3

Decomposing Events and Storylines

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Abstract. Stories are typically represented as a set of events and temporal or causal relations among events. In the metro map model of storylines, participants are represented as histories and events as interactions between participant histories. The metro map model calls for a decomposition of events into what each participant does (or what happens to each participant), as well as the interactions among participants. Such a decompositional model of events has been developed in linguistic semantics. Here, we describe this decompositional model of events and how it can be combined with a metro map model of storylines.

3.1 Introduction: Events within Stories and Events within Events

Stories are typically represented as a set of events and temporal or causal relations among events (see Chapter 6). Linguistically, this is manifested by implicit or explicit relations between clauses. Explicitly, there are coordinating and subordinating conjunctions expressing temporal, causal or other relations between events and time expressions that can be used to determine temporal relations. Implicitly, the order of sentences in a document often reflects temporal and sometimes causal relations.

The storyline approach to discourse structure we present here is similar to metro map models of storyline analysis (Shahaf et al., 2012; van Erp et al., 2014). A storyline is a time-sequenced series of intersecting paths in a graph-like structure that represents the interactions of entities and events. Like van Erp et al. (2014), our storylines are "entity-centered," in the sense that the representation is centered around participant histories over time (edges in the graph), which contain the events that the participant is engaged in. Participants are related to each other via the events that they

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interact in (at the graph nodes). We envision that storylines will be useful for data analytics as a tool to visualize participant histories and for causal inference.

We argue that an entity-centered approach is a better model of storyline analysis than the more "event-centered" models. In this context, event-centered means the representation is centered around events and their temporal and causal relations. In the task of summarizing events and entities and their relations, an analyst requires a logical means to cluster information. With a storyline, information is organized by the participants involved, which may serve as an interpretative model for the connections among events (Caselli and Vossen, 2016). In addition, the salience of events may be determined by a metric based on interactions of interest. A rich model will also include event–event causal relations, which we believe will be inferable in part based on participant interactions.

One needs a model of event structure to go with a storyline approach, specifically a model that clearly indicates what each participant does or what happens to each participant in a particular event. Thus, the participant's history – the central representation in an entity-centered storyline – will consist of a joint representation for what each participant does or what happens to each participant over the time course of the story.

Most analyses of event structure in text assume that a single clause headed by a verb denotes a single event. However, participants in a monoclausal event interact causally as well, and monoclausal events unfold in temporal phases. These observations underlie the decompositional analyses of verb meaning found widely in theoretical linguistics, as surveyed in Levin and Rappaport Hovav (2005) and also in computational linguistics (e.g., Narayanan, 1997). Many of the event decompositions in linguistics do not explicitly represent the temporal dimension and distribute participants across different event components. Such representations do not lend themselves well to integration with storyline analysis.

The model of event decomposition in Croft (2012) synthesizes discoveries in verbal semantics and accounts for crosslinguistic generalizations about the grammar of verbs. It is relevant to the analysis of events within stories in that the monoclausal event is decomposed in terms of time, causation, and qualitative state or change.

Croft's analysis of events explicitly represents time as a geometric dimension, as part of the representation of aspect – the structure of events as they unfold in successive phases over time. In addition to explicit representation of the temporal dimension, Croft introduces a second dimension, qualitative states, to model change over the course of the event. These two dimensions

allow one to represent directly the prestate and poststate of events (Im and Pustejovsky, 2010; Segers et al., 2016) as different states on the qualitative dimension and as different points of time on the temporal dimension.

Croft's analysis also decomposes events into distinct subevents for each participant. The subevents directly represent the interactions of participants, instead of representing them indirectly and incompletely by semantic role labels. Having distinct subevents for each participant allows for a model of stories where stories are made up of participant histories; that is, the participant's existence through time. A participant history is in turn made up of subevents, namely, the states and processes that the participant has or undergoes during each interval of time. The participant histories are related to each other through participant interactions; that is, subevent relations within events at certain times. This model of subevents is similar to the model of stories in van Erp et al. (2014), who used a modified metro map visualization (Shahaf et al., 2012), with participants as "lines" and events as "stations."

For our storyline analysis, event meaning is decompositional: a node in a storyline graph represents a multiparticipant event composed of a set of subevents, one for each participant, with participant interaction defined in terms of causal and noncausal relations. Characteristics of each participant's subevent are defined along three dimensions: time (how the subevent unfolds over time), qualitative state (the role of the participant as an external agent or the resulting change it undergoes), and force-dynamic relations that describe the interactions between the participants in the event.

This chapter describes how we bring current theories of event structure decomposition from linguistics into computational linguistics and the potential application of these theories to the representation of the roles of participants in stories.

3.2 Constructions as Well as Verbs Determine the Internal Structure of Events

The first linguistic issue that must be addressed is where in the sentence the decompositional structure of events is encoded. It is generally assumed that events are expressed by verbs. But a major issue in annotation of verb meaning is that a verb can be construed in multiple ways, largely though not entirely depending on the clausal constructions in which it occurs.

For example, one and the same verb can describe events of different aspectual types (Moens and Steedman, 1988; Croft, 2012; examples from

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Corpus of Contemporary American English [COCA; Davies, 2008, 1a–e] and Google Books):

(1) a. He **touched** the tip of his hat, then left a few bills on the bar and slid off his stool.
b. But **touching** the wound again and again, and remaining concentrated on the wound is not going to heal it.
c. We can say the chair is **touching** the wall it is leaning against, but there really is not an encounter between them, but only a spatial relation of contiguity.
d. Her fingers **touched** the ball, and she gripped.
e. The desert **touches** the boundaries of rural and urban settlements alike.

Example (1a) describes an instant of contact (usually called semelfactive); example (1b) an activity of repeated contact; example (1c) a transitory state of maintained contact; example (1d) an achievement (instantaneous change) from non-contact to contact; and example (1e) a stable physical relationship between two landscape entities. The different aspectual interpretations are constrained partly by the tense–aspect construction (simple past, simple present, progressive) but also partly by contextual factors – for example, (1a) and (1d) are both simple past but have different aspectual interpretations.

The same ambiguity is found in the force-dynamic structure of events denoted by a single verb. Examples (2a–2e) illustrates the ambiguities, with the standard labels for the force-dynamic type given in brackets (examples from COCA and Google Books):

(2) a. She flailed with her feet to get her balance and managed to **kick** the chair. [contact]
b. So he's going to shoot if I have to **kick** him black and blue. [change of state]
c. **Kick** the ball into Lake Michigan . . . [ballistic motion]
d. Go on, **kick** him the ball and let's see what he'll do with it. [transfer]
e. You **kick** wildly at the plastic bottle, finally knocking it loose. [conative – action aimed toward a target entity]

Thus, a semantic annotation of the event expressed by a clause cannot rely simply on a verb's lexical semantics taken out of grammatical context.

There is a strong correlation between a construction's form and the semantics of the event. That is, particular argument structure constructions have meaning, as construction grammarians have argued (Fillmore et al., 1988; Goldberg, 1995, 2006). The correlation is not perfect: there is some

lexical idiosyncrasy in the choice of prepositions for some argument structure constructions, for example. Nevertheless, the need for semantic annotation of event structure partly independent of a verb's lexical semantics is evident from the many-to-many mappings between verbs and argument structure constructions.

The goal of an annotation scheme is to allow annotators to identify semantic types and properties in a text with a degree of reliability to make the manually annotated corpus useful for training and also to allow automated integration with formal reasoning (Mani and Pustejovsky, 2012). We therefore propose an annotation scheme with holistic labels for aspectual and causal event types. Force-dynamic and aspectual structure are annotated separately from verb meaning and from each other, because verb meaning does not wholly determine aspectual or force-dynamic interpretation. The aspectual and causal event types for a clause are the product of the combination of the verb meaning and the tense–aspect and argument structure constructions of the clause. The holistic annotation relieves the annotator of identifying the contribution of the construction vs. the predicate to the event's semantic structure. The aspectual and force dynamic annotations can be translated into the decompositional analyses described in this chapter, which can in turn form the basis of formal reasoning about the events in a text.

3.3 Time and Qualitative State (Change)

3.3.1 The Semantics of Aspect

The semantic analysis of aspect is considerably more fine-grained than that used in previous annotations in computational linguistics (Siegel and McKeown, 2001; Zarcone and Lenci, 2008; Mathew and Katz, 2009; Friedrich and Palmer, 2014; Xue and Zhang, 2014). It has long been known that the four-way aspectual classification of events by Vendler (1957) into states (static), activities (dynamic, durative, unbounded), achievements (dynamic, punctual, bounded) and accomplishments (dynamic, durative, bounded) does not appear to include a number of other aspectual types that have been described in the linguistics literature. The decomposition of aspect into time and qualitative state allows us to represent all of the observed aspectual types of simple verbs.

Semanticists have identified a number of different aspectual types of events, most of which can be analyzed as special cases of Vendler's categories of states, achievements, activities and accomplishments (Vendler, 1957;

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Croft et al., 2016). States lack change on the qualitative dimension. Some states are inherent properties of an individual (*She is French*), others are reversible (*The window is open*) or irreversible (*The window is broken*), and still others exist only in a point of time (*The sun is at its zenith*; Carlson, 1979; Talmy, 1985; Mittwoch, 1988).

Achievements represent a transition, construed as instantaneous, from one qualitative state to another. Directed achievements transition to a result state (*The window broke*; Talmy, 1985). Accomplishments represent a gradual change on a qualitative dimension over time, attaining a natural endpoint. Incremental accomplishments represent a measurable, monotonic change (*She ran into the gym*), whereas nonincremental accomplishments describe an activity that is not monotonic before achieving the result state (*He repaired the computer*; Croft, 1998; Rothstein, 2004). Activities represent change that does not have a natural endpoint. Directed activities represent a monotonic change (*The balloon rose*; Dowty, 1979; Talmy, 1985; Bertinetto and Squartini, 1995), whereas the change described by undirected activities is nonmonotonic (*The fans were dancing*).

There is another Vendler-like category: processes that terminate, returning to the base state. These events, which we call *endeavors*, are temporally bounded but not by reaching a natural endpoint. They may be directed or undirected. Semelfactives, which transition to the result state and back to the initial state (*The light flashed*; Talmy, 1985; Jackendoff, 1991; Smith, 1991) are punctual endeavors. Endeavors are not lexicalized as such in English, but certain subevents in complex events are endeavors. In Russian, there are lexicalized endeavors (Forsyth, 1970). Undirected endeavors are derived from undirected activities with the prefix *po-*, as in *On po-spal posle obeda* "He had a sleep after dinner." Directed endeavors are derived from directed activities with the prefixes *pri-, pod-*, and *nad-*, as in *On pri-otkryl dver'* "He opened the door a little."

Croft's graphic representations of two aspectual types are given in Figure 3.1.

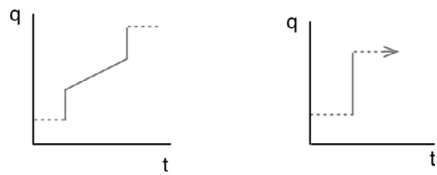

Figure 3.1 Aspectual representation of an incremental accomplishment and an irreversible directed achievement.

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The incremental accomplishment includes five phases: the rest state, the inception transition, the directed change, the completion transition and the (transitory) result state. The directed change and the transitions that bound it (solid line) are profiled (Langacker, 1987); that is, they are the phases encoded by the sentence. The directed achievement consists only of the rest state, the transition and the permanent result state; only the transition is profiled.

3.3.2 Formalization of Aspectual Structure

Our formalization uses the interval calculus for both the temporal and qualitative dimensions (Allen, 1984; Mani and Pustejovsky, 2012) and the commonsense knowledge axioms of Gordon and Hobbs (2017). We model the qualitative structure of a subevent by the qualitative dimension q orthogonal to the time dimension t. Different verbs or predicates define different relevant qualitative states for each participant subevent. Hence, each subevent has a distinct set of qualitative states. One can consider each predicate's set of qualitative states as an interval on the q dimension. Alternatively, each predicate can be thought of as representing a distinct qualitative dimension (see Section 3.6).

Following Allen (1984), we represent "points" in time as very small intervals. One reason for treating points as the smallest intervals is that an event that is construed as occurring in an "instant" (*The bridge collapsed*) may also be construed as occurring over an interval (*The bridge is collapsing*). We would represent these two construals as both occurring over intervals with different granularities (Hobbs, 1985) such that there are no smaller intervals than the event interval for the coarser-grained temporal metric, though this is the case for a finer-grained temporal one.

We analyze the structure of the qualitative dimension q for each subevent also using the interval calculus, which is not specific to time (Hobbs and Pan, 2004; Mani and Pustejovsky, 2012). Verbs and other predicates impose more specific structure on q.

All event types except inherent states have a rest state or base state, a point on the quality dimension that we designate b. Telic events also have a result state, which we designate r. The point r is also the quality expressed by a state predicate. Achievements have only b and r defined on the q dimension. Durative processes – that is, any event involving change over an extended interval – define qualities on a central extended interval between b and r that we designate c.

A phase is defined as a function from an interval i on t to an interval j on q. Phases can be distinguished by properties of the domain and/or range. A state

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is a phase whose range is a point on q. A process is a phase whose domain and range are extended on t and q, respectively. Processes may be monotonic (Mon(p)) or nonmonotonic.

A subevent has an aspectual type. Aspectual types are composite entities composed of one or more phases. Aspectual types are what is annotated; they correspond to the subtypes of the Vendler types described above, such as incremental accomplishments or semelfactives.

3.4 Causation

3.4.1 The Force Dynamics of Physical Events

Participant subevents cause other participant subevents; this is the domain of force dynamics (Talmy, 1976, 1988). Croft (2012) extended Talmy's notion of force dynamics to cover a wide range of asymmetric relations between participants.

Croft et al. (2016) proposed an analysis of the semantic types of argument structure constructions in terms of force-dynamic relations between participants, causal and noncausal, and the type of change that the theme participant undergoes. Among the most common types of force-dynamic relations are Force, the prototypical physical transmission of force relation, and Path, the spatial figure–ground relation.

Croft et al. (2016) defined four types of physical changes, based in part on different types of incremental theme (Dowty, 1991; Hay et al., 1999). The simplest change subevent of the affected entity in a causal interaction is a change of state of the entity; that is, a change in a scalar property of the entity as a whole (Hay et al., 1999).

Events involving change in a spatial figure–ground relation proceed in two different ways. Motion events of various kinds, such as *The boy ran across the road*, define a spatial path on the qualitative dimension that the figure traverses as a whole; for this reason, Dowty (1991) calls the figure a "holistic theme."

Application, removal, combining and separating events, such as *The man picked pears from the tree*, define a mereological change in the location of the figure on the qualitative dimension; this is Dowty's incremental theme proper. Covering and uncovering events, such as *I buttered the toast with hazelnut butter* and *They stripped the trees of bark*, differ from application and removal events in that the incremental change is conceptualized as happening to the ground object (toast, trees) rather than the figure.

Croft et al. (2016) defined another type of theme change, called a Design theme, for creation of an object with a certain identity, for events of creation (*They built a shelter*) and formation (*She carved a toy out of a stick*).

Another type of physical change not described by Croft et al. (2016) is the internal change of a single participant, such as *The flag fluttered*. Internal events often also express a locative relation: *The flag fluttered (over the fort)*. Finally, simple static location is included as an internal event type, albeit stative: *The flag is over the fort*.

The relations between subevents and properties of subevents summarized above cover most if not all of the inventory of physical processes expressed by simple verbs in English.

3.4.2 Mental Events

Mental events generally, though not always, occur oriented to some external situation: an entity, a static state of affairs or the occurrence of a dynamic event. Mental events have two primary participants: the person whose mental state/process is being described, usually called the *experiencer*, and the external situation (entity, etc.), called the *stimulus*; the stimulus of emotion predicates is also called the target/subject matter of emotion (T/SM) following Pesetsky (1995).

Mental events differ from physical events in two major ways. First, there is no physical transmission of force between the external situation and the person's mental state. Second, what is happening in the mind is not outwardly apparent to the observer. Hence, the speaker construes whether the mental event is a state or process and what the "direction" of causation is in mental events.

The semantics literature has described three common construals of the mental force dynamic relation between the experiencer and the stimulus. The Attend construal highlights the experiencer directing her or his attention to the stimulus (Viberg, 1983; Croft, 1993) and consistently expresses the experiencer as subject (Croft, 1993). The Attend construal corresponds to Levin's *Marvel* verb class (Levin, 1993; emotion verbs) and *Peer* verb class (perception verbs; Levin does not include cognition verbs, which usually take sentential complements).

The Affect construal highlights the stimulus causing a change in mental state of the experiencer (Croft, 1993; Zaenen, 1993; Pesetsky, 1995; Levin and Grafmiller, 2013; Doron, 2020) and consistently expresses the stimulus as subject (Croft, 1993). The Affect construal corresponds to Levin's *Amuse* verb

class (emotion verbs); there are no basic perception verbs with this construal. Affect also describes the relation between an event and its beneficiary (or maleficiary).

The Experience construal construes the mental event as a stative relation holding between the experiencer and the stimulus. The Experience construal corresponds to Levin's *Admire* verb class (emotion verbs) and *See* and *Sight* verb classes (perception verbs). This construal allows either the experiencer as subject or the stimulus as subject; we distinguish the latter encoding as Experience*.

Two other force-dynamic mental construals were identified in the survey of mental events by Croft et al. (2018). Judge describes an active mental process mostly under the control of the experiencer, like Attend: it describes mental processes such as comparing, categorizing, inferring and measuring something, as in *more respondents judged it a threat*. Unlike Attend, however, Judge describes the result of the mental process; that is, the conclusion, classification or measurement arrived at.

Finally, Intend describes the relationship between a volitional agent and the agent's as-yet-unrealized, and possibly never realized, action with respect to the other participant, as in *This is the way to cook a chicken for any kind of cold chicken salad, Asian or Western*. Hence, the Intend relation can be used for purpose arguments for all types of events, not unlike Affect with respect to the beneficiary of an event.

3.4.3 Social Events and Event Nominals

Social events are little discussed in the theoretical linguistics literature. Social events are fairly extensively covered in VerbNet (Kipper et al., 2008) and more extensively in FrameNet (Fillmore et al., 2003). Nevertheless, this is a vast and relatively little explored domain. Our preliminary research indicates that the majority of verbs describing social events in VerbNet and FrameNet fall into three domains: transfer of possession, communication (transfer of information) and social role or status, either formal (marry, elect, hire) or informal (befriend, shun). Possession requires positing a social relation between persons and things (control). Communication invokes a mental relation (cognition), plus its transfer via language or other symbolic means. Social role or state requires positing a relation between a person/their role and a social structure.

There are four other force-dynamic novelties found (mostly) in social events. First, the force-dynamic image schemas for social events are predominantly metaphorical extensions of force-dynamic image schemas for

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physical events. For example, *I gave the book to him* uses the positive mereological figure Place image schema for transfer of possession.

Second, there is interpersonal force-dynamics. In addition to the asymmetric interpersonal interaction termed Inducive (Talmy, 1976; Croft, 1991), there is also a more symmetric and reciprocal type of interpersonal interaction, which we term Mutual.

Third, clauses describing social (and mental) events often have event nominals or sentential complements as arguments. It can be argued that event nominals and complements express participant subevents (Croft and Vigus, 2017, 2020). However, one also finds sentences in which that participant and its subevent are expressed as separate syntactic argument phrases, as in *Rebuilding a life in Black Forest won't completely free* ***[her] [of the emotional turmoil that has marked the past year]****, she said.* As a result, we posit the additional annotations Engage and its negative, Refrain, to capture the relation between a participant argument phrase and its subevent event nominal.

Fourth, the social force dynamic interactions are not simply causal chains: they include at least cyclic interactions, as when a buyer gives money to a seller and the seller gives the goods to the buyer. In fact, there is some cyclicity in certain physical events as well. For example, in ingestion events, an Eater uses a Utensil, which moves the Food to the Eater's mouth, and the Eater consumes the Food, as in *Jill ate the chicken with chopsticks.* In vehicular motion events, a Rider enters a Vehicle, which then transports the Rider to a Destination, as in *Brenda went to Berlin by train.* These more complex interactions between participants have led us to distinguish the causal chain expressed by an argument structure construction from the more complex causal network that is evoked by the verb (Kalm et al., 2019).

3.4.4 Formalization of Force-Dynamic Structure

Events expressed by single clauses are analyzed as interactions between participants for multiparticipant events. For example, in *The rock broke the window*, the rock acted on the window. We analyze these force-dynamic relations as relations between subevents that are components of the participant's history. In our example, the rock's contact subevent caused the window's change of state subevent (the specific qualitative state being contributed by the semantics of the verb *break*). The rock's contact subevent is a component of the rock's history, and likewise the window's change of state event is a component of the window's history.

The unity of an event expressed by a single clause (verb and argument structure construction) is defined by the fact that all subevents of an event are

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simultaneous, what Croft (2012) called the temporal unity of events, and by the presence of force dynamic relations between the subevents.

We model the type of incremental change that a participant undergoes, described in Section 3.4.1, as a property of that participant's subevent or, more precisely, the qualitative dimension of that subevent. The types of change described in Section 3.4.1 are Property change (Prop), Motion (Mot), Mereological change (Mer), Design change (Des) and Internal change (Int).

We also provide an analysis of the qualities of subevents of the agent and instrument not discussed by Croft et al. (2016). Agents interact in physical processes using their body. Most of the time what the agent does is volitional; that is, a process involving mental as well as physical aspects of a person. For now, we model volitionality as the type of action that an agent engages in; that is, the agent's subevent has the property Vol. Instruments in physical events interact solely physically, of course, ultimately through some sort of contact. We model the interaction of instruments by attributing the property Contact to the instrument's subevent.

3.5 Annotation Scheme

The theoretical model described above has been implemented in an annotation scheme. We have tested the annotation scheme on texts in different genres, including newswire texts from the Richer Event Description (RED) corpus (O'Gorman et al., 2016; Croft et al., 2016, 2018) and *The Pear Stories*, a set of oral narratives compiled by Chafe (1980; Croft et al., 2017). We have also annotated several hundred VerbNet example sentences with this annotation scheme. The VerbNet annotations can be accessed online through the Unified Verb Index website.[1]

Our annotation scheme currently requires separate manual annotation of the aspectual and force-dynamic event structures for each argument structure construction.

The aspectual annotation uses a four-way categorization into State (stative, all types), Activity (unbounded processes), Performance (completed processes) and Endeavors (terminated processes). This is a coarse-grained version of an annotation scheme with a fine-grained set of aspectual types (Croft et al., 2016). In practice, however, we found that certain aspectual semantic distinctions are difficult to consistently annotate in texts: stable vs. transitory states, punctual vs. durative events and incremental vs. nonincremental change. These distinctions are neutralized in the four-category annotation scheme

[1] https://uvi.colorado.edu.

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described in the text. Examples such as *He is driving* and *He is driving down the hill* are both annotated as Activity. However, an example such as *He drove the package to New York* is annotated as Performance because it describes a completed process.

The annotation of force-dynamic structure involves the annotation of up to three subevents, each with a single label. One is the "core" subevent, which is the most salient change that is asserted by the predicate. The "core" event has a Theme participant and possibly a second participant, such as the Ground object in a spatial relation. The "core" event is defined by the type of change that it involves:

- Property: COS (Change of State, one participant), Relation (two participants)
- Path: Motion
- Mereology: Place, Remove (figure is mereological theme); Provide/Cover, Deprive/Uncover (ground is mereological theme)
- Design: Create ("de novo"), Form (includes inputs to creation)
- Existence: Internal (figure without reference to ground), Location (internal change applies to figure), Dynamic Texture (internal change construed as applying to ground)
- Mental: Attend, Affect, Experience, Experience*, Judge, Intend

We also annotate the external cause of the "core" event, if any. The annotation categories for the external cause are as follows:

- Autonomous: no external cause
- Self-Volitional: no external cause; theme argument brings about action volitionally
- Physical: external physical cause
- Volitional: external volitional cause; no distinct instrument
- Instrumental: external volitional cause with distinct instrument

To demonstrate the annotation procedure, we briefly discuss our annotation of two motion examples in (3) from the VerbNet roll-51.3.1 class.

(3) a. Bill rolled the ball down the hill. [Volitional Motion]
b. The ball rolled down the hill. [Autonomous Motion]

The annotation label for the "core" event in both of the examples in (3) is the same: Motion. The examples describe a spatial figure-ground relation in which the entity *ball* moves holistically with respect to the Ground *hill*. The semantic difference between the two examples is reflected in the assignment

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of distinct annotation labels for the type of external cause. In the first example (3a), the core motion event is initiated by an external entity, a volitional agent, who applies physical force to the theme. The annotation label for the external cause in (3a) is Volitional. In the second example (3b), there is no external cause that brings about the motion event; it is annotated Autonomous because the motion theme *ball* denotes a nonvolitional entity.

We applied the annotation scheme for mental events to a set of sentences in a news corpus annotated in RED (Croft et al., 2018). Croft et al. (2018) reported 81% agreement for the causal structure annotation of 92 argument structure constructions that describe real-world events. A respectable level of interannotator agreement points to a working annotation scheme. We continue to refine the annotation scheme, and it will be expanded to apply to social events.

3.6 Visualization

We are also developing a visualization to capture the evolving interactions of participants over time. The basic idea is a modified metro map (Shahaf et al., 2012), in which the lines represent participant histories and the nodes represent interactions among participants; that is, clausal events. Figure 3.2 presents a visualization of the events, participants and interactions in the following passage:

124 he comes down, . . . from the ladder,

125 and he's wearing an apron,

126 And he dumps them into some baskets . . .

Clausal events are related to other clausal events through temporal relations and relations of shared participants, as in van Erp et al. (2014). As with other storyline visualizations, temporally sequenced events – Before, After and Meets in the interval logic – can be arranged horizontally, with sequenced events sharing participants aligned horizontally. Temporally overlapping events – Equal, Overlap, During and Contain – can be arranged vertically. Events whose temporal location is constrained but not totally specified would be situated relative to those events to which they hold temporal relations.

Of course, such metro maps get very tangled very quickly, because coherent narratives normally express many interwoven events with many different combinations of many different participants. Algorithms such as that of Liu

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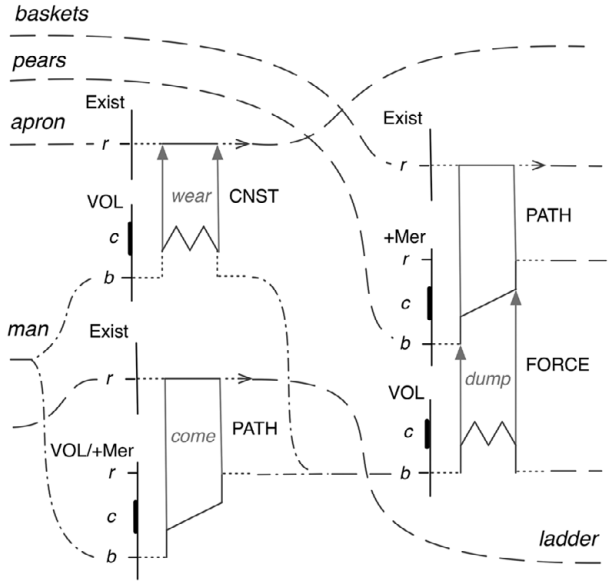

Figure 3.2 Event decomposition and interactions of participants.

et al. (2013) will, we hope, generate visually presentable metro maps of more complex participant interactions over time.

The primary innovation in the visualization is that the interactions between participants in a single clausal event are made explicit, as in Croft (2012) and Croft et al. (2016). That is, the nodes in the metro map visualization are elaborated as interactions between the participants. The roles of participants within a clausal event are kept separate because each participant has its own subevent. The qualitative states and changes of each participant are also explicitly represented. The visualization therefore describes not only the interactions that each participant engages in over the time of the story but also exactly what they do or what happens to them.

Precise representation of participants and their states in events requires addressing certain issues. A group of participants may act as a unit in some events but separately in other events:

41 they gather all the pears
42 and put them in the basket,
43 and one of the guys, helps him
44 brush off the dust,
45 and another guy picks up the rock,

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In this case, we must allow the history for the group of three boys to split in order to represent the interaction of individual boys from the group with other entities (the cyclist and the rock).

In other cases, the same participant is playing different roles in two different events at the same time:

140 then he . . . takes a pear,
141 after carefully watching the man in the tree.
142 Who's still picking.

The man in the tree is functioning as the target of the watching event in 141 at the same time that he is the agent of the picking event in 142.

In order to represent the distinct qualitative states of the man in the overlapping events, we allow a "virtual split" of the line representing the man's history, representing the different qualitative states of being watched and picking. Such virtual splits will be visualized in a distinct way from actual splits as found in passages 41–45 above. In Figure 3.2, we represent the virtual split of the man by dot-dashed lines.

3.7 Conclusion

The event decomposition developed in our research allows us to implement current models of event structure in theoretical linguistics. The event decomposition is also expandable to domains such as social events that are less well explored theoretically, because it is based on basic ontological dimensions of time, qualitative state and causation. Finally, the event decomposition can be integrated into a metro map representation of story structure that links participant histories to what happens to them, and between them, in the course of a narrative.

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