed of an action.

It is clear that Karlin's first two primary categories describe modifiers that are concerned with the repetition of an action³, and these are examined in detail in the next sections. First, though, it is useful to consider that with any action, we have a time interval, during which the action is to be performed – once or more than once. We can then characterise the extent of repetition in terms of this time interval. Modifiers of Karlin's category 2 tell us how long the time interval is, while modifiers of category 1 tell us how to carve up the time interval. One instruction may give information for both categories, but this usually is for two different actions, such as

Roast for 45 minutes, basting twice. (3)

Number of repetitions – carving the interval

In this category, Karlin enumerates classes of modifier as follows:

- cardinal count adverbials – *turn the fish twice*
- frequency adverbials – *turn the fish occasionally*
- plural objects – *turn the pieces of fish*

In the discussion of frequency adverbials, Karlin describes frequency as a continuous scale with gradable terms, such as *occasionally*, *often*. This class should include explicit frequency in time units, as in *every 5 minutes*.

Duration of an action – delimiting the interval

Here, Karlin enumerates the following kinds of modifier:

- explicit duration in time intervals – *fry the fish for 10 minutes*
- duration given by gradable terms – *fry the fish briefly*
- duration co-extensive with the duration of another action – *continue to fry the millet, stirring, until the water boils*
- duration characterized by a state change – *fry the fish until it is opaque*
- disjuncts of explicit durations and state changes – *fry the fish for 5 minutes or until it becomes opaque*

³I will not consider the third, which contributes to "quality" of execution of an action, and does not pertain to extent of repetition.

In this category, Karlin does distinguish between “explicit duration” and “duration in gradable terms”, whereas in the “frequency adverbials” classification, there are not separate classes for vague and explicit frequency (say *turn the fish every 5 minutes* and *turn the fish often*). To be more consistent, there should be one class within the category “number of repetitions of an action” that contains frequency adverbials⁴, and only one class within the category “duration of an action” that contains duration in terms of time⁵. In both classes there should be the possibility of being explicit or vague. It is also preferable to call Karlin’s second category “duration of repetition of an action”. The name “duration of an action” conflates the concept of the basic action and its repetition. The separation is pertinent to the view that repetition has scope and extent.

Karlin analyses the remaining three classes in category 2 explicitly in the context of cooking tasks. In particular, the analysis is related to the view that all processes in the cooking domain must have culminations. The validity of this approach is discussed in the next section. However, before doing that we examine Karlin’s final class, “disjuncts of explicit durations and state changes”. This is a class of instructions found mainly in the cooking domain. The example used by Karlin is (4).

Steam for 2 minutes or until the mussels open. (4)

Karlin asserts that ‘the meaning of sentences in this category is not the same as that of logical disjunction’ [3, pg 64], and claims that the meaning of the disjunction is that ‘the state change (the mussels are open) is to be used to determine the duration of the action (2 minutes)’ [ibid] (my parentheses)⁶.

I agree that the meaning is not simply that of logical disjunction, but we need to examine the issue further. Data that I have collected gives evidence that the use of the *or* is not significant. There are many examples where a recipe book will give the same instruction, both with and without it. For example,

... at least 10 minutes or until the flour is well browned [2, pg 120] (5)

Bake for about 2 hours, until the rabbit and lentils are tender [2, pg119] (6)

Bake for 45 minutes or until the rabbit is tender [2, pg118] (7)

In all of these, we have an instruction describing one of the following scenarios⁷:

Do some action until an expected state change occurs. This should take the duration specified. (8)

⁴This is as Karlin’s classification

⁵This is different from Karlin’s classification

⁶Karlin sees these as metalinguistic disjunction, which I believe is similar to part of my view.

⁷I make no claims about exactly which of these scenarios is being described.

Do some action for a specified duration. If the expected state change does not occur during this time, then it is likely that something has gone wrong. (9)

What is really being given is a way to decide when to stop the action, and the use of two clauses provides a way of deciding whether the stop state is successful or a failure. For success, if the state change has occurred, then we will expect that the duration has also passed⁸. If the duration has passed but the state change has not occurred, or if the state change has occurred but the duration has not passed, we still reach the stop state, but in the failed mode. We then have disjunction for stopping (we stop if either the duration or the state change is true) but conjunction for success (stop and a normal outcome is only true if both the clauses are true). We note that often domain knowledge will allow the hearer to determine whether the duration is given as a minimum or maximum time, and what the effect of failure is. The analysis presented here does not take the use of domain knowledge into account, to give a more general analysis.

From the point of view of repetition, what we are given is a stopping condition, that is coded in terms of two alternatives. Using an informal notation, what is being expressed with and without *or* respectively, are the following, which are equivalent:

should-stop(action,t) ← (difference(start,t,x), x ≥ duration) ∨ (state(q,t))

should-stop(action,t) ← (difference(start,t,x), x ≥ duration) ∧

should-stop(action,t) ← (state(q,t))

Thus (7) and (6) can be represented as

should-stop(bake,t) ← (difference(start,t,x), x ≥ 45-minutes) ∨ (tender(rabbit,t))

should-stop(bake,t) ← (difference(start,t,x), x ≥ about-2-hours) ∧

should-stop(bake,t) ← (tender(rabbit-and-lentils,t))

Sometimes, the order of the two modifiers is different⁹ indicating that the positioning of the clauses is not important.

... until the meat is tender, about 45 minutes [2, pg 119] (10)

... until the meat is meltingly tender about 30 minutes [2, pg119] (11)

Karlin proposes that the duration modifier is only an approximation, and that it is the state change modifier that determines the truth of the sentence¹⁰. Most durations, however, in the domain of cooking tasks, are approximations. Deciding whether a state change has been reached is also

⁸This in fact seems closer to logical conjunction than logical disjunction.

⁹The exchanged order is usually used without the *or*.

¹⁰The terms left disjunct and right disjunct are used by Karlin, but in sentences like (10) and (11) these are not helpful indicators.

approximate. In a domain where durations and evidence of state change are less approximate (say in chemistry), it is not clear that it is always one of the clauses that is performing the role of establishing the truth of the sentence.

Aspectual category and verbal modifiers

Karlin's discussion is given in the context of the aspectual category of an event (according to Moens & Steedman [4]). This is useful as it gives a way of extracting semantic information.

Karlin claims that points, culminations and culminated processes (but not process type events) can have a number of repetitions associated with them (category 1). An expression whose aspectual type is a process or culminated process can co-occur with a duration modifier (category 2). This second claim requires closer examination.

First, Moens & Steedman say that 'culminated processes ... (do not combine readily) with a *for*-adverbial'. Yet *for*-adverbials are one of the classes of duration modifier enumerated by Karlin. We look at two of the examples presented by Karlin.

Stir for 1 minute. (12)

Saute over high heat until moisture is evaporated. (13)

The expressions in both of these (without their modifiers - that is *Stir* and *Saute over high heat*) are processes, but not culminated processes. An essential part of a culmination is that there is a consequent state [4, pg 16]. None of the examples Karlin uses has a culminated process as the aspectual type of the action expressed. (13) could be seen as culminated processes if viewed together with the duration modifier (in other words, if it already co-occurs with a duration modifier), while (12) is a process, even with the modifier. Thus, the view of Moens & Steedman holds and is in fact useful in extracting semantic information. An *until*-clause signals a culmination, thus making a process into a culminated process. A *for*-adverbial does not change the aspectual type of a process.

We now look at the assertion that 'Each process in the cooking domain must have a culmination ...' [3, pg 62]. This is accompanied by a claim that a verb may contain inherent information about the endpoint of the action it describes, as in

Chop the onion. (14)

which, according to Karlin, describes a culminated process whose endpoint is defined by the state of the onion. This seems quite feasible, even if it does require that some world knowledge is required. However, if we consider instead the example

Stir the soup. (15)

this does **not** describe any culmination, as there is no consequent state. Yet it is a process, as it may be extended in time.

Karlin's justification for the above assertion is that cooking tasks involve a sequence of steps with the goal of bringing about a state change. There are also instructions for preventing a state change though, for example stirring (to prevent sticking). We could argue that stirring brings us to the changed state "*stirred*". But then, if we look back to the Moens & Steedman analysis, where *he climbed* has no culmination, we could claim that this has the changed state "*has climbed*". This is not the spirit intended by the Moens & Steedman analysis, and it is more useful to see some actions in cooking as not having culminations. We can then examine what kinds of modifiers change aspectual category and in what manner, as presented above for the *for*- and *until*-adverbials.

Conclusion

The semantics of repetition in instructions is more clearly understood if we view repetition as having scope and extent. Within this framework, Karlin's work on the semantics of verbal modifiers provides a useful starting point. In particular, relating this to the aspectual category of an instruction according to Moens & Steedman [4] is important. We can make use of Moens & Steedman's schema for the way aspect changes when modifiers are added to expressions, to extract semantic information. This will allow a fuller treatment of extent, for use in the development of a semantics for repetition that treats both scope and extent more completely.

References

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