

# A semantics for temporally dependent referring expressions

We are concerned here with temporal side-effects of the interpretation of some noun phrases, such as in the following examples (adapted from [Tonhauser, 2000, Musan, 1995]):

- (1) Every art student visited the Musée d'Orsay.
- (2) An hostage attended the party in its honour.

Formal semantics theories, for the most part, have ignored the question of the semantics of NPs in such contexts, assuming either that NPs are a-temporal, or that their interpretation is directly dependent on the temporal index of the verb predicate. But this view is clearly inadequate, since nominal predicates can also be interpreted at a time which is different from that of the main clause, a point first made by [Enç, 1986]. This is illustrated by example (2), for the individuals picked up by the the predicate "hostage" are no longer hostages when they attend the party. More precisely, the predicates "hostages" and "attend the party" are not true of the individuals at the same time. Notice that there might be some fluctuation as to how different predicates should be temporally interpreted with respect to one another. Thus, a sentence like (1) is ambiguous, depending on whether the individuals in question are already art students at the time they visit the Musée d'Orsay.

Existing formal accounts of temporal NPs (e.g., [Enç, 1986], and more recently [Tonhauser, 2002]) deal with the above sentences by adding a time index to the interpretation of nouns. Thus, [Tonhauser, 2002] proposes the following logical form (3) for example (2) (some of the DRT details from her analysis have here been simplified away), instead of the classical davidsonian representation given in (4):

- (3)  $\exists x, e (\text{hostage}(t, x) \wedge \text{attend\_the\_party}(e, x) \wedge e < \text{now})$
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In her account, the identity of "t" is to be resolved by a contextual accommodation; she takes the verb's temporal index to be the default resolution (i.e., when the context is empty or irrelevant).

Tonhauser's account is interesting but pragmatic accommodation of the verbal time is questionable in the case of quantified NPs such as in example (1); indeed, she claims that the time of the quantified noun is presupposed (hence, outside the scope of the quantifier), which makes it impossible to interpret. Besides, Tonhauser's account remains vague on the semantic interpretation to be given to such predicates. In [Tonhauser, 2000], she argues that the universe of discourse is composed of a-temporal entities which are picked up by a temporal function that in turn defines the domain of interpretation of a proposition at a given time.

This approach has two undesirable implications. First, it predicts that a referent has to exist at a given time  $t$  if it is to be the argument of a predicate at  $t$ . But this is clearly wrong (e.g., *Frege is dead*). Second, Tonhauser is forced to assume that plurals denote a set of entities with intersecting lifetimes [Tonhauser, 2000]:38. But this is again problematic, as shown by: *The US presidents made the country what it is today*. Finally, there is no direct way within this account to handle Musan's examples such as *A thousand boats passed under the bridge*, where the same boat can pass more than one time and what matters is the number of events occurring.

In this paper, we propose a unified treatment of these cases of temporal reference by appealing to a different ontological framework. Musan [Musan, 1995] makes the hypothesis that some of these sentences with quantified temporal NPs actually express something about *stages* of objects and not objects themselves. The distinction between entities and stages is inspired from Carlson's dissertation [Carlson, 1980], but it can actually be traced back to works by philosophers such as [Whitehead, 1929] or [Quine, 1960], who hold the view that every material object reduces to a spatio-temporal process. In a similar perspective, more recent studies consider entities we speak about as essentially temporal [Noonan, 1976, Heller, 1990]. As far as we know, these ideas and their implications for formal semantics have been entirely overlooked. They seem to suggest a very natural revision of classical semantic interpretations, one that allows temporal relations on predicate arguments to be expressed. We shall investigate such a revision, here. For instance, we propose that example (2) be given the following logical form:

- (5)  $\exists t, e, y (\text{stage}(t, y) \wedge \text{hostage}(t) \wedge \text{attend\_the\_party}(e, y) \wedge e < \text{now})$

In words, the hostage "episode"  $t$  of some entity  $y$  is temporally independent from the event  $e$  described by the verbal predicate (we could have  $t < e$  or  $t \subseteq e$ ). Alternatively, one might posit that verbs too are only predicated of stages of individuals (so stages are all there is):

$$(6) \quad \exists t_1, t_2, t_3 (\text{stage}(t_1, t_3) \wedge \text{stage}(t_2, t_3) \wedge \text{hostage}(t_1) \wedge \text{attend\_the\_party}(t_2) \wedge t_2 < \text{now})$$

This representation makes it clearer that the interpretation of any element of our domain of interpretation is temporally extended. This amounts to considering everything as a kind of event; this is line with recent work by Pustejovsky.

Adjectives (but also prepositions) are also interpreted as introducing a temporal stage, and context can determine if it depends on another stage or not. This point is made with an example like (7), where the N, the Adj, and the V seem to correspond to different temporal 'slices':

$$(7) \quad \text{The freed hostages arrived at the party at 6pm.}$$

Plurals are no longer problematic, provided that one has some sort of part-of relation at one's disposal over the domain of entities: a plural is a set of disconnected (with no common parts) singular entities. Thus, men living at different times can be parts of a collective entity, such as *the US presidents*. The framework argued for here requires some changes on the way one interprets quantifiers, such as *every*. That is, one does not want *every* to quantify over stages of an entity but over (contextually) maximal stages of individuals, a point already made by [Noonan, 1976], pp 34-35. So in *Every man had one drink* e.g., people can only stay sober if only the contextually maximal stage (for each man) is allowed one drink (8), yielding (9), which says there can be no proper stage  $y$  of  $x$  having a drink:

$$(8) \quad [\text{every}] = \lambda P \lambda Q (\forall x (P(x) \rightarrow Q(x) \wedge [\forall y (\text{stage}(y, x) \wedge Q(y)) \rightarrow x = y]))$$

$$(9) \quad \forall x (\text{man}(x) \rightarrow \text{has\_one\_drink}(x) \wedge [\forall y (\text{stage}(y, x) \wedge \text{has\_one\_drink}(y)) \rightarrow x = y])$$

Note finally, that an axiomatisation of such a domain (i.e., where entities are considered as material entities in space-time) already exists and can be found for instance in [Muller, 1998]. We thus provides an arguably clearer ontological and formally well-founded framework for temporal interpretation of noun phrases.

## References

- [Carlson, 1980] G. N. Carlson. *Reference to Kinds in English*. Garland Publishing, New York, 1980.
- [Enç, 1986] M. Enç. Towards a referential analysis of temporal expressions. *Linguistics and Philosophy*, 9(4), 1986.
- [Heller, 1990] M. Heller. *The Ontology of Physical Objects: Four-Dimension Hunks of Matter*. Cambridge University Press, 1990.
- [Muller, 1998] P. Muller. Space-time as a primitive for space and motion. In *Proceedings of the International Conference on Formal Ontology in Information Systems (FOIS98)*, Frontiers in Artificial Intelligence and Applications. IOS Press, 1998.
- [Musn, 1995] Renate Musn. *On the Temporal Interpretation of Noun Phrases*. PhD thesis, MIT, 1995. Also published with Garland Publishers, New York, 1997.
- [Noonan, 1976] H. W. Noonan. The four-dimensional world. *Analysis*, 37:32–39, 1976.
- [Quine, 1960] Quine. *Word and Object*. MIT Press, 1960.
- [Tonhauser, 2000] Judith Tonhauser. Dynamic semantics and the temporal interpretation of noun phrases. Master's thesis, Institute for Computational Linguistics, University of Stuttgart, 2000. Published as SFB report No. 159.
- [Tonhauser, 2002] Judith Tonhauser. A dynamic semantic account of the temporal interpretation of noun phrases. In Brendan Jackson, editor, *Proceedings of Semantics and Linguistics Theory XII (SALT XII)*, Cornell, 2002. CLC Publications.
- [Whitehead, 1929] A.N. Whitehead. *Process and reality*. Mac Millan, New-York, 1929.