The Features of Spatial Aspect: Examining the Inherent Semantics of Space in English Verbs

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ABSTRACT

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"Aspect" as a grammatical distinction expresses how the event denoted by a verb relates to the flow of time. By analogy, this definition can be extended to address concepts of space, and how the event denoted by a verb relates to the spatial configuration in which the event takes place. While the well-studied temporal aspect is morphosyntactically marked in English, the hypothetical classification of "spatial aspect" is not known to be morphosyntactically marked, but rather is an inherent feature of the verb itself, in that certain verbs select for specific spatial configurations. In this paper, evidence is presented that not only is spatial aspect a valid linguistic categorization, but that there are specific sets of features that surround verbs of different spatial aspects.

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I Introduction

As language is an inherently temporal phenomenon, consisting of sequential symbolic representations expressed over time, temporal aspect in language is well-studied. As a grammatical category, a verb's temporal aspect marks how the action, event, or state denoted by the verb relates to the flow of time, and is a common feature in languages across the world. Using this definition, it is a simple matter of analogy to extend the concept of aspect into space—namely, with a notion of "spatial aspect" that marks how the action, event, or state denoted by the verb relates to its configuration in space (Pustejovsky, 2013). A few simple examples reveal this to be a reasonable distinction: you may enter or exit a room or building or other delineated space, but you may not do the same to, say, a table or other object that creates a space by its presence, except in unusual circumstances.

However, as I will show, this distinction is not necessarily morphosyntactically marked as temporal aspect is, at least in English. Therefore, it is reasonable to assume that the spatial aspect of a verb is a feature inherent to the verb itself, and to change the spatial aspect of the event, you must change the verb itself. If this is the case, then certain verbs must necessarily select for certain spatial configurations.

In this paper, I attempt to demonstrate that a spatial aspect distinction is in fact a salient feature of certain verbs, to use common computational linguistic algorithms and techniques to produce an extensive though non-exhaustive list of spatial aspects and verbs that select for them, and to show that there are specific sets of syntactic and semantic features that correlate with different spatial aspects.

I.1 Spatial Aspect Hypothesis

Since temporal aspect relates a verb's event to the flow of time, "spatial aspect" analogically relates the event to the configuration of space. A temporal aspectual construction like the present progressive "I am eating" described how the action continues over the time at the time of utterance, while one like the present perfect "I have eaten" describes how the action is complete at the time of utterance, and the simple present "I eat" describes a single, current action. In general terms, temporal aspect reflects how the event changes (or does not change) with respect to time. Extending the analogy to space, we can say that a "spatial aspect" would be expected to express differences in how the event changes (or does not change) with respect to space.

This difference, however, is not morphosyntactially marked in English, as shown below:

Consider an English perfective: "Bob walks," versus an imperfective (in this case, a progressive): "Bob is walk**ing**." The "be VERB-ing" construction is the morphosyntactic marking of the English progressive aspect, and there exist other, purely morphosyntactic ways of changing a verb's temporal aspect. These methods are common crosslinguistically: Mandarin Chinese has aspect markers like -*le*,

-zhe, *-zài*, and *-guò*, as well as adverbs that function spectrally; K'iche' Mayan uses prefixed *k-* and *x-* to distinguish imperfectives and perfectives; English uses "to be VERB-ing" to mark a progressive, and "to have VERB-ed" to mark a perfect. No such techniques exist (in English) to alter a verb's spatial aspect: in the sentence Tom *enters* the room, no matter what happens to the verb *enter*, the action of entering remains the same, as does the spatial configuration:

$$\exists x \exists y (\texttt{tom}(x) \wedge \texttt{room}(y) \wedge \texttt{enter}(x,y))$$

Thus, we can reasonably say that, in English, temporal aspect is a *grammatical* aspect categorization, while spatial aspect would be *lexical*. To change the spatial aspect of the action requires the use of a different verb entirely: for example, *Tom* ***leaves*** *the room*.

With *enter*, the motion is from outside the room to inside, and this remains true as long as the argument (*room*) is being entered. To reverse the direction of the motion, the verb must be changed to an antonym, such as, *leave*. To make the motion circular, use *circumnavigate* or some similar verb. When the verb changes, the spatial configuration of the event has necessarily changed due with the use of a different verb, and the relevant difference in the spatial configuration is one which shall herein be termed "aspectual."

I.2 Qualia Structure and Argument Types

Qualia structure, as defined by Pustejovsky (1995), is a mode of explanation of the predicative force for a lexical item. Qualia are the qualities that give a given word its meaning. Within qualia structure, there are four defined modes of explanation that can be associated with said lexical item:

1. FORMAL: The ontological category which distinguishes the object within a larger domain
2. CONSTITUTIVE: The relationship between the object and its component parts
3. TELIC: the purpose or function of the object
4. AGENTIVE: the force by which the object came into being

Depending on the lexical item, some of these qualia may be nil or nonexistent. The above definitions, however, apply only to the qualities of objects or nouns. As verbs are processes or events, and not objects, the definition of the four qualia must be adapted to explain processes instead:

The *formal* quale of a verb is defined as the resultant state at the completion of the process denoted by the verb. For example, for the verb *enter*, with the formula $\exists x \exists y(\texttt{enter(x,y)})$, where x is some agent and y is some space, the formal quale can be defined by a different predicate formula $\exists x \exists y(\texttt{inside(x,y)})$, because, at the completion of the *enter* action, x is *inside* y.

The *constitutive* quale of a verb is not yet well explored in literature. An interpretation of verb qualia as analogous to noun qualia might suggest that for a complex process, the constitutive quale might be a structure containing the predicates defining the subprocesses of the overarching process, such as (for a given agent x):

$\exists x \exists y(\texttt{egg(y)} \wedge \texttt{break(x,y)})$ (break an egg),

$\exists x \exists y(\texttt{egg(y)} \wedge \texttt{whisk(x,y)})$ (whisk the egg),

$\exists x \exists z(\texttt{spinach(z)} \wedge \texttt{chop(x,z)})$ (chop spinach), and

$\exists x \exists y \exists z(\texttt{egg(y)} \wedge \texttt{spinach(z)} \wedge \texttt{mix(x,y,z)})$ (mix egg and spinach)

for a larger process $\exists x \exists y(\texttt{florentine\_omelette(y)} \wedge \texttt{make(x,y)})$, where x is some agent making a florentine omelette.

The *telic* quale of a verb is the purpose for which the process was undergone. Simply put, it is the answer to the question "why am I doing this?" This means that for verbs with intentionality (such as in *Tom* ***hit*** *the ball*), the telic and formal qualia are the same as the state resulting from the successful action is the same as the purpose for which it was undertaken. If the verb's subject is not an agent (as in *The ball* ***hit*** *Tom*), its telic quale is often nil, though this is not always the case, as in *The ball* ***rolled*** *to Tom*, the telic quale of *roll* may be regarded as "around," for instance.

Despite the name, the *agentive* quale of a verb has little to do with its semantic agent. Instead, taken in analogy to the agentive quale of a noun, that of a verb is the process by which the original process in question comes into being. This is the say, the agentive quale is a sequence of events, and thus a representation of the verb's event structure (Pustejovsky and Jezek, 2013). For example, for the verb *enter*, there exist two distinct events within the scope of the entering process: one ingressive that describes the motion toward the space to be entered and one satisfaction condition that describes the moment at which the space goes from being unentered to entered. Thus, *Tom enters the room* can be described as:

$\exists x \exists y(\texttt{tom(x)} \wedge \texttt{doorway(y)} \wedge \texttt{move\_toward(x,y)})$ (Tom moves toward the doorway), followed by

$\exists x \exists z(\texttt{tom(x)} \wedge \texttt{threshold(z)} \wedge \texttt{cross(x,z)})$ (Tom crosses the threshold)

Upon the completion of these two events, the *enter* event is considered to exist in the current context (i.e the room has been entered and all subsequent events that Tom participates in are not considered to be *entering* events and cannot possibly be until the *entered* condition is no longer true). This bears a relationship to

the definition of the constitutive quale outlined above, but the agentive quale is concerned with the events and subevents that lead up to satisfaction of the inherent proposition of the original verb, and not simply with subprocesses.

Overall, we can say that the total meaning of a given verb sense is generated from its qualia, that qualia are calculated based on context, and that different verbs and different verbal senses of the same lexical item have different qualia from each other.

However, as verb qualia must be calculated based on the context in which the verb appears, they are not the only components that can reveal information about the spatial configuration of the sentence. Certain verbs can select for multiple types of objects that change the sentence's spatial configuration. For example, consider two senses of the same verb: (A) *Tom entered the room* vs. (B) *Tom entered the contest*. A *room* is a delineated space, but a *contest* is not, so the sense of *enter* in sentence A is taking an argument of a different semantic type, one with significantly different noun qualia (Pustejovsky, 1995), than the sense of the same lexical item in sentence B. The different senses of the verb require arguments of different types, and the semantics of the arguments can change the sense of the verb.

Thus, it becomes necessary to examine what types of entities the various arguments of the verb are. The same predicate (e.g. *enter*) uses a different sense with certain arguments (*room*) than it does with others (*contest*), as shown by Chen and Palmer (2009). Framing this in generative lexicon terms, the verb exploits different properties of its argument(s) when it changes its own sense.

According to Pustejovsky's generative lexicon, possible relations between a predicate and its arguments include selection and coercion. With type selection, the

argument satisfies the typing requirements of the predicate. Type coercion encompasses exploitation, wherein a part of the argument type is used to satisfy the predicate's typing requirements, and introduction, wherein a type that does satisfy the predicate's typing requirements is used to wrap the argument entirely. By examining a few sample sentences, we can see how this works:

- *John* (HUMAN) *entered the room* (LOCATION) — The type of *room* is LOCATION. This sense of *enter* describes for a spatial configuration.

- *John* (HUMAN) *entered the contest* (EVENT) — The type of *contest* is EVENT. Enter in this sense does not describe a spatial configuration.

- *Put the book* (PHYSICAL OBJECT • INFORMATION) *on the table* (LOCATION) — *book* is a complex type, consisting of the physical object and the information contained within. Here, since the *table* is a location, the verb-particle construction *put on* exploits the PHYSICAL OBJECT type of *book* in order to use it together with the LOCATION *table* to describe the spatial relationship between the two.

- *Put the book* (PHYSICAL OBJECT • INFORMATION) *on my iPad* (PHYSICAL OBJECT • INFORMATION) — Here the complex PHYS • INFO object *book* is used with *iPad*, another PHYS • INFO object (a physical object as well as the information contained on it). While the sentence could be a command to take a PHYSICAL OBJECT *book* and set it on top of a PHYSICAL OBJECT *iPad*—a spatial configuration—a more usual interpretation would be to take the INFORMATION present in the *book* (say, as an e-book or PDF file), and add it to a virtual library of INFORMATION present on the *iPad*, which would not be describing a spatial configuration.

Thus, it can be shown that the spatial aspect of the verb can be deduced from a combination of the verb's qualia and the typing of its arguments. The marking of verb qualia will be discussed further in Section II.1.3, and the specification for the Generative Lexicon Markup Language (Pustejovsky et al., 2008) provides a list of argument types available within the generative lexicon, which is used in this research.

II Methodology

I used a corpus-based, machine-learning approach to classify verbs as either *spatially aspectual* in context (i.e. describing a distinct spatial configuration between their arguments) or *spatially nonaspectual* (describing no distinct configuration) and then use clustering to group those verbs and their features into categories before qualitatively analyzing the similarities in those categories.

The entire experiment consisted of three primary components: annotation, training, and evaluation. Training and evaluation involved training a maximum entropy classifier to classify the content-bearing verbs of a small corpus of verb-centered clausal segments as ether spatially aspectual or nonaspectual, based on their qualia and the typing of their arguments. However, since no corpus exists that marks verb qualia, a significant part of this project was building that corpus, and annotating it to conduct machine learning over. Similarly, no specification exists that deals directly with the qualia of verbs, so I had to develop that specification before proceeding with the annotation.

II.1 Annotation

I used the GLML (generative lexicon markup language) as outlined by Pustejovsky, et al. (2008) as a model for developing my specification, and the MAE (multipurpose annotation environment) tool for annotating the data.

The annotation specification (SpAsML, or *Sp*atial *As*pect *M*arkup *L*anguage) specifies three entity types: CLAUSE, ARGUMENT, and VERB.

II.1.1 Annotation: CLAUSE

The CLAUSE tag in SpAsML is intended to capture clausal segments centered around a non-helping, content-bearing verb. This may, on occasion, differ from the canonical definition of a syntactic clause. CLAUSE entities are extents of text intended to capture, at the bare minimum, the content-bearing verb of the sentence being examined and any arguments that that verb operates over or modify it directly. The exception to this rule is when an argument of the main verb is syntactically zero by means of anaphora. Thus for a sentence like *He shook his head*, the clausal segment consists of the whole sentence. However, a sentence like *He went to the front door and opened it and looked in* actually contains three clausal segments according to SpAsML:

1. ***He went to the front door***
2. ***opened it***
3. ***looked in***

All of the above clausal segments have *He* as a subject, but this is only captured in the extent of the first segment. This method of capturing clausal segments can yield segments that consist of the verb alone when the verb is intransitive and the subject is syntactically zero due to anaphora (***He stumbled*** *and* ***fell***). For this reason, the ID that each CLAUSE extent is assigned by MAE is recorded and maintained to ensure the argument information is fully recoverable.

Clausal segments are not intended to capture adjuncts. For *John killed Bill in Central Park on Sunday*, the only segment that needs to be captured would be ***John killed Bill***. However, some prepositional phrase adjuncts contain an indirect object that the content-bearing verb of the clausal segment necessarily requires for the sentence to be grammatical. For the sentence *Carruthers crossed the room to a metal door with an open grillework in the top half*, the only segment that needs to be captured as such is ***Carruthers crossed the room***, but had the original sentence been simply *Carruthers crossed to a metal door with an open grillework in the top half*, the first adjust *to a metal door* would need to be captured as well to fulfill the requirements of **cross**. Similarly, the salient clausal segment from the sentence *She put the slipper neatly by its mate at the foot of the bed* should be captured as ***She put the slipper neatly by its mate***. When determining what extent of the sentence needs to be captured as a CLAUSE entity, the heuristic is to drop the adjunct phrase and assess if the remaining sentence remains very obviously grammatical. So, for *Carruthers crossed the room to a metal door with an open grillework in the top half*, the adjunct *to a metal door with an open grillework in the top half* can be dropped, leaving a grammatical sentence *Carruthers crossed the room*, thus this segment is all that needs to be captured. If, however, the original sentence being examined is something like *He put it in his own pocket*, dropping the adjunct leaves the ungrammatical **He put it*, so that adjunct should

be included. Similarly, with *She put the slipper neatly by its mate at the foot of the bed*, dropping both adjuncts yields the ungrammatical **She put the slipper neatly*, but dropping only the second adjunct (*at the foot of the bed*) leaves, as above, the perfectly grammatical *She put the slipper neatly by its mate*, because *put* in this context requires some kind of prepositional adjunct. This heuristic allows compound verb-particle constructions to be captured in the annotated data while leaving out prepositional phrases that convey only adjunct information to intransitive verbs.

The attributes of a CLAUSE entity include its spatial aspect information according to the definition outlined in Section II.1.1.

A clausal segment is said to contain a spatially aspectual verb according to the above definition if the content-bearing verb in the segment imposes a constraint on its arguments in such a way that a scene depicting the content of the extent captured in the clausal segment would require the objects representing the arguments to be positioned or orientated in one of a limited number of specific ways in order to accurately represent the content of the clausal segment *and* if no verbs can be substituted for the existing verb in the selfsame environment that would necessarily impose a constraint of the same form but of greater specificity on the arguments.

For determining the spatial characteristics of a clausal segment, the SpAsML specification specifies that all aspect, modality, and polarity should be stripped from the verb, and that it should be considered as a simple past tense. Thus, *it will take a little time* is considered as *it took a little time*, and *he could not go through the fields* is considered as *he went through the fields.*

Sometimes the original construction can leave the transformation that should be done ambiguous. In the sentence *Camel spiders run at you, screaming*, the dangling participle leaves a question of who is screaming, *camel spiders* or *you*. If the first, the clausal segment to be considered is simply *Camel spiders run at you*, transformed to *Camel spiders* ***ran*** *at you*. If the second, there is actually a second clausal segment to be considered: *you, screaming*, considered as *you* ***screamed***. The SpAsML guidelines would recommend the first interpretation, as *run* might potentially be spatially aspectual since it is a manner-of-motion verb, and *scream* is almost certainly not in this sense, as a non-motion verb.

Examining the sentence *I wasn't far behind him when he entered the parking lot and hurried over to his car* reveals three clausal segments:

a. **I wasn't far behind him**

This clausal segment is considered as *I was far behind him*, due the transformation discussed above. The central verb is *be*. *Be* here says nothing about the space in which the event of *being* takes place, and a visualization of a scene representing *be* would not require the verb's arguments to be positioned or oriented in any particular way. Thus, *be* in this clausal segment is not spatially aspectual. In annotation, this is marked with `spatial=`**no**.

b. **he entered the parking lot**

This clausal segment is centered around *enter*. *Enter* here describes a transition from outside the "parking lot" object to inside it. A scene depicting this would require the objects representing "he" to begin outside the boundaries of the space delineated by "parking lot" and end within it, as it would only be describing an *enter* event if that constraint is met. In other words, given:

Event $P(A,\ B)$: An *enter* event with arguments A and B

`and`

Constraint $Q(A,\ B)$: A transitions from outside bounds of B to within them

`then`

$$P \longleftrightarrow Q$$

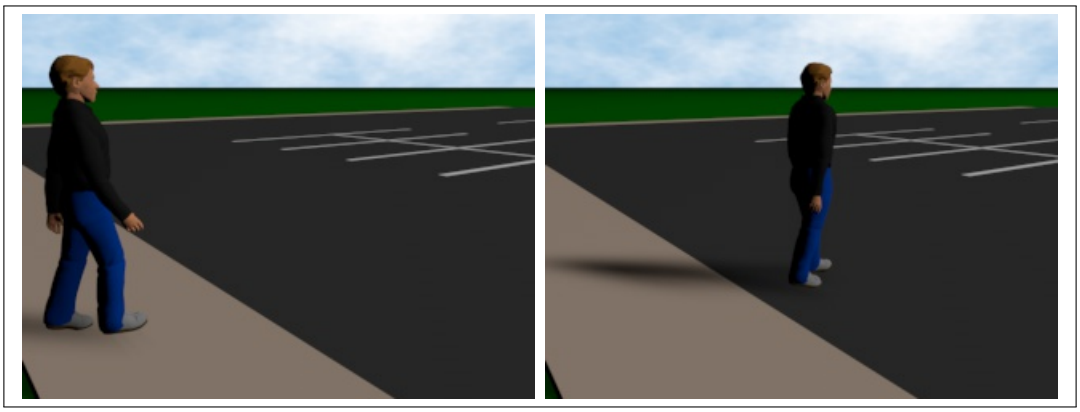


FIGURE II.1: Possible configuration of an *enter* event.

The above figure shows a possible configuration of an *enter* event meeting the given constraint. The constraint is met and cannot be made more specific by substituting of a different verb into the same environment, so *enter* in this clausal segment is considered spatially aspectual: `spatial=yes`.

c. **hurried over to his car**

This is considered as *[he] hurried over to his car* per the anaphora consideration discussed above. *Hurry* is a manner of motion verb, similar to *hop* or *crawl* or simply *walk* (Pustejovsky and Moszkowicz, 2011), but while we can safely say that it describes *a* path taken, the verb says nothing about what the path is. A scene depicting this event would have an object representing "he" at some position, and

an object representing "his car" at another, with any potential path between them realized.

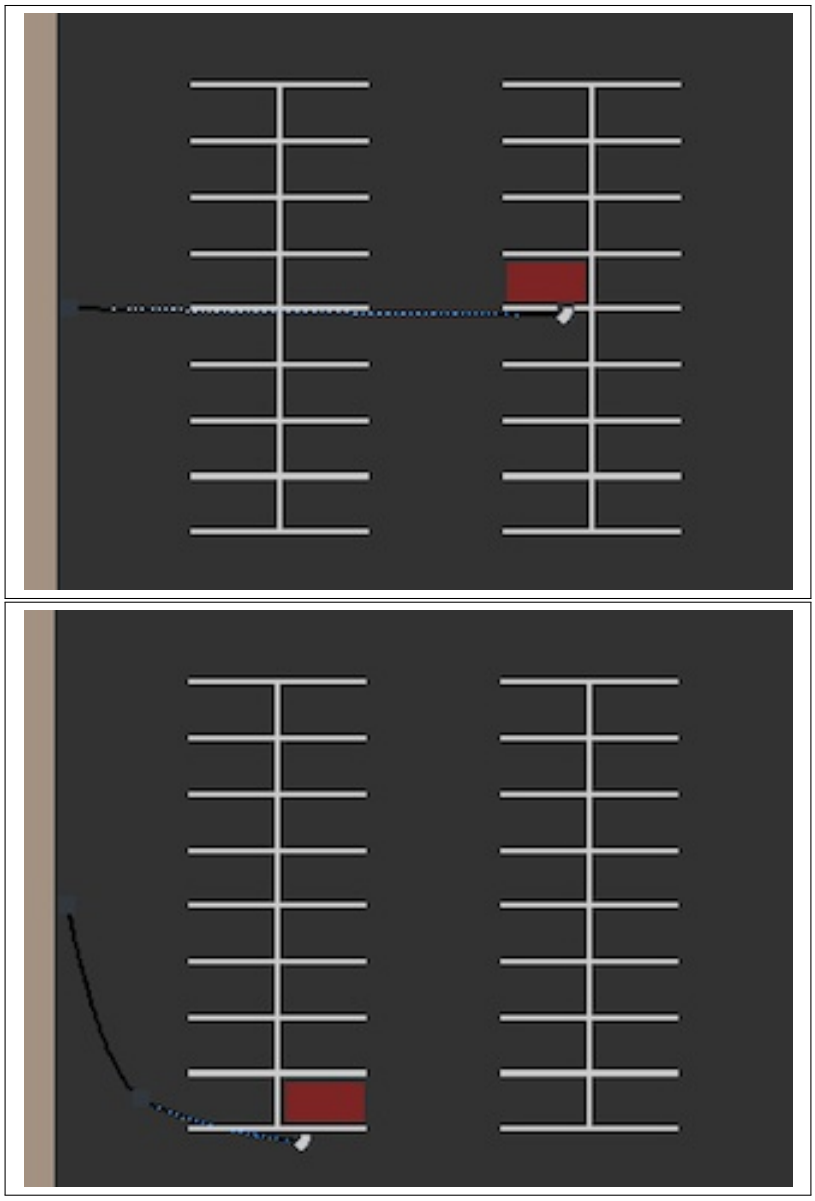


FIGURE II.2: Possible configurations of a *hurry* event.

Both paths in the figure above could describe this *hurry* event. *Hurry* imposes no necessary spatial constraint on the motion in the event it describes. All the path

information in this clausal segment is contained in the adjunct *to his car*. Thus, the verb *hurry* is not spatially aspectual: `spatial=`**no**.

If the clausal segment has been determined to be spatially aspectual, then the annotation specification specifies that and additional distinction needs to be made: whether the configuration imposed on the verb's arguments is static or dynamic. If depicted visually, a static configuration could be captured in a single frame. A dynamic configuration would require at least two frames to describe the process denoted by the verb.

Enter, as shown above, is a dynamic configuration. If *enter* is described by an event $P(A,\ B)$, argument A changes its configuration with respect to argument B over the course of the *enter* process P. In annotation, this is marked with `dynamism=`**dynamic**.

If, however, given some verb $P(A,\ B)$, the configuration between A and B is subject to a constraint imposed by P but the configuration does not change over the course of the event denoted by P, that verb is judged to be spatially aspectual, and static in context. For example:

d. **Alec leaned on the desk**

Given:

Event $P(A,\ B)$: An *lean* event with arguments A and B

`and`

Constraint $Q(A,\ B)$: A is tilted at an angle and B at least partially supports A

`then`

$$P \longleftrightarrow Q$$

The constraint is met and cannot be made more specific by substituting another verb into the same environment, so the verb in the clausal segment is spatially aspectual, but as the configuration between (here) "Alec" and "the desk" does not change over the course of the event, the verb is the clausal segment is static: `spatial=`**yes** `dynamism=`**static**.

The clausal segment can also contain a verb imposing a constraint over a single argument.

e. **Dice rolled**

Given:

Event $P(A)$: An *roll* event with argument A

`and`

Constraint $Q(A)$: A revolves by turning around at least one non-vertical axis

`then`

$P \longleftrightarrow Q$

The constraint is met, so *roll* in this sense is spatially aspectual. In addition, since there is only one argument, and the configuration of that argument changes over the course of the event *roll*, so *roll* is also dynamic: `spatial=`**yes** `dynamism=`**dynamic**.

In general, a clausal segment may contain a spatially aspectual verb if it evokes the image of a specific positioning or orientation of an object or a specific series of positions that an object changes to and from. If this condition is met, the content-bearing verb of the sentence may be spatially aspectual. A verb does not select for spatial aspect in its context if the only positional information in the sentence comes from an attached prepositional phrase, if it could be accurately represented

by more than one specific positioning, orientation, or changes of position (e.g. "The dog *rested* on the couch," "The woman *explored* the city.")

Pustejovsky and Moszkowicz (2011) cite the distinction made between *path* verbs and *manner-of-motion* verbs (path verbs presuppose a path, manner verbs create a path). I will take that distinction one step further and propose a correlation between path verbs and spatial aspect. As paths are simply special cases of a direction of motion constraint over a verb's arguments, most path verbs appear to fall into a subcategory of spatially aspectual, dynamic verbs. For example, *enter* and *leave* are canonical examples of path verbs, as well as of spatially aspectual verbs. Table II.1 shows a possible taxonomy of spatial constraints, and the position of path constraints in it.

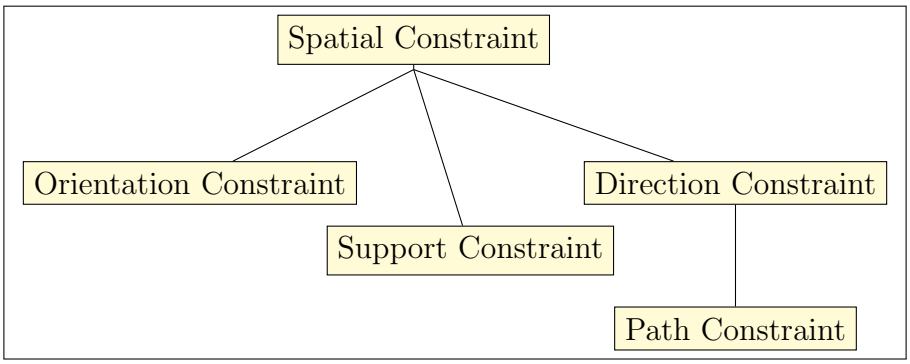


TABLE II.1: Possible taxonomy of spatial constraints.

The relationship between manner-of-motion verbs and spatial aspect is more complex. If the verb is a manner of motion verb (e.g. *run* or *swim*), it may be spatially aspectual but is not necessarily, as shown above with *hurry*. If the constraint imposed by the verb is identical to the constraint imposed by other verbs that are not necessarily synonyms of the original verb, the original verb is not spatially aspectual under this definition. For example, while *run* imposes a constraint on

the figure (the running body) and the ground (the surface being run over), of the figure being upright and mostly perpendicular to the ground, making contact with the ground at some point during the process, this constraint is also satisfied by other verbs that are not synonymous with *run*, e.g. *walk*, *saunter*, *skip*, etc. Similarly, *swim* imposes a "floating, moving through some liquid body" constraint, but says nothing about the orientation of the figure to the ground, while other verbs like *front crawl* or *backstroke* do provide this information. Thus, *swim* is not spatially aspectual, but some of these more specific hyponyms, also manner-of-motion verbs, are.

Simply put, given a set P of path verbs, a set M of manner-of-motion verbs, and a set A of spatially aspectual verbs, they hypothetically exist not in a distinct taxonomy, but with the relations $P \subset A$ and $M \cap A \neq \emptyset$.

Example (1) shows CLAUSE extents identified followed by a pseudo-XML representation of their attributes.

(1) [**I wasn't far behind him**$_{C249}$] when [**he entered the parking lot**$_{C250}$] and [**hurried over to his car**$_{C251}$].

CLAUSE (`id`=C249 `spatial`=no)

CLAUSE (`id`=C250 `spatial`=yes `dynamism`=dynamic)

CLAUSE (`id`=C251 `spatial`=no)

II.1.2 Annotation: ARGUMENT

Each clausal segment must have a subject, though this may not be necessarily captured in its extent, and the extent may contain one or more objects if the verb is transitive. Each argument should capture an extent of structure `Det? Adv*`

`Adj* N` or similar (e.g. *cat*, *big cat*, *really big cat*, *a really big cat*, etc.), and annotators were asked to capture the maximal applicable extent (i.e. to prefer *a really big cat* over simply *cat*). This formula does not apply to propositions or information, which may be represented by an entire subordinate clause. In that case, annotators were asked to capture that entire clause as the argument. Certain properties of these arguments are then also captured in the annotation.

SpAsML captures the syntactic role of the argument, as **subject**, **direct_object** or **indirect_object**. No arguments should fall within an adjunctive modifier as described in Section II.1.1. As adjunctive modifiers should not be captured within the extent of a CLAUSE entity, all arguments should be contained with the extent of some CLAUSE entity. An argument need not be within the extent of every clausal segment it is an argument of (for example, it may appear in one clausal segment, and then be zero in a subsequent segment due to anaphora), and only needs to be captured once no matter how many clauses it is syntactically contained within. For the clausal segments above: *[**he entered the parking lot**$_{C250}$] and [**hurried over to his car**$_{C251}$]—he* is syntactically an argument of both clausal segments, but is only captured in the extent of the first. It does not need to be captured again to be used as part of the second.

Annotation also captures semantic information about the argument, as defined by the generative lexicon. The list of generative lexicon semantic types used here is based on a list of types taken from the Brandeis Shallow Ontology and outline in Pustejovsky et al. (2008), but somewhat altered in order to emphasize types more likely to participate in spatial relations, and to make the search space for annotation less extensive:

BSO Types	SpAsML Types
human	human
animate	animate
organization	organic
physical object	organization
artifact	physical object
event	artifact
proposition	event
information	proposition
sensation	information
location	location
time period	time period
attitude	abstract
emotion	unknown
property	
obligation	
rule	

TABLE II.2: Brandeis Shallow Ontology types vs. SpAsML types.

Anaphors of arguments of a given type are annotated with that same type. If *John* is a **human** and is later referred to as *he*, that *he* should also be annotated with the **human** type. Each specific semantic type in the SpAsML specification is discussed below:

- **human** - A human being (or collection of human beings), by any reference (name, title, etc.). Examples include:

  John

  The president

  Her (when referring to a person)

  The board of directors

- **animate** - A living or lifelike, animate and moving entity. Examples include:

  Felix the cat

  This bird

  A colony of ants

  The robots

- **organic** - Living organisms, object composed of living tissue. Examples include:

  The oak tree

  A nearby forest

  My arm

  This banana

- **organization** - This could refer to a group of individuals, such as:

  The protestors

  A flock of seagulls

  Brandeis University

  This can also refer to systems that have discrete, recognizable stages or components, such as:

  The digestive system

  The food chain

  The water cycle

- **physical_object** - Anything with a substantive physical form. Examples include:

  The rug

My house (referring to the building itself)

Her shoes

That table

- **artifact** - An object to which a (single) specific function or purpose is attached. Examples include:

  The coat

  My hammer

  Our building's elevator

  These are in contrast to **physical object**s such as *table* for which there are multiple possible uses intended.

- **event** - An action that occurs and takes place within a specific timeframe. Examples include:

  Our town fair

  The meteorite's impact

  Mary's arrival

  John's party

- **proposition** - An asserted meaning in the Aristotelian sense, often expressed by a subordinate clause. Examples include:

  That we should go to the store

  John is busy

  Note that this can overlap with **information** depending on the verb used. In *I **know** John is busy*, that John is busy is **information**, because information is known. In *I **believe** John is busy*, it is a **proposition**, because propositions are believed.

- **information** - Anything that delivers, carries, or contains information. Examples include:

  This book

  A news broadcast

  The library (when referring to the books and collection with)

- **location** - A defined space or place. Examples include:

  The library (when referring to the library's address or space that it occupies)

  France

  Her house

  Downtown

- **time_period** - Anything defining a chunk of time, either by absolute date or relative timing. Examples include:

  Tuesday

  This afternoon

  Last week

  About an hour

- **abstract** - Abstract notions such as attitudes, emotions, properties, sensory phenomena, and obligations that are otherwise not captured by another category. This category is intended for a time when the argument has a distinct, discernible type, but it is not covered by any of the other category. Examples include:

  His distaste for comedy

My opinions

Her fear of ghosts

Intense anger

Happiness

Distress

His height

The color blue

Heaviness

The look of her dress

The scent of his cologne

The sound of music playing

Having to mow the lawn

- **unknown** - In the event that absolutely nothing about an argument can be inferred from context, SpAsML provides a category of *unknown*. Certain can be inferred about an argument that takes it out of this category. For example, little is known about *it* in the sentence *He put it in his pocket*, but physical objects are usually the kind of things that get put in pockets, so it would be reasonable to mark *it* as *physical object*. A situation warranting the *unknown* designation would be something like *It came into the room*. Here, *it* could be a physical being, but it could also be a noise or a scent. Since the corpus used in this research consisted of clausal segments considered without context, no outside information could be brought to bear, so the argument *it* here would be marked *unknown*.

Annotators were allowed to assign up to three of the above types to any argument. As discussed in Section I.2, *book* consists of both the physical book and the information on it, so a *book* argument could be annotated as **physical object** and **information**. *The board of directors* is a group of people but also an organization, so could be tagged as both **organization** and **human**. Sometimes in context, one type may be made very evident over another in context (such as *Put the book* (***physical object***) *on the table* (***location***)), so only one type is needed though more than one may apply. Qualitative judgements of this type were left up to the annotators' discretion.

Annotators were instructed to choose the best types for the argument under examination. Though **human** is clearly a subtype of **animate**, which is a subtype of **organic**, which is a subtype of **physical object**, marking a human argument as all four is redundant, and marking it as **human** alone is sufficient.

If more than three types apply, annotators were instructed to select the three most specific types. For example, *library* could arguably be an **organization** (the people who run the library), **location** (the plot of land the library occupies), **information** (the library's collection), and **physical object** (the building itself). Annotators could choose which is least applicable in the context the argument appears in and drop it.

Examples (2-4) show ARGUMENT extents identified followed by a pseudo-XML representation of their attributes.

(2) [**I**$_{\text{A397}}$] wasn't far behind [**him**$_{\text{A398}}$]

ARGUMENT (`id`=A397 `syntype`=subject `gltype`=human)

ARGUMENT (`id`=A398 `syntype`=indirect_object `gltype`=human)

(3) [**he**$_{A399}$] entered [**the parking lot**$_{A400}$]

ARGUMENT (`id`=A399 `syntype`=subject `gltype`=human)

ARGUMENT (`id`=A400 `syntype`=direct_object `gltype`=location)

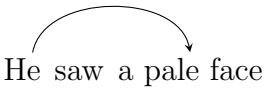
(4) hurried over to [**his car**$_{A401}$]

ARGUMENT (`id`=A401 `syntype`=indirect_object `gltype`=location• physical_object)

II.1.3 Annotation: VERB

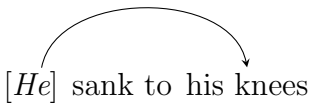
VERB entities are captured in SpAsML as links between the verb's arguments. Since the MAE tool requires two entities to create a link, the annotation specification and guidelines had to propose various strategies to handle verbs of different valencies.

To create a link representing a binary verb with a subject and an object, whether direct or indirect, annotators simply had to create a normal link between the two arguments, such as:



This creates a predicate link between the arguments representable by a first-order formula as for the above example: ∃x∃y(`he(x)`∧`pale_face(y)`∧`see(x,y)`).

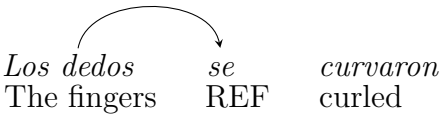
This is the case even if the subject falls outside the extent of the clause:



For CLAUSE extents where the central verb is intransitive, annotators were asked to create the link between the subject and itself.

This is functionally identical to linking the subject argument to a second, syntactically zero argument coreferential with the first: ∃x∃y(fingers(x)∧y=x∧curl(x,y)).

English maintains a set of *-self* pronouns that express reflexivity in explicitly middle-voice expressions like *he washed himself*. While restricted to specific instances in English, English is in this way an oddity among Germanic and Indo-European languages, according McWhorter (2009), and many other languages explicitly realize a reflexive pronoun for a wide variety of otherwise active-voice intransitive verbs (Peitsara, 1997). For instance, the same sentence in Spanish would look like:



This results in the same first-order formula: ∃x∃y(fingers(x)∧y=x∧curl(x,y)).

As above, this is the case even if the subject falls outside the extent of the clause:

In cases of ditransitive verbs, annotators were asked to select a relation for each relevant argument pairing:

This results in three links in the annotation that represent the predicate of a ditransitive verb, as for the above example:
$\exists x \exists y \exists z(\texttt{old\_man(x)} \wedge \texttt{cat(y)} \wedge \texttt{toy(z)} \wedge \texttt{give(x,y,z)})$, where the arguments form a triad.

After creating the links, annotators were asked to manually put in the lemma of the verb that links the arguments, as well as the ID of the CLAUSE entity centered around that verb.

The remaining attributes concern the verb's qualia. Of the four generative lexicon qualia, three are captured in some form or another. Since qualia values are relatively non-discrete and difficult to quantify in natural language, the annotation guideline had to provide ways to reduce them to multiple-choice values to conduct machine learning over. The constitutive quale, rather than trying to enumerate all the potential subprocesses of a verb, was initially framed as the relation between the process in question and its subprocesses. However, such a consideration was eventually judged to be largely irrelevant to determining a verb's spatial aspect quality. Thus, the SpAsML specification captures information relating to the verb's **formal**, **telic**, and **agentive** qualia.

II.1.3.1 The Formal Quale

Per Pustejovsky and Jezek (2013), the **formal** quale of a verb is the state resulting after the verb's completion. In order to discretize this search space, my annotation group and I came up with a number of potential categories to represent the

relationship that results between the verb's arguments after the process denoted by the verb has finished. They may not capture the full information content of formal quale, but are intended to capture the spatial information content, or lack thereof. Not all examples given below are of spatially aspectual verbs.

- **container_containee** - At the end of the action, one argument is contained by another. Examples include:

  Tom *entered* the room.

  The cup *covers* the ball.

- **container_noncontained** - At the end of the action, one argument is no longer contained by another. Examples include:

  Tom *exited* the room.

  The king *has left* the building.

- **event_participant** - One argument is an event or process, and at the end of the action, another participates in it. Examples include:

  Tom *entered* the contest.

  The program *is beginning* an infinite loop.

  Tom *threw* a potluck.

- **event_nonparticipant** - One argument is an event or process, and at the end of the action, another is no longer participating in it. Examples include:

  Tom *left* the party.

  The program *exited* the loop.

  Tom *finished* washing the dishes.

- **organization_member** - One argument is a structured entity or organization (as defined in Section II.1.2 above), and at the end of the action, another argument is a member of it. Examples include:

  Tom *entered* the job market.

  Julia *is joining* the team.

- **organization_nonmember** - One argument is a structured entity or organization (as defined above), and at the end of the action, another argument is explicitly no longer a member of it.

  Tom *left* art school.

  Upon its extinction, the dodo bird *departed* the food chain.

- **acquired_attitude** - One argument is an attitude or emotion, and at the end of the action, another argument begins experiencing or feeling it. Examples include:

  Tom *is learning* to like fish.

  The girl *grew* happy.

  The dog *becomes* sad.

- **lost_attitude** - One argument is an attitude or emotion, and at the end of the action, another argument stops experiencing or feeling it. Examples include:

  Tom *outgrew* his love of dinosaurs.

  Jill *has conquered* her depression.

- **supporter_supportee** - At the end of the action, one argument is physically supported by another. Examples include:

Tom *lifts* the table.

The dog *sat* in the chair.

- **supporter_nonsupported** - At the end of the action, one argument is no longer supported by another. Examples include:

  Tom *drops* the table.

  The dog *leapt* from the couch.

- **giver_taker** - At the end of the action, one argument has given something to another argument. This could be either a physical object or information. Examples include:

  Tom *gives* the cat a toy. (Here the giver is *Tom* and the taker is *the cat.*)

  Mary *told* Tom that Jenny was cheating on him. (Here the giver is *Mary* and the taker is *Tom.*)

  John *will donate* to charity.

- **giver_given** - At the end of the action, one argument has been given to someone or something by another argument. Examples include:

  Tom *gives* the cat a toy. (Here the giver is *Tom* and the given is *a toy.*)

  Mary *told* Tom that Jenny was cheating on him. (Here the giver is *Mary* and the given is *that Jenny was cheating on him.*)

  John *will spend* his money.

- **taker_taken** - At the end of the action, one argument has been given to another argument. Examples include:

  Tom *gives* the cat a toy. (Here the taker is *the cat* and the taken is *a toy.*)

Mary *told* Tom that Jenny was cheating on him. (Here the taker is *Tom* and the taken is *that Jenny was cheating on him.*)

John *will receive* a gift.

- **spatially_proximal** - At the end of the action, two arguments are closer to one another, without one being inside the other. This is intended to include cases where arguments touch without interpenetrating, if the relation is not also one of support. Examples include:

  Tom *joins* Mary at the picnic table.

  The goat *approached* the mountain.

  Tom *grabbed* Mary's arm.

- **spatially_distal** - At the end of the action, two arguments are further from one another. Examples include:

  Tom *left* Mary at the picnic table.

  The goat *flees* the mountain.

  Tom *released* Mary's arm.

- **spatially_altered** - At the end of the action, the position of one argument has changed relative to another, without necessarily drawing closer or further away. Examples include:

  Tom *passed* the school. (*Pass* specifies that Tom moved from one side of the school to the other, but it does not specify a change in distance.)

  The dog *circles* the tree.

  This includes position changes only. Dimension and orientation changes are covered below.

- **time_change** - One of the arguments defines how long another argument spent over the course of the action. Examples include:

  Tom *spent* five years in the Navy.

  I *will wait* three more months to graduate.

  It *has taken* months to write this paper.

- **dimension_change** - At the end of the action, the physical dimensions of an argument have changed. Examples include:

  Alice *shrunk*.

  The sponge *will expand* in water.

  The plant *grew* too big for its pot.

- **orientation_change** - At the end of the action, the physical orientation of an argument (or part of an argument) has changed. Examples include:

  Tom *knelt* down.

  The cat *contorted* to fit in the small box.

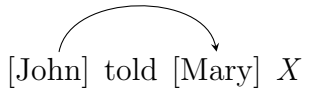
- **other** - In the event that absolutely no category can fit, *other* should be used, but this category was intended to be used as sparingly as possible. Examples include:

  Tom *is* a human.

  Coffee *goes* well with donuts.

Since ditransitive verbs result in three links in the annotation, each of those links may have different formal qualia based on the nature of the two arguments related in that particular link.

For instance, *John told Mary he would be there at seven* produces the following links:



`formal=`**giver_taker**

`formal=`**giver_given**

`formal=`**taker_taken**

II.1.3.2 The Telic Quale

As discussed in I.2, the **telic** quale of a verb denotes the purpose for which the verb's process was undertaken. Since for verbs with intentionality, the telic and formal qualia can be the same, and since some canonical examples of spatially aspectual verbs are often undertaken intentionally (for example, one usually intends to enter a room rather than it happening accidentally), my group and I had to formulate some way of representing the telic quale differently from the formal quale, but still allow options in a discrete, finite search space.

Versley's work in German (Versley, 2012) references the fact that telic relations necessarily cross part-of-speech boundaries (such as "the purpose of a book [n.] is to be read [v.]"). However, simply reversing this and having the telic quale of a verb be represented by a noun (such as "the purpose of reading [v.] is to be applied to books [n.]") is both redundant, and leaves the search space for verbal telic qualia as large as before. Thus, the telic quale needed to somehow be represented by a closed class. This assumption, coupled with the fact that the SpAsML specification is primarily concerned with capturing the spatial information of verbs and clauses, makes *prepositions* a natural vehicle to capture this telic information.

SpAsML frames the telic quale was as the *single-word preposition* that best describes the purpose for which the process denoted by the verb being examined in context was undertaken, if any such prepositions apply. For example, the purpose of *John* ***entered*** *the room* might be for John to be **in** the room. Assuming the verb's telic quale can be expressed by a preposition, annotators were instructed to choose the most basic form of the preposition, such that *inside* should be expressed as *in* and *out of* should be expressed as *out* rather than *of*. In some cases, this preposition may appear in the sentence itself:

- Tom sat *on* the stool. `telic=`**on**
- The dog runs *through* the grass. `telic=`**through**
- John sold the book *to* Mary. `telic=`**to**

In some cases, a preposition may appear in the sentence, but does not adequately express the telic quale of the verb:

- Tom sat in the chair. `telic=`**on**—*sit* here expresses a support relation, not a container relation.

- The ball rolls down the stairs. `telic=`**around**—*roll* implies a repeated motion *around* an axis; the direction of motion is incidental

In all other cases, annotators were asked to make a qualitative judgement about the positional qualities of a verb's telic quale and the preposition that best represented them:

- He can make you work papers. `telic=`**for**
- Thornburg arrived. `telic=`**at**
- Siamese cats are intertwined. `telic=`**around**

In some cases, the verb has no evident telic quale, or has one that cannot be represented by a preposition. In both these cases, annotators were asked to leave the telic quale as nil:

- Eileen seemed to *feel* the same way.
- Andy did not *see* the newspapers the next day.
- I knew they *knew* it.

  "Perception" verbs like the above have no inherent purpose.

Thus, the telic information captured in the SpAsML specification does not capture the entirety of a verb's telic information, but does capture if the verb has telic information that is potentially relevant spatially, and if so, what it is.

II.1.3.3 The Agentive Quale

The **agentive** quale of a verb according to the generative lexicon, is a representation of the verb's event structure, showing the process by which the process denoted by the verb being examined comes to exist.

In annotation, this once again causes the same discreteness problem mentioned in relation to the formal and telic qualia—an entire event structure is difficult to capture in annotation and too large and nondiscrete a search space to easily conduct machine learning over. To resolve this, I turned to work done by Yamada and Baldwin (2004) in identifying the verbs that denote the agentive quale of nouns. According to Yamada and Baldwin, a given noun possesses the four generative lexicon qualia that all combine to create the object denoted by that noun. For example, a book is formally a *publication* (noun) and constitutively *text* (noun). Its telic role is *read* (a verb), which is to say a book's purpose is fulfilled once it is read, and its agentive role is *write* (a verb), which is to say a book comes into being when it is written.

While the agentive role of book consists of the entire writing process, the crucial transition that turns the constitutive *text* of an in-progress object like, say, *manuscript* to the constitutive *text* of the complete object *book* would be the moment that the process of *writing* is completed, however that is defined (say, at the moment the last revisions are submitted to the publisher). Thus, it is this crucial satisfaction condition that defines the agentive role. A book has not fulfilled its agentive role until the writing process is complete.

Extending this to verbs, and referring back to Section I.2, given a verb *enter* and its agentive structure for some agent x:

Event P. $\exists$x$\exists$y(doorway(y)$\wedge$move_toward(x,y))
Event Q. $\exists$x$\exists$z(threshold(z)$\wedge$cross(x,z))

If P and Q are considered as separate events, we can test their saliency to the proposition asserted by the original event:

Event $P(X)$: $\exists$x$\exists$y(doorway(y)$\wedge$move_toward(x,y)) alone, where agent x=X

and

Proposition $E(X,\ Y)$: X has *enter*ed Y

then

$P \longrightarrow \neg\Box E$

If event P, the agent moving toward the doorway, is all the event consists of, an *enter* event cannot be said to necessarily have taken place. P does not necessarily and may *never* necessarily, in the absence of other events, fulfill the creation of the *enter* process E. For a given set of worlds G where P is true, E is not proven to be true for any elements of G (although it may still be).

However:

Event $Q(X)$: $\exists$x$\exists$z(threshold(z)$\wedge$cross(x,z)) alone, where agent x=X

and

Proposition $E(X,\ Y)$: X has *enter*ed Y

then

$Q \longrightarrow \Diamond E$

Q, the crossing of the threshold alone, may fulfill the entering (E) of the room, provided other, non-event conditions C are met, for C=$\{$the threshold being part

of a doorway that actually leads into a room (and not just part of a door in a single wall in the middle of nowhere), etc.}. For a given set of worlds G where Q is true, E is true for at least those worlds in G where conditions in C are also true.

Thus, this satisfaction condition, while not representative of the whole of a verb's agentive quale, is essential to it and represents a crucial part of it in the absence of a representation of the full event structure. It is the characteristics of this satisfaction condition that the SpAsML specification captures as a verb's agentive quale attribute, making the agentive quale of, say, an *enter* event, the answer to the question "what makes it an *entry*?"

For the agentive quale, annotators were asked to annotate the condition(s) that must hold for the action or process defined by the verb being examined to begin. For example, in the sentence *John sits in the chair*, the *sit* action begins when *John* starts being supported by *the chair*. The annotation specification provides the following categories for the agentive quale:

- **joining** - The action defined by the verb begins the moment one argument comes into contact with or becomes a part or member of another argument.

  Tom *touched* the wall.

  Julia *joins* the board of directors.

  Tammy *received* a book.

- **support** - The action defined by the verb begins the moment one argument begins to support another. This may appear to overlap with joining, however support actions such as *lift* typically require preliminary touching (e.g. grabbing hold of) before the start of the action. As a rule, if support was present, annotators were asked to choose this category as it is more specific.

Tom *lifted* the table.

The dog *lays* in the chair.

- **separation** - The action defined by the verb begins the moment one argument separates from another, either by physically detaching or otherwise severing connection.

  The ball *bounced* off the wall.

  Tom *left* art school.

  Sandra *gave* away her favorite sweater.

- **spatial_overlap** - The action defined by the verb begins the moment one argument at least partially occupies the space defined by another.

  Tom *enters* the room.

  The *needle* punctured my arm.

- **continued_overlap** - The action defined by the verb begins the moment one argument remains physically connected to or contained by another. This can also apply to group membership. This differs from joining in that the arguments are not implied to have been previously disjoint before the action here.

  Tom *waited* in the school. (He was in the school, and continued to wait there.)

  Julia *sat* on the board of directors. (She continued to sit on it.)

  The ball *rests* beneath the cup. (This is describing a continuing state.)

  The dog *navigates* the sea of people.

- **continued_separation** - The action defined by the verb begins the moment one argument remains physically disjoint from another. This can also apply

to group membership. This differs from separation in that the arguments are not implied to have been previously connected here.

Tom *passed* the school.

Jane *avoids* the gang's territory.

The dog *leapt* the hurdle with ease.

Eric *skipped* the party.

- **axial_traversal** - The action defined by the verb begins the moment one argument traverses a major axis of the space defined by another, with the implication that it moves from the outside to the inside with the goal of ultimately being outside again.

  Tom *crossed* the road.

  The dog *traverses* the length of the park.

- **transaction** - The action defined by the verb begins the moment one argument begins to transfer something to another.

  Tom *gave* Mary the book.

  Joan *adds* egg to the batter.

- **motion_initiation** - The action defined by the verb begins the moment an argument begins to move.

  Tom *pushed* the chair.

  Mary *throws* the ball.

  The plane *lifts* off.

- **motion_repetition** - The action defined by the verb begins the moment an argument starts repeating a motion.

Tom *walked*. (Over some time period, Tom is continually walking.)

The carpenter *hammered* all day. (The hammering motion was repeated over and over during the time period.)

The ball *rolls* down the hill.

- **motion_cessation** - The action defined by the verb begins the moment some argument stops moving.

  Tom *stopped* the car.

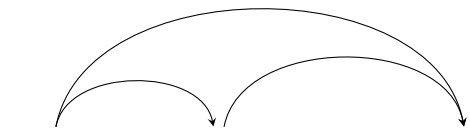
  The plane *landed*.

- **other** - As with the formal, an *other* category was provided in the event none of the above categories fit, but annotators were instructed to use it as sparingly as possible.

  He *stared* out the window.

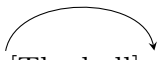
  He *did not care*.

Since the telic and agentive qualia are concerned with the process more than the arguments' relation, they remain the same over all links in a ditransitive triad.



`telic=`**to**
`agentive=`**transaction**

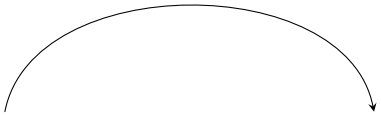
In English, where the valency of a verb is not fixed, verbs all of the same lexical item but with different valencies may in some cases all take slightly different qualia values:



formal=**spatially_altered**
telic=**down**
agentive=**motion_initiation**

formal=**supporter_nonsupported**
telic=**down**
agentive=**separation**

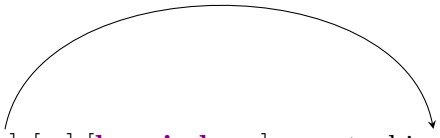
Examples (5-7) show VERB links identified followed by a pseudo-XML representation of their attributes.

(5) 

VERB (id=V267 fromID=A397 fromText="I" toID=A398 toText="him" lemma="be" formal=other telic=nil agentive=other)

(6) 

VERB (id=V268 fromID=A399 fromText="he" toID=A400 toText="the parking lot" lemma="enter" formal=container_containee telic=in agentive=spatial_overlap)

(7) 

VERB (`id`=V269 `fromID`=A399 `fromText`="he" `toID`=A401 `toText`="his car" `lemma`="hurry" `formal`=spatially_altered `telic`=to `agentive`=motion_initiation)

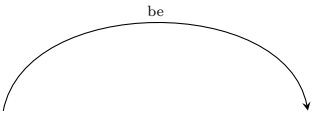
The SpAsML annotation specification captures three of the four levels of computational resources available to a lexical item, as specified in Pustejovksy (1995):

- **Lexical typing structure**
- **Argument structure**
- **Qualia structure**, with the exception of the constitutive quale, which was judged to be unhelpful in classifying spatial aspect, and with the further exception of the pre-satisfaction condition events of the agentive quale

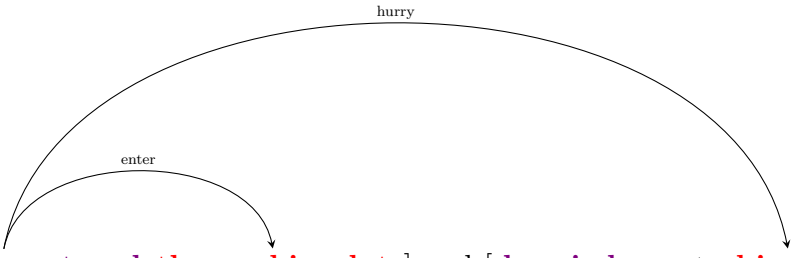
Event structure is difficult to quantify and thus capture in annotation. This discrete quantification problem is one that manifested itself at nearly every stage of developing the annotation specification.

Example (8) shows a sentence with all extents, links, and attributes represented in pseudo-XML, a composite of what was shown in the previous sections.

(8)



[**I wasn't** far behind **him**] when



[**he entered the parking lot**] and [**hurried** over to **his car**].

CLAUSE (`id`=C249 `spatial`=no)

CLAUSE (`id`=C250 `spatial`=yes `dynamism`=dynamic)

CLAUSE (`id`=C251 `spatial`=no)

ARGUMENT (`id`=A397 `syntype`=subject `gltype`=human)

ARGUMENT (`id`=A398 `syntype`=indirect_object `gltype`=human)

ARGUMENT (`id`=A399 `syntype`=subject `gltype`=human)

ARGUMENT (`id`=A400 `syntype`=direct_object `gltype`=location)

ARGUMENT (`id`=A401 `syntype`=indirect_object `gltype`=location• physical_object)

VERB (`id`=V267 `fromID`=A397 `fromText`="I" `toID`=A398 `toText`="him" `lemma`="be" `formal`=other `telic`=nil `agentive`=other)

VERB (`id`=V268 `fromID`=A399 `fromText`="he" `toID`=A400 `toText`="the parking lot" `lemma`="enter" `formal`=container_containee `telic`=in `agentive`=spatial_overlap)

VERB (`id`=V269 `fromID`=A399 `fromText`="he" `toID`=A401 `toText`="his car" `lemma`="hurry" `formal`=spatially_altered `telic`=to `agentive`=motion_initiation)

II.2 Corpus Building

Training and testing corpora were built from subsections of the Brown Corpus—specifically the genre corpora. My annotation group and I made a qualitative judgement that works of fiction would more likely to contain scenes and verbs describing motion, space, and action than typical computational linguistic corpora like the *Wall Street Journal*.

From the Brown science fiction, adventure, mystery, romance, and general fiction genre corpora, we eliminated all sentences that contained no non-helping verb (i.e. all sentences that contained no words whose Brown part-of-speech tag began with VB).

We then trained a Naive Bayes classifier on bag-of-words environments surrounding a some canonical examples of spatially aspectual verbs (such as *enter*, *sit*, and *cross*). From the winnowed list of genre corpora sentences mentioned above, we used this classifier to extract a set of sentences thought likely to be roughly balanced between spatially aspectual and nonaspectual clauses. These sentences were thus often taken largely out of context, allowing annotators to analyze the qualia of verbs in isolation, and not requiring them to consider phenomena such as verbal anaphora to inform their judgement, though they were allowed to if evidence was present and considering it would clarify an ambiguous meaning.

II.3 Classification and Clustering

After annotating data and receiving annotated data from others who assisted with the process, and gathering a total of 500 annotated clauses for training and

a further 60 clauses for testing, I used the Python Natural Language Toolkit's learning algorithm to train a Maximum Entropy classifier over the annotated data to classify similarly annotated, unlabeled test clauses as either spatially aspectual or spatially nonaspectual according to the definition described in Sections I.1 and II.1.1.

Finally, the content-bearing verbs of all clausal segments from the testing data that were correctly classified as having a spatially aspectual verb were run through the Natural Language Toolkit's k-means clustering algorithm to determine finer-grained categories of spatial aspect.

III Feature Engineering and Model Training

On a development test set of 50 clauses held out from the aforementioned 500, the following features were determined to have the greatest success rate of correctly classifying verbs according to their spatially aspectual quality:

Feature	**Notes**
Formal quale value	
Agentive quale value	
Telic quale present?	Boolean value
Telic quale value	*nil* if telic quale is not present
Syntactic roles of all arguments	
Arguments' generative lexicon types	1-3 per argument
Verb is transitive?	Boolean value

TABLE III.1: Spatial aspect features for classification.

In order to find finer-grained clusters of spatially aspectual verbs, a heuristic was used that assumed that a "good" cluster would group verbs that, while not necessarily synonyms, belong to similar formal classes. Thus, the qualia features were weighted higher than other features during clustering. In order to reduce the search space and the number of features being considered during clustering, I performed

global dimensionality reduction by only considering the features that actually appear in the correctly classified positive examples. For example, if `telic="in"`, `telic="around"`, and `telic="between"` are features that appear in the trained model, and only verbs with features of `telic="in"` and `telic="around"` are correctly classified positive examples, only `telic="in"` and `telic="around"` features would be used during clustering. This prevents too many features with values of 0 and too many total features being considered by the clustering algorithm.

Feature	**Notes**	**Weight**
Formal quale value		2.0
Agentive quale value		2.0
Telic quale value	*nil* if telic quale is not present	2.0
Syntactic roles of all arguments		1.0
Arguments' generative lexicon types	1-3 per argument	1.0
Verb is transitive?	Boolean value	1.0
Aspect is dynamic?	Boolean value	1.0

TABLE III.2: Spatial aspect features for clustering.

With the aforementioned 500 clauses, a Maximum Entropy classifier was trained, and cross-validated using 10-fold, 5-fold, 4-fold, and 3-fold cross-validation. Two models were created for cross-validation in order to test the feature set: one in which the spatial aspect label was a simple two-way spatially aspectual/nonaspectual distinction, and one in which the spatial aspect label used the dynamism distinction mentioned in Section II.1.1, giving a three-way classification scheme of spatially nonaspectual/statically aspectual/dynamically aspectual.

Each holdout set was tested against a model trained on the rest of the data, and the scores were then averaged. Cross-validation results follow:

k	F1 (2 labels)	F1 (3 labels)
3	0.8692	0.7335
4	0.8836	0.7596
5	0.8865	0.7780
10	0.8828	0.7614

TABLE III.3: Avg. cross-validation F1-scores of annotation-trained model.

The two-way distinction resulted in much higher F1-scores and more total clauses classified as spatially aspectual. The three-way distinction produced too small a search space for clustering by incorrectly classifying a number of positive, spatially aspectual examples. For this reason, it was decided to train the final model for evaluation using the simple two-way distinction, establishing a clear divide between spatially aspectual and spatially nonaspectual verbs, and to use the spatial dynamism of the verb as a feature during clustering instead, in the hopes of providing finer-grained results over a larger sample size.

Next, in order to establish a baseline for comparing how well the model trained over annotation-dependent features performs compared to a model simply trained over n-grams, I trained a model whose only features were the words in a n-gram window surrounding a clause's content-bearing verb. I conducted two trials of this model, one in which n=5 and another in which n=7. In most cases, these ranges capture both the subject and the object of the verb, especially in clauses with a subject-verb-direct object structure. This model was cross-validated using the same *k*s:

k	**F1 (n=5)**	**F1 (n=7)**
3	0.6139	0.6360
4	0.5951	0.5995
5	0.6079	0.6105
10	0.6098	0.6262

TABLE III.4: Avg. cross-validation F1-scores of n-gram-trained models.

The model trained over annotation-dependent features showed an improvement of 25-30% over the baseline. Using this as a rough estimate for expected performance, a model was trained over the entire training set of annotated data, using the two-way spatially aspectual/nonaspectual distinction, was used for testing and evaluation.

IV Results

The classifier judged whether or not the verb in each clausal segment in the testing data imposed a specific specific spatial configuration or constraint on the relative placement of its argument. Classification results were obtained with a training corpus consisting of 500 annotated clausal segments and a testing corpus of sixty annotated clausal segments. Clustering results were obtained using all the clausal segments that the classifier correctly classified as spatially aspectual.

IV.1 Classification

Using the model trained on the verb-centered 5-gram windows, classifying the sixty test clausal segments resulted in a F1-score of 0.6079. Given this score, and the average 10-fold cross-validation score of this model from Table III.3 (ten being the k closest to $\frac{500}{60}$), which are roughly commensurate, we can see that using n-gram environments to predict whether or not a verb is spatially aspectual succeeds only ten percent more often then simple chance. In fact, more clausal segments containing spatially aspectual verbs were classified as spatially nonaspectual than were classified correctly.

(row = reference; column = test)

	no	yes
no	29	*6*
yes	*16*	9
Precision:	59.43%	
Recall:	62.22%	
F1-score:	0.6079	

TABLE IV.1: Classification results using baseline model.

The clausal segments correctly classified as spatially aspectual by this baseline model were (brackets show the n-gram windows used for features, not including sentence beginning and ending markers):

[before Payne] *loomed* [the Old] Clubhouse
[he] *turned* [to the] window
the [log was] *spinning*
[John] *entered* [the vast] church
[John] *lifted* [his hand]
[he] *rose*
[he] *crossed* [the lobby]
[he] *climbed* [the steps]
[they] *rolled*

TABLE IV.2: Spatially aspectual clausal segments according to baseline model.

Increasing the n-gram window from 5 to 7 increased the precision, recall, and F1-scores by single percentages, but this gain was only in correctly classified negative examples. The correctly classified positive clausal segments under this mode were identical to those in IV.2, and the 7-gram window covered the entire extent of the clausal segment.

(row = reference; column = test)

	no	yes
no	31	*4*
yes	*16*	9
Precision:	62.29%	
Recall:	67.59%	
F1-score:	0.6483	

TABLE IV.3: Classification results using 7-gram model.

As mentioned in Section III, the n-gram windows used the baseline model often captures the subject and direct object of the clausal segment, and in the above results, where n=5, four of the correctly classified segments show S-V-DO structure, two show S-V-IO or IO-V-S structure, and three show S-V alone.

Using the model trained on the SpAsML annotation-dependent features and the same datasets resulted in an F1-score of 0.9485. This is a nearly 35% improvement over the baseline, as opposed to an improvement of approximately 4% when the n-gram window was increased to n=7 from a baseline of n=5.

(row = reference; column = test)

	no	yes
no	34	*1*
yes	*2*	23
Precision:	94.57%	
Recall:	95.14%	
F1-score:	0.9485	

TABLE IV.4: Classification results using model trained on annotation-dependent features.

The clausal segments correctly classified as spatially aspectual by this model were:

before Payne *loomed* the Old Clubhouse
he was still *falling*
he *turned* to the window
the log was *spinning*
John *entered* the vast church
John *lifted* his hand
Galli *arrived*
he *rose*
Roberta and Dave began to *back* toward the door
she *pushed* it back
sank to his knees
the fingers *curled*
the body *lay*
it won't *open*
Rilly or Glendora had *entered* her room
he *crossed* the lobby
Hub was *sitting* in a chair
opened it
a newspaper open at stock-market reports *lay* on one of them
he *climbed* the steps
they *rolled*
Alec *leaned* on the desk
Clayton *lifted* him

TABLE IV.5: Spatially aspectual clausal segments according to model trained on annotation-dependent features.

Three clausal segments were classified incorrectly:

they had *passed* through the barbed wire (actual = yes, classified = no)
he *reached* down (actual = no, classified = yes)
I *dropped* into the doctor's office (actual = no, classified = yes)

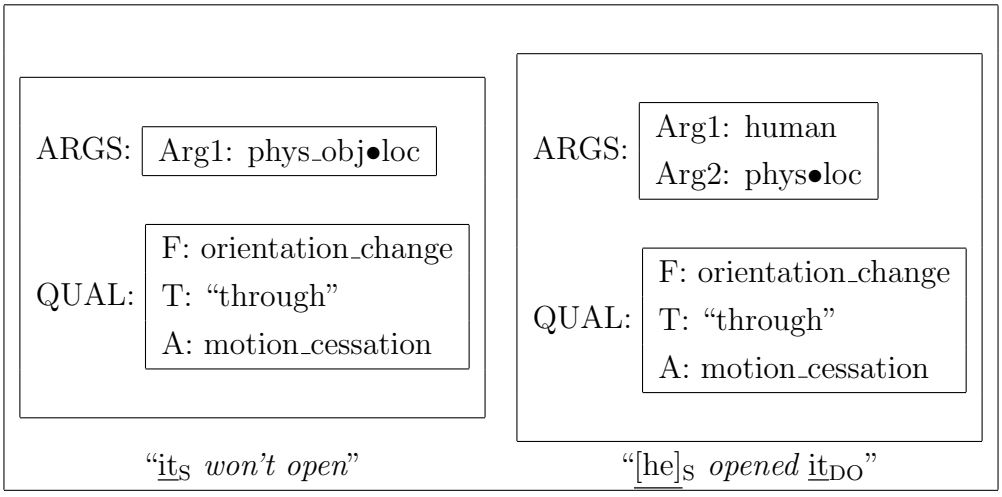
TABLE IV.6: Incorrectly classified clausal segments according model trained on annotation-dependent features.

These clausal segments include all the segments similarly classified by the baseline model. Table IV.7 shows the verb lemmas from the testing data that were classified as spatially aspectual in context.

loom	fall	turn
spin	enter	lift
arrive	rise	back
push	sink	curl
lie	open	cross
sit	climb	roll
lean		

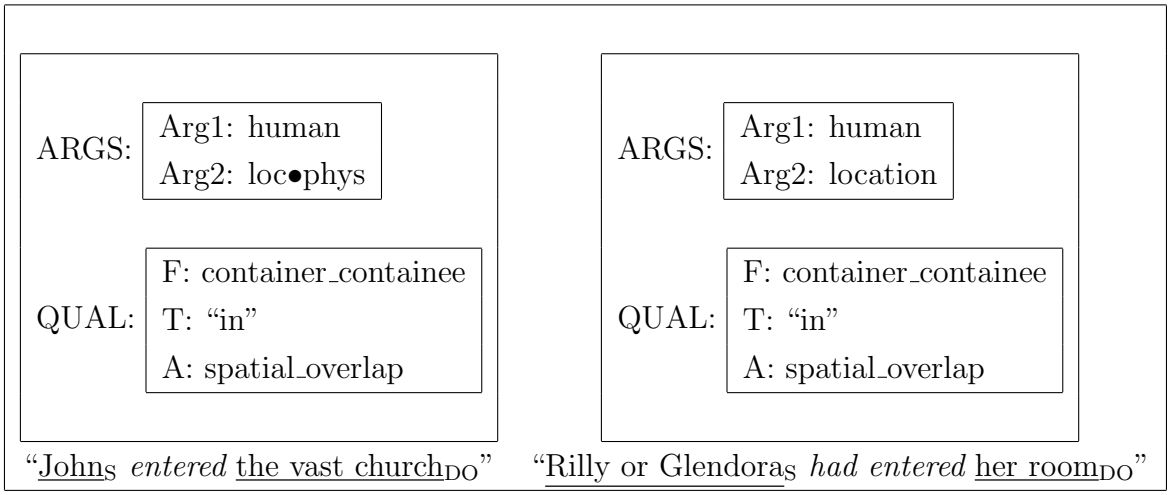
TABLE IV.7: Some spatially aspectual verbs.

Two instances each of *open* and *enter* appeared in the testing data, all correctly classified as spatially aspectual. Both instances of *open* had the same qualia, as did both instances of *enter*.



The most noticeable difference between the two instances of *open* is that one is intransitive and one is transitive. However, `orientation_change`, the quale value defined by the SpAsML specification as the physical orientation of an argument or part of an argument has change relative to its starting orientation or the orientation of the other argument. This, it can be used with both intransitive and transitive verbs. In the first instance above, *it*'s orientation changes relative to its starting

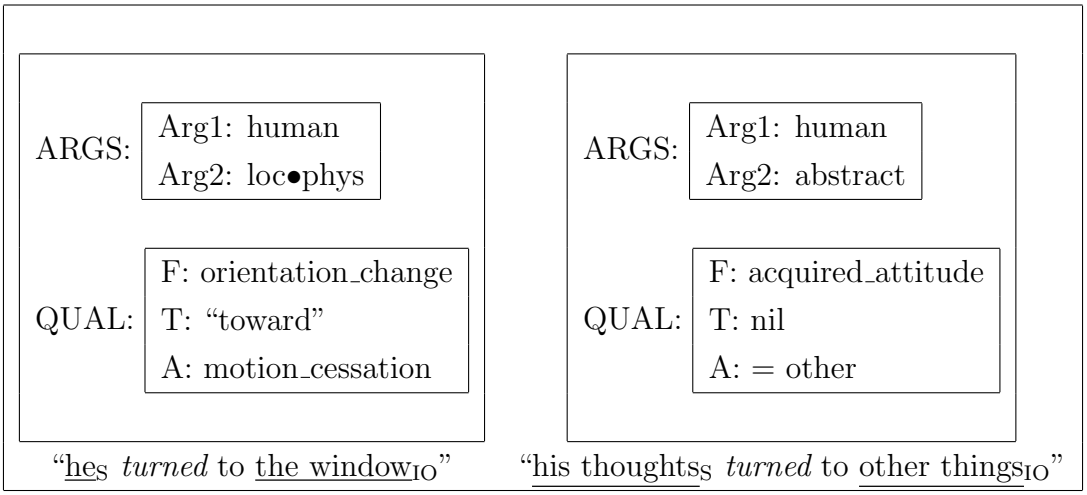
position (context reveals *it* to be a door). In the second, the orientation of *it* (also a door) changes both relative to its starting position and the position of the agent of its opening, *he*. *Open* is a process that can be executed on many things (doors, rooms, boxes, hearts, etc.). Both examples in the testing data concerned doors, so the qualia were the same. Opening a door and a box may have different qualia (e.g. the purpose of opening a door is to go or look "through" it while the purpose of opening a box may be to look "in" it.).



Both instances of *enter* in the testing data took some kind of location as a direct object, resulting in a container relation and a spatial overlap satisfaction condition as their formal and agentive qualia, respectively.

Lie and *lift* also occurred twice each in the testing data, both in the same sense each time. All these instances were classified correctly as spatially aspectual.

Some of these verbs are spatially aspectual only in certain contexts. For example, while *turn* appears twice in the testing data, only one instance (*he turned to the window*) is classified as spatially aspectual:



Turn takes a spatial sense and associated qualia with arguments of types that can interact in spatial terms. Otherwise, the verb takes a sense that has no spatial aspect.

The tables below show the frequency of some features of the verbs that were correctly classified as spatially aspectual, their arguments, or the contexts in which they appeared:

Arg1 = subject	8
Arg1 = subject, Arg2 = direct object	10
Arg1 = subject, Arg2 = indirect object	4
Arg1 = indirect object, Arg2 = subject	1

TABLE IV.8: Phrasal structure of clausal segments with spatially aspectual verbs.

subject	human	17
	physical_object•location	2
	organic	1
	physical_object	1
	physical_object•organic	1
direct object	physical_object	3
	location	2
	location•physical_object	2
	human	1
	organic	1
	physical_object•artifact	1
indirect object	location•physical_object	3
	human	1
	location•organic	1

TABLE IV.9: Argument typing of spatially aspectual verbs.

subject	human	18
	physical_object	4
	location	3
	organic	3
direct object	physical_object	6
	location	4
	artifact	1
	human	1
	organic	1
indirect object	location	4
	physical_object	3
	human	1
	organic	1

TABLE IV.10: Exploitable information in arguments of spatially aspectual verbs.

formal	orientation_change	9
	supporter_supportee	7
	spatially_altered	3
	container_containee	2
	spatially_proximal	2
telic	"on"	5
	"around"	3
	"up"	3
	"down"	2
	"in"	2
	"through"	2
	"toward"	2
	"across"	1
	"at"	1
	"back"	1
	"over"	1
agentive	support	6
	motion_initiation	5
	motion_cessation	5
	spatial_overlap	3
	motion_repetition	2
	axial_traversal	1
	continued_separation	1

TABLE IV.11: Qualia values of spatially aspectual verbs.

The classifier's complete output can be found in Appendix A. Further discussion of these results will follow in Section V.

IV.2 Clustering

The 23 correctly classified spatially aspectual clausal segments were then clustered using the features and weights given in table 4. Since there is no set number of spatial aspects and it is not even known what different spatial aspects verbs can fall into, there is no standard number of means to cluster around. Thus, I ran the clausal segments through two different clustering runs, one using 6 means, for an average of about 4 verbs (just under) per cluster, and one using 8 means, for an average of just under 3 verbs per cluster.

Table IV.12 shows the central verbs from the twenty-three correctly classified spatially aspectual clausal segments in Table IV.5 clustered around six means. Table IV.13 shows the same verbs clustered around eight means. Some verbs which appear more than once in the positive examples from testing data may have been placed into different clusters.

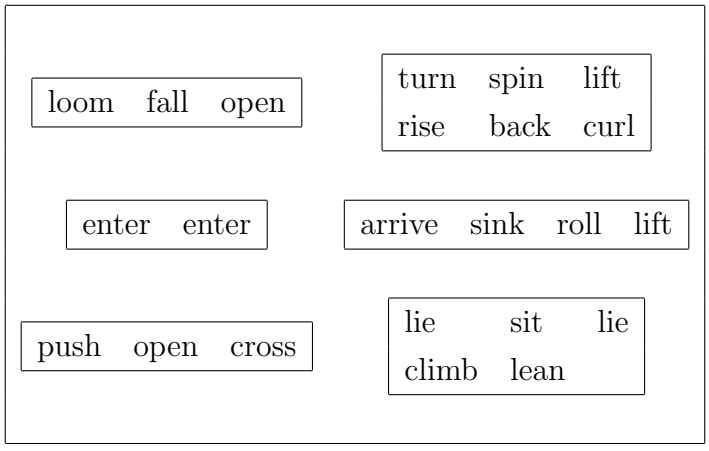


TABLE IV.12: Spatially aspectual verbs clustered around six means.

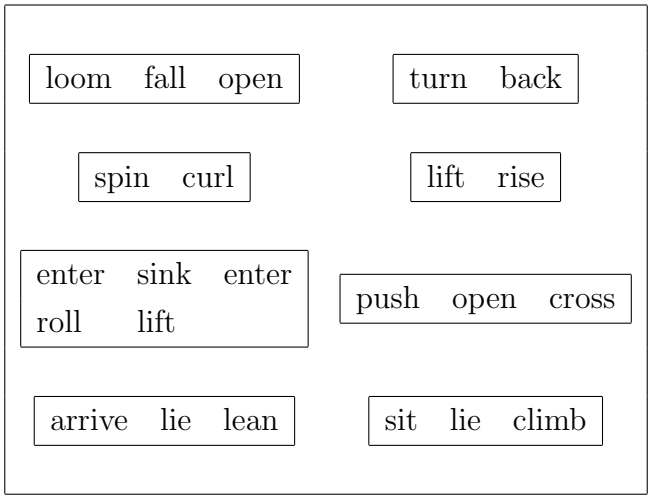


TABLE IV.13: Spatially aspectual verbs clustered around eight means.

Qualitative analysis shows some patterns: *enter* clustered with itself, *lie* clustered with other "support" verbs like *lean*, *sit*, and *climb*, "turning" verbs *spin* and *curl*. Other groupings seem less justified: *open* does not cluster with itself using either number of means, and does not appear to have much in common with *loom* or *fall*, or *push* or *cross*, the verbs with which it is clustered, in one sense or another; and using eight means, *turn* is clustered with *back* instead of the other "turning" verbs, *spin* and *curl*.

Without an established way to assess the clusters generated above, I relied on both qualitative analysis as described above and a metric based on Lin similarly according to WordNet. Lin similarity was computed for each pair of WordNet senses of each verb. The similarities for the closest senses of every pair of words were then averaged, resulting in a value for the average similarity between all verbs in the cluster. This assumes that for verbs with both spatial and non-spatial senses, like "enter" or "lie," the spatial senses should be closer to the spatial senses of other verbs than to the non-spatial senses. Since the verbs being clustered have already been classified as spatially aspectual, and thus inherently using a spatial

sense, this assumption should hold. These values are only meaningful relative to each other, and higher average similarities imply a "tighter" cluster according to WordNet. Table IV.14 shows the average similarity values computed for all the clusters shown above.

	6-mean clustering	
	Cluster contents	**Avg. similarity**
A_6	loom, fall, open	0.2435
B_6	turn, spin, lift, rise, back, curl	0.3981
C_6	enter, enter	1.0000
D_6	arrive, sink, roll, lift	0.2181
E_6	push, open, cross	0.2258
F_6	lie, sit, lie, climb, lean	0.5354
	8-mean clustering	
	Cluster contents	**Avg. similarity**
A_8	loom, fall, open	0.2435
B_8	turn, back	0.3561
C_8	spin, curl	0.5224
D_8	lift, rise	1.0000
E_8	enter, sink, enter roll, lift	0.4479
F_8	push, open, cross	0.2258
G_8	arrive, lie, lean	0.1230
H_8	sit, lie, climb	0.5292

TABLE IV.14: Average similarity values for clusters.

A few correspondences appear between the two sets of clusters. Given a universe U defined as the union of all the sets defined by the clusters given above, the sets of clusters can be related through the following equivalencies:

$$A_6 = A_8$$

$$E_6 = F_8$$

$$B_6 = B_8 \cup C_8 \cup D_8$$

$$F_6 = (D_6\prime \cap (C_6\prime \cap E_8))\prime \cap (H_8 \cup G_8)$$

C_6 groups *enter* with itself, for a similarity of 1. D_8 also has a similarity of 1, but over two different verbs, *lift* and *rise*. The closest senses of these verbs in WordNet are synonyms, making this a very strong cluster by WordNet standards.

F_6 and H_8 are two clusters whose verbs have formal quale values of *supporter_supportee* and agentive quale values of *support*. F_6 has an average similarity value of 0.5354 and H_8 has an average similarity value of 0.5292, so these support relations appear to be relatively strongly encoded in WordNet, where *lie* and *sit* are sister terms, related to *climb* through a *change posture* category, and cousins to *lean* through *lay*. C_8 contains *spin* and *curl*, both verbs which imply orientational changes (and have *orientation_change* as their formal qualia value). This cluster has a relatively high average similarity value of 0.5224, roughly commensurate with the similarity values of F_6 and H_8. However, B_8, a group also containing verbs sharing a formal quale value of *orientation_change*, has a much lower average similarity value of 0.3561. *Turn* and *back* are not synonyms, though share a telic quale of *toward* in the testing data. In WordNet, *turn* and *back* are only distantly related through a larger *move* category. So, certain orientational relations appear to be more strongly encoded in the SpAsML specification than in WordNet.

The complete clustering output can be found in Appendix B. Further discussion of these results will follow in Section V.

V Discussion

The increase in the F1-score using the annotated model data compared to the 5-gram model data shows that spatial aspect is not a feature that can easily be extracted from surface-level processing. The high F1-score of the classifier was achieved using information about semantic typing, qualia structure, and verb transitivity that would require significant extra effort to extract computationally from the raw data. While these features may not be the only way to identify spatially aspectual verbs, the high success rate of the classifier suggests that they form a strong core to the complete feature set of spatially aspectual verbs.

A corpus of the size used proved to not be quite enough to reliably extract a static/dynamic distinction within spatially aspectual verbs. To do so would require a much larger corpus and test set to classify as spatially aspectual or not, and then taking the true positive results from that classifier to train a new model to extract the static/dynamic distinction. The dynamism distinction did, however, appear to be a moderately useful feature for clustering.

Though the classifier made few errors, examining them revealed some confusion that arises when defining spatial aspect.

Idiomatic uses of verb-particle constructions tend to cause confusion, as they may defy compositionality (Stevenson et al., 2004). In "I dropped into the doctor's

office," the semantics of the event are not fully contained in the verb *drop* nor in the preposition *into*. The classifier classified this as spatially aspectual although *drop* alone in this context does not impose a specific configuration on *I* and *doctor's office*.

"Light verb" constructions, like "John took his leave from the room" with spatially nonaspectual *take*, would likely cause similar confusion for similar reasons, though none occur in the testing data.

$$\text{drop} = \left[\begin{array}{l} \text{ARGSTR} = \left[\begin{array}{l} \text{Arg1} = \text{human} \\ \text{Arg2} = \text{location} \bullet \text{organization} \end{array}\right] \\ \\ \text{QUALIA} = \left[\begin{array}{l} \text{Formal} = \text{container\_containee} \\ \text{Telic} = \text{"into"} \\ \text{Agentive} = \text{motion\_initiation} \end{array}\right] \end{array}\right]$$

"$\underline{\text{I}}_{\text{S}}$ *dropped* into $\underline{\text{the doctor's office}}_{\text{IO}}$"

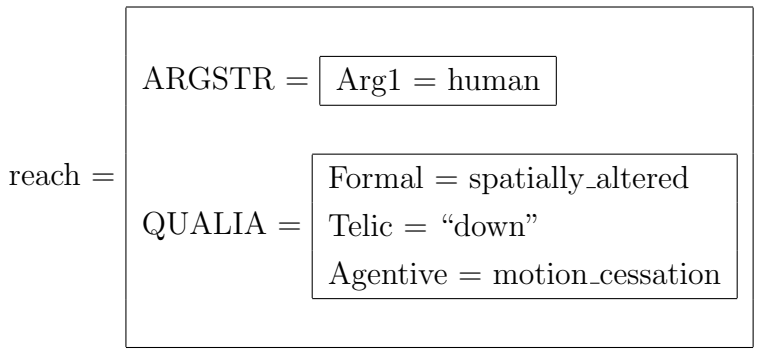
Passed through in the sense below is spatially aspectual but was classified as spatially nonaspectual. The problem seems to be that the only other verb in the training or testing data whose formal quale is *spatially_altered* and whose agentive quale is *axial_traversal* is *cross*, which usually takes a telic quale value of *across*, not *through*. *Pass* in some other contexts can have qualia values of [Args = [human, location], Formal = spatially_altered, Telic = "by", Agentive = continued_separation] ("he passed the school"), or [Args = [human, event], Formal = event_nonparticipant, Telic = "out", Agentive = separation] ("he passed the class"), but *pass through* here takes spatial (physical) arguments with somewhat

unfamiliar qualia, which likely confused the classifier. A larger, more diverse set of training data would likely solve problems like these.

$$\text{pass} = \left[\begin{array}{l} \text{ARGSTR} = \left[\begin{array}{l} \text{Arg1} = \text{human} \\ \text{Arg2} = \text{physical\_object} \end{array}\right] \\ \text{QUALIA} = \left[\begin{array}{l} \text{Formal} = \text{spatially\_altered} \\ \text{Telic} = \text{“through”} \\ \text{Agentive} = \text{axial\_traversal} \end{array}\right] \end{array}\right]$$

“$\underline{\text{they}}_{\text{S}}$ *had passed* through $\underline{\text{the barbed wire}}_{\text{IO}}$”

Reach, as below, provides an example of the difference transitivity can make in determining a verb's spatial aspect quality. *Reach* used purely intransitively or with only direct objects, as below, refers to a very different motion from *reach* used transitively (e.g. a reaching motion with an arm vs. a near-synonym of arrive). The former, as in *he reached the apartment complex*, is probably spatially aspectual (cf. *arrive* in Table IV.7), but the instance below is not spatially aspectual but is classified incorrectly. A larger data set might solve this, but a feature set that involves taking a closer look at how transitivity affects spatial aspect may as well.



"he$_S$ *reached* down"

What we can draw from the above is that certain verbs impose a spatial configuration on their arguments, but may also syntactically require a preposition (for instance *lean again*, *sit on*), which makes the object of the sentence an indirect object structurally, and causes the verb-preposition couple to act as a single verbal predicate. These verbs in isolation (e.g. *put* in *put in*) are not considered spatially aspectual according to the definition used here in, but they provide an obvious area in which to expand the definition of a spatially aspectual verb: If these verb-preposition pairs can be replaced with a synonymous single verb in which the argument of the preposition is turned into a direct object, and the synonym is spatially aspectual according to the established definition, the verb-preposition pair can also considered to be spatially aspectual as a whole. Since *lean* and *sit* can be spatially aspectual in the right context, *lean against* and *sit on* can be considered so, too, since the preposition is simply a syntactic requirement of the verb. While *insert* would be spatially aspectual according to the definition used here and it requires an *into* syntactically, the functionally similar *put in* would be considered spatially aspectual as a whole even though *put* alone is not. Similarly *sit* is spatially aspectual in contexts where it may take *in* or *on* (*John sat in*

the chair), while the functionally similar *set on* may be spatially aspectual even though *set* alone is not.

A few further hypotheses about spatial aspect can be made based on the above discussion. There are distinct differences between transitive spatially aspectual verbs that impose a configuration or constraint on both their arguments ("John left the room"), and verbs that are not necessarily transitive, but are spatially aspectual and impose a configuration or constraint on only one argument ("The ball rolled").

In "the ball rolled", (formal quale value = *orientation_change*), the constraint is only on the movement of *ball*. The addition of an adjunct like "down the stairs" places the configuration of *ball* in space relative to *stairs*, but the manner of motion constraint remains on *ball* alone. In "John left the room" (formal quale value = *container_noncontained*), the constraint is necessarily on the movement of *John* with respect to the location *room*. "John left," while grammatically, requires that some prior context that establishes the location being left, such as "The room was an awful place to be. John left."

As above, certain verbs may impose a spatial configuration on their arguments, even if some argument are syntactically zero (as in "John left" above). *Leave* necessitates an in-to-out motion if the arguments are of a type capable of participating in spatial relations. Similarly, "John climbed" would also be spatially aspectual if the context is established as being some space, such as *stairs* or *tree*. If what John climbed is established as non-spatial, like *society*, *climb* is not spatial in that sense. However, as long as the context is established as being some space, spatially aspectual verbs, such as *climb* or *leave* are definite and distinct for each argument or set of arguments. Discovering if there are any formalized distinctions between spatially aspectual verbs in these expanded contexts and in the contexts

seen in this study would require a method of handling anaphora resolution on a multiple sentence level.

The hard preference toward human argument types, especially in subject position, is probably attributable to bias in the corpus, as it was taken from novels and novels most often are about humans. However, as mentioned in Section II.1.2, some types exist in a hierarchy, including `physical_object`→`organic`→`animate`→`human` and `physical_object`→`artifact`. By this measure, we can see that all the arguments that participate in these spatially aspectual relations are all either physical objects or some subtype there of, or locations. Thus, we can essentially reduce spatially aspectual relations, at least those that have shown up in this testing data, to `physical_object-physical_object` or `physical_object-location` relations. This doesn't seem to cover sentences like *The party left the bar at 9PM*, but it might if we consider *party* to be of a complex type `event•human`, that is, an event defined in part by the humans that participate in it. The human (physical) type of *party* is leaving the location *bar* and taking their event with them. This distinction was not discovered because it did not appear in the corpus.

The data provided by clustering is still relatively sparse, but below I tentatively relate clusters of spatially aspectual verbs to noun cases in various world languages. As has been shown in English, positional information can be conveyed by certain verbs, but is also marked with adpositional adjuncts. As other languages often mark these adpositional distinctions grammatically on the noun, the relation seems qualitatively evident (case information comes from Fuchs and Robert (1997)).

Some clusters appear to be qualitatively very sound—namely B_8 and C_8 (orientational, telic *toward* or *around*, similar to the *orientative*, a grammatical case found in Chukchi and Manchu), and D_8 (upward motion, similar to the *superlative* case), and C_6 groups two uses of *enter* with itself in an *illative* group (the illative

case is found in Uralic languages—Finnish, Estonian, and Hungarian). F_6 and H_8 group, to different levels, verbs with formal and agentive support and telic *on* into a kind of support-relation group, which finds parallels in a number of grammatical cases—the *prosecutive* (Kalaallisut), *prolative* (Tlingit, Erzya), or *superessive* (Hungarian, Ossetic, Tsez).

Other clusters, however, contain verbs that do not appear to have much in common. *Loom*, *fall*, and *open* (transitive) are clustered together, and *push*, *open* (intransitive) and *cross* are clustered together in both the six-mean and eight-mean clustering, and at first glance these clusters do not appear to share many qualities (or qualia). *Sink* and *lift* (support relation) are clustered together in both sets of classification results, but *sink* and *lift* are near-antonymic. Similar curious results occur, such as clustering of path verb *arrive* with support verbs *lie* and *lean* and *roll* grouped with the odd *sink*/*lift* pair instead of other orientation-changing verbs *spin* and *curl*. Given all this, it seems reasonable to state that the features that define spatial aspect in contrast to verbs that have no spatial aspect are not fine-grained enough to make solid distinctions of subcategories within spatial aspect.

VI Future Work

While temporal aspect is widespread and well-studied, grammaticalized spatial distinctions are less so, certain languages, particularly indigenous languages of the Americas and Sub-Saharan Africa do make these distinctions to some extent. Kikuyu, a Bantu language spoken in Kenya, maintains a series of adverbs for proximal, distal, and perspectival distinctions ("here," "there," "from where you see it"), that have alternate forms depending on if the space of the event is an enclosed space ("in the house") or an open space ("in the field"). Yupik, in Alaska and Siberia, maintains a similar distinction with, an up/down, in/out, and nonspecific split in the distal adverb (McWhorter, 2011). This research shows that a similar distinction, albeit less formalized, exists in English verbs, and that certain verbs must be used if a certain constraint is to be imposed on the verb's argument. In addition, I suspect this phenomenon is common crosslinguistically, and maybe correlated with noun case usage in morphologically rich languages.

This survey technique will need to be expanded to other languages in order to determine the crosslinguistic validity of the spatial aspect category, but I believe that the above conclusions will be borne out for languages across the Indo-European family, as well as languages worldwide. Phenomena in some lesser-known languages from Africa and the Americas would be particularly interesting to study.

The size of the corpus and dataset that I used were enough to show a distinction between spatially aspectual and spatially nonaspectual verbs, but the subsequent sparseness of data made it difficult to show finer-grained distinctions, except hypothetically. A larger and more diverse dataset may help resolve this problem.

As mentioned in Section V, the next logical step would be to come up with a set of features that better distinguish subcategories or distinct spatial aspects within the larger category of spatially aspectual verbs. In morphologically rich languages, especially those with well-developed case systems, I believe that further research could demonstrate a relationship between the spatial aspect of a verb and the case of its arguments. I should note that this definition of spatial aspect does not describe all spatial configurations, and in fact some verb classed as spatially nonaspectual (such as *rests* in "The cats rests on the table") do in fact describe some kind of spatial configuration, but one that was judged to be non-specific and excluded from the definition of spatial aspect in order to shrink the search space.

There are also distinctions between spatially nonaspectual verbs that could be discoverable using a similar generative lexicon-based method. For instance, neither *walk* nor *put* are spatially aspectual according to the definition used here, but *walk* may imply some non-specific figure-ground configuration requirement be satisfied (with the exception of spacewalks), which *put* does not. Neither are they interchangeable verbs, and there are distinct differences in the processes which they respectively describe. If any of these distinctions end up singling out a relative location of arguments, the definition of spatial aspect should be reevaluated in a way that accommodates them.

Since this study was conducted only on the sentence level, I would like to extend the survey to the level of whole paragraphs. Annotating paragraphs for spatial aspect requires solving problems that arise due to anaphora resolution. The spatial

configuration created by the use of a certain verb may persist or change throughout the paragraph, even though the verb is never used again after the first sentence.

I believe the data has shown that the category of spatial aspect is a valid one and that there exist specific features in English that correlate with specific spatial aspects. Knowledge of spatial aspect distinctions provides an automatic wealth of knowledge about event localization, clues toward solving various spatial reasoning problems, and insight into deep understanding relating to spatial language.

A Classification Results

A.1 Results from Baseline Model

Clausal segment: *he looked at his son*
Classified: SPATIAL = no
Actual: SPATIAL = no
{w_{i-2} = <s>, w_{i-1} = he, w_{i+1} = at, w_{i+2} = his}

Clausal segment: *they had passed through the barbed wire*
Classified: SPATIAL = no
Actual: SPATIAL = yes
{w_{i-2} = they, w_{i-1} = had, w_{i+1} = through, w_{i+2} = the}

Clausal segment: *he made the decision*
Classified: SPATIAL = no
Actual: SPATIAL = yes
{w_{i-2} = <s>, w_{i-1} = he, w_{i+1} = the, w_{i+2} = decision}

Clausal segment: *before Payne loomed the Old Clubhouse*
Classified: SPATIAL = yes
Actual: SPATIAL = yes
{w_{i-2} = before, w_{i-1} = Payne, w_{i+1} = the, w_{i+2} = Old}

Clausal segment: *he went for the bed*
Classified: SPATIAL = no
Actual: SPATIAL = no
{w_{i-2} = <s>, w_{i-1} = he, w_{i+1} = for, w_{i+2} = the}

Clausal segment: *he came to an open field*
Classified: SPATIAL = yes
Actual: SPATIAL = no
{w_{i-2} = <s>, w_{i-1} = he, w_{i+1} = to, w_{i+2} = an}

Clausal segment: *he was still falling*
Classified: SPATIAL = no
Actual: SPATIAL = yes
{w_{i-2} = was, w_{i-1} = still, w_{i+1} = </s>, w_{i+2} = </s>}

Clausal segment: *the skies grew dark*
Classified: SPATIAL = no
Actual: SPATIAL = no
{w_{i-2} = the, w_{i-1} = skies, w_{i+1} = dark, w_{i+2} = </s>}

Clausal segment: *his thoughts turned to other things*
Classified: SPATIAL = no
Actual: SPATIAL = no
{w_{i-2} = his, w_{i-1} = thoughts, w_{i+1} = other, w_{i+2} = things}

Clausal segment: *he turned to the window*
Classified: SPATIAL = yes
Actual: SPATIAL = yes
{w_{i-2} = <s>, w_{i-1} = he, w_{i+1} = to, w_{i+2} = the}

Clausal segment: *the log was spinning*
Classified: SPATIAL = yes
Actual: SPATIAL = yes
{w_{i-2} = log, w_{i-1} = was, w_{i+1} = </s>, w_{i+2} = </s>}

Clausal segment: *John entered the vast church*
Classified: SPATIAL = yes
Actual: SPATIAL = yes
{w_{i-2} = <s>, w_{i-1} = John, w_{i+1} = the, w_{i+2} = vast}

Clausal segment: *John lifted his hand*
Classified: SPATIAL = yes
Actual: SPATIAL = yes
{w_{i-2} = <s>, w_{i-1} = John, w_{i+1} = his, w_{i+2} = hand}

Clausal segment: *Adam looked at the pot*
Classified: SPATIAL = no
Actual: SPATIAL = no
{w_{i-2} = <s>, w_{i-1} = Adam, w_{i+1} = at, w_{i+2} = the}

Clausal segment: *the concierge called out to them*
Classified: SPATIAL = no
Actual: SPATIAL = no
{w_{i-2} = the, w_{i-1} = concierge, w_{i+1} = out, w_{i+2} = to}

Clausal segment: *Galli arrived*
Classified: SPATIAL = no
Actual: SPATIAL = yes
{w_{i-2} = <s>, w_{i-1} = Galli, w_{i+1} = </s>, w_{i+2} = </s>}

Clausal segment: *his watch told him he was still early*
Classified: SPATIAL = no
Actual: SPATIAL = no
{w_{i-2} = his, w_{i-1} = watch, w_{i+1} = him, w_{i+2} = he}

Clausal segment: *he can make you work papers*
Classified: SPATIAL = no
Actual: SPATIAL = no
{w_{i-2} = he, w_{i-1} = can, w_{i+1} = you, w_{i+2} = work}

Clausal segment: *he slept*
Classified: SPATIAL = yes
Actual: SPATIAL = no
{w_{i-2} = <s>, w_{i-1} = he, w_{i+1} = </s>, w_{i+2} = </s>}

Clausal segment: *he rose*
Classified: SPATIAL = yes
Actual: SPATIAL = yes
{w_{i-2} = <s>, w_{i-1} = he, w_{i+1} = </s>, w_{i+2} = </s>}

Clausal segment: *Hillman had ordered him not to leave the far bank*
Classified: SPATIAL = no
Actual: SPATIAL = no
{w_{i-2} = Hillman, w_{i-1} = had, w_{i+1} = him, w_{i+2} = not}

Clausal segment: *he reached down*
Classified: SPATIAL = no
Actual: SPATIAL = yes
{w_{i-2} = <s>, w_{i-1} = he, w_{i+1} = he, w_{i+2} = </s>}

Clausal segment: *he had not felt that*
Classified: SPATIAL = no
Actual: SPATIAL = no
{w_{i-2} = had, w_{i-1} = not, w_{i+1} = that, w_{i+2} = </s>}

Clausal segment: *he enjoyed it*
Classified: SPATIAL = no
Actual: SPATIAL = no
{w_{i-2} = <s>, w_{i-1} = he, w_{i+1} = it, w_{i+2} = </s>}

Clausal segment: *she looked mighty interested*
Classified: SPATIAL = yes
Actual: SPATIAL = no
{w_{i-2} = <s>, w_{i-1} = she, w_{i+1} = mighty, w_{i+2} = interested}

Clausal segment: *he hurried to the living room*
Classified: SPATIAL = no
Actual: SPATIAL = no
{w_{i-2} = <s>, w_{i-1} = he, w_{i+1} = to, w_{i+2} = the }

Clausal segment: *I never want to see her again*
Classified: SPATIAL = no
Actual: SPATIAL = no
{w_{i-2} = want, w_{i-1} = to, w_{i+1} = her, w_{i+2} = again }

Clausal segment: *Roberta and Dave began to back toward the door*
Classified: SPATIAL = no
Actual: SPATIAL = yes
{w_{i-2} = began, w_{i-1} = to, w_{i+1} = toward, w_{i+2} = the}

Clausal segment: *she pushed it back*
Classified: SPATIAL = no
Actual: SPATIAL = yes
{w_{i-2} = <s>, w_{i-1} = she, w_{i+1} = it, w_{i+2} = back}

Clausal segment: *he looked straight at Marty*
Classified: SPATIAL = no
Actual: SPATIAL = no
{w_{i-2} = <s>, w_{i-1} = he, w_{i+1} = straight, w_{i+2} = a }

Clausal segment: *sank to his knees*
Classified: SPATIAL = no
Actual: SPATIAL = yes
{w_{i-2} = <s>, w_{i-1} = <s>, w_{i+1} = to, w_{i+2} = his}

Clausal segment: *I was watching for numbers*
Classified: SPATIAL = no
Actual: SPATIAL = no
{w_{i-2} = I, w_{i-1} = was, w_{i+1} = for, w_{i+2} = numbers}

Clausal segment: *the fingers curled*
Classified: SPATIAL = no
Actual: SPATIAL = yes
{w_{i-2} = <s>, w_{i-1} = the, w_{i+1} = curled, w_{i+2} = </s>}

Clausal segment: *he found the razor*
Classified: SPATIAL = no
Actual: SPATIAL = no
{w_{i-2} = <s>, w_{i-1} = he, w_{i+1} = the, w_{i+2} = razor}

Clausal segment: *the body lay*
Classified: SPATIAL = no
Actual: SPATIAL = yes
{w_{i-2} = the, w_{i-1} = body, w_{i+1} = </s>, w_{i+2} = </s>}

Clausal segment: *he put in a call to Cunningham*
Classified: SPATIAL = no
Actual: SPATIAL = no
{w_{i-2} = <s>, w_{i-1} = he, w_{i+1} = in, w_{i+2} = a}

Clausal segment: *it won't open*
Classified: SPATIAL = no
Actual: SPATIAL = yes
{w_{i-2} = it, w_{i-1} = won't, w_{i+1} = </s>, w_{i+2} = </s>}

Clausal segment: *she wanted much*
Classified: SPATIAL = no
Actual: SPATIAL = no
{w_{i-2} = <s>, w_{i-1} = she, w_{i+1} = much, w_{i+2} = </s>}

Clausal segment: *Rilly or Glendora had entered her room*
Classified: SPATIAL = no
Actual: SPATIAL = yes
{w_{i-2} = Glendora, w_{i-1} = had, w_{i+1} = her, w_{i+2} = room}

Clausal segment: *she told anyone of the opium*
Classified: SPATIAL = no
Actual: SPATIAL = no
{w_{i-2} = <s>, w_{i-1} = she, w_{i+1} = anyone, w_{i+2} = of}

Clausal segment: *he crossed the lobby*
Classified: SPATIAL = yes
Actual: SPATIAL = yes
{w_{i-2} = <s>, w_{i-1} = he, w_{i+1} = the, w_{i+2} = lobby}

Clausal segment: *he hadn't come back*
Classified: SPATIAL = yes
Actual: SPATIAL = yes
{w_{i-2} = he, w_{i-1} = hadn't, w_{i+1} = back, w_{i+2} = </s>}

Clausal segment: *Hub was sitting in a chair*
Classified: SPATIAL = no
Actual: SPATIAL = yes
{w_{i-2} = Hub, w_{i-1} = was, w_{i+1} = in, w_{i+2} = a}

Clausal segment: *he wants to ask you some questions*
Classified: SPATIAL = no
Actual: SPATIAL = no
{w_{i-2} = <s>, w_{i-1} = he, w_{i+1} = to, w_{i+2} = ask}

Clausal segment: *opened it*
Classified: SPATIAL = no
Actual: SPATIAL = yes
{w_{i-2} = <s>, w_{i-1} = <s>, w_{i+1} = it, w_{i+2} = </s>}

Clausal segment: *a newspaper open at stock-market reports lay on one of them*
Classified: SPATIAL = no
Actual: SPATIAL = yes
{w_{i-2} = stock-market, w_{i-1} = reports, w_{i+1} = on, w_{i+2} = one}

Clausal segment: *he climbed the steps*
Classified: SPATIAL = yes
Actual: SPATIAL = yes
{w_{i-2} = <s>, w_{i-1} = he, w_{i+1} = the, w_{i+2} = steps}

Clausal segment: *you don't know me*
Classified: SPATIAL = no
Actual: SPATIAL = no
{w_{i-2} = you, w_{i-1} = don't, w_{i+1} = me, w_{i+2} = </s>}

Clausal segment: *they rolled*
Classified: SPATIAL = yes
Actual: SPATIAL = yes
{w_{i-2} = <s>, w_{i-1} = they, w_{i+1} = </s>, w_{i+2} = </s>}

Clausal segment: *I dropped into the doctor's office*
Classified: SPATIAL = yes
Actual: SPATIAL = yes
{w_{i-2} = <s>, w_{i-1} = I, w_{i+1} = into, w_{i+2} = the}

Clausal segment: *Alec leaned on the desk*
Classified: SPATIAL = no
Actual: SPATIAL = yes
{w_{i-2} = <s>, w_{i-1} = Alec, w_{i+1} = on, w_{i+2} = the}

Clausal segment: *something heavy shook the floor*
Classified: SPATIAL = yes
Actual: SPATIAL = no
{w_{i-2} = something, w_{i-1} = heavy, w_{i+1} = the, w_{i+2} = floor}

Clausal segment: *I'd told them a lot of it*
Classified: SPATIAL = no
Actual: SPATIAL = no
{w_{i-2} = <s>, w_{i-1} = I'd, w_{i+1} = them, w_{i+2} = a}

Clausal segment: *he went back to work*
Classified: SPATIAL = no
Actual: SPATIAL = no
{w_{i-2} = <s>, w_{i-1} = he, w_{i+1} = back, w_{i+2} = to}

Clausal segment: *we'll never know which*
Classified: SPATIAL = no
Actual: SPATIAL = no
{w_{i-2} = we'll, w_{i-1} = never, w_{i+1} = which, w_{i+2} = </s>}

Clausal segment: *he had lost his audience*
Classified: SPATIAL = no
Actual: SPATIAL = no
{w_{i-2} = he, w_{i-1} = had, w_{i+1} = his, w_{i+2} = audience}

Clausal segment: *there were nine qualified scouts sitting around*
Classified: SPATIAL = no
Actual: SPATIAL = no
{w_{i-2} = qualified, w_{i-1} = scouts, w_{i+1} = around, w_{i+2} = </s>}

Clausal segment: *Morgan hesitated*
Classified: SPATIAL = yes
Actual: SPATIAL = no
{w_{i-2} = <s>, w_{i-1} = Morgan, w_{i+1} = </s>, w_{i+2} = </s>}

Clausal segment: *she stared*
Classified: SPATIAL = no
Actual: SPATIAL = no
{w_{i-2} = <s>, w_{i-1} = she, w_{i+1} = </s>, w_{i+2} = </s>}

Clausal segment: *Clayton lifted him*
Classified: SPATIAL = no
Actual: SPATIAL = yes
{w_{i-2} = <s>, w_{i-1} = Clayton, w_{i+1} = him, w_{i+2} = </s>}

A.2 Results from Annotation-Dependent Feature-Based Model

Clausal segment: *he looked at his son*
Classified: SPATIAL = no
Actual: SPATIAL = no

look =
- ARGSTR =
  - Arg1 = human
  - Arg2 = human
- QUALIA =
  - Formal = other
  - Telic = nil
  - Agentive = other

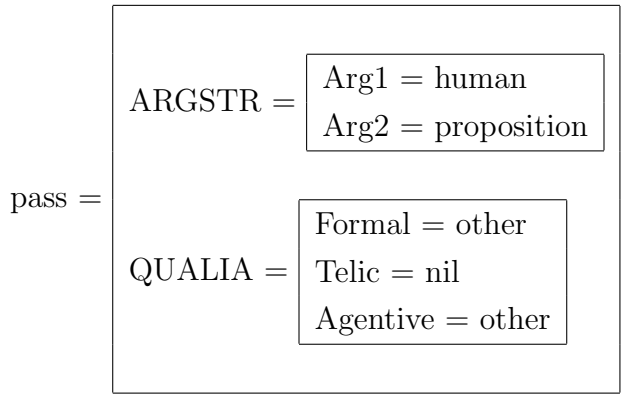
"he$_{S}$ *looked* at his son$_{IO}$"

Clausal segment: *they had passed through the barbed wire*
Classified: SPATIAL = no
Actual: SPATIAL = yes

pass =
- ARGSTR =
  - Arg1 = human
  - Arg2 = physical_object
- QUALIA =
  - Formal = spatially_altered
  - Telic = "through"
  - Agentive = axial_traversal

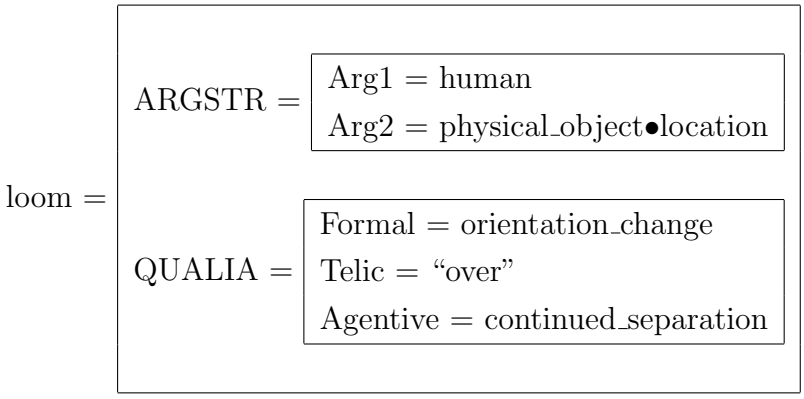
"they$_{S}$ *had passed* through the barbed wire$_{IO}$"

Clausal segment: *he made the decision*
Classified: SPATIAL = no
Actual: SPATIAL = no



"$\underline{\text{he}}_{\text{S}}$ *made* $\underline{\text{the decision}}_{\text{DO}}$"

Clausal segment: *before Payne loomed the Old Clubhouse*
Classified: SPATIAL = yes
Actual: SPATIAL = yes



"before $\underline{\text{Payne}}_{\text{IO}}$ *loomed* $\underline{\text{the Old Clubhouse}}_{\text{S}}$"

Clausal segment: *he went for the bed*
Classified: SPATIAL = no
Actual: SPATIAL = no

go = [ARGSTR = [Arg1 = human
Arg2 = location•artifact•physical_object]
QUALIA = [Formal = spatially_altered
Telic = "for"
Agentive = motion_initiation]]

"$\underline{\text{he}}_{\text{S}}$ *went* for $\underline{\text{the bed}}_{\text{IO}}$"

Clausal segment: *he came to an open field*
Classified: SPATIAL = no
Actual: SPATIAL = no

come = [ARGSTR = [Arg1 = human
Arg2 = location]
QUALIA = [Formal = spatially_altered
Telic = "to"
Agentive = motion_cessation]]

"$\underline{\text{he}}_{\text{S}}$ *came* to $\underline{\text{an open field}}_{\text{IO}}$"

Clausal segment: *he was still falling*
Classified: SPATIAL = yes
Actual: SPATIAL = yes

$$\text{fall} = \left[\begin{array}{ll} \text{ARGSTR} = & \boxed{\text{Arg1} = \text{human}} \\ \text{QUALIA} = & \boxed{\begin{array}{l}\text{Formal} = \text{spatially\_altered} \\ \text{Telic} = \text{“down”} \\ \text{Agentive} = \text{motion\_initiation}\end{array}} \end{array}\right]$$

“$\underline{\text{he}}_{\text{S}}$ *was still falling*”

Clausal segment: *the skies grew dark*
Classified: SPATIAL = no
Actual: SPATIAL = no

$$\text{grow} = \left[\begin{array}{ll} \text{ARGSTR} = & \boxed{\text{Arg1} = \text{location}} \\ \text{QUALIA} = & \boxed{\begin{array}{l}\text{Formal} = \text{other} \\ \text{Telic} = \text{nil} \\ \text{Agentive} = \text{other}\end{array}} \end{array}\right]$$

“$\underline{\text{the skies}}_{\text{S}}$ *grew* dark”

Clausal segment: *his thoughts turned to other things*
Classified: SPATIAL = no
Actual: SPATIAL = no

$$\text{turn} = \left[\begin{array}{l} \text{ARGSTR} = \left[\begin{array}{l}\text{Arg1} = \text{abstract}\\ \text{Arg2} = \text{abstract}\end{array}\right] \\ \\ \text{QUALIA} = \left[\begin{array}{l}\text{Formal} = \text{acquired\_attitude}\\ \text{Telic} = \text{nil}\\ \text{Agentive} = \text{other}\end{array}\right] \end{array}\right]$$

"his thoughts$_{\text{S}}$ *turned* to other things$_{\text{IO}}$"

Clausal segment: *he turned to the window*
Classified: SPATIAL = yes
Actual: SPATIAL = yes

$$\text{turn} = \left[\begin{array}{l} \text{ARGSTR} = \left[\begin{array}{l}\text{Arg1} = \text{human}\\ \text{Arg2} = \text{location}\bullet\text{physical\_object}\end{array}\right] \\ \\ \text{QUALIA} = \left[\begin{array}{l}\text{Formal} = \text{orientation\_change}\\ \text{Telic} = \text{"toward"}\\ \text{Agentive} = \text{motion\_cessation}\end{array}\right] \end{array}\right]$$

"he$_{\text{S}}$ *turned* to the window$_{\text{IO}}$"

Clausal segment: *the log was still spinning*
Classified: SPATIAL = yes
Actual: SPATIAL = yes

$$\text{turn} = \left[\begin{array}{l} \text{ARGSTR} = \left[\text{Arg1} = \text{physical\_object}\bullet\text{organic}\right] \\ \text{QUALIA} = \left[\begin{array}{l}\text{Formal} = \text{orientation\_change} \\ \text{Telic} = \text{“around”} \\ \text{Agentive} = \text{motion\_repetition}\end{array}\right] \end{array}\right]$$

“the log$_{\text{S}}$ *was still spinning*”

Clausal segment: *John entered the vast church*
Classified: SPATIAL = yes
Actual: SPATIAL = yes

$$\text{enter} = \left[\begin{array}{l} \text{ARGSTR} = \left[\begin{array}{l}\text{Arg1} = \text{human} \\ \text{Arg2} = \text{location}\bullet\text{physical\_object}\end{array}\right] \\ \text{QUALIA} = \left[\begin{array}{l}\text{Formal} = \text{container\_containee} \\ \text{Telic} = \text{“in”} \\ \text{Agentive} = \text{spatial\_overlap}\end{array}\right] \end{array}\right]$$

“John$_{\text{S}}$ *entered* the vast church$_{\text{DO}}$”

Clausal segment: *John lifted his hand*
Classified: SPATIAL = yes
Actual: SPATIAL = yes

$$\text{lift} = \left[\begin{array}{l} \text{ARGSTR} = \left[\begin{array}{l}\text{Arg1} = \text{human}\\ \text{Arg2} = \text{organic}\end{array}\right] \\ \text{QUALIA} = \left[\begin{array}{l}\text{Formal} = \text{spatially\_altered}\\ \text{Telic} = \text{“up”}\\ \text{Agentive} = \text{motion\_initiation}\end{array}\right] \end{array}\right]$$

“$\underline{\text{John}}_{\text{S}}$ *lifted* $\underline{\text{his hand}}_{\text{DO}}$”

Clausal segment: *Adam looked at the pot*
Classified: SPATIAL = no
Actual: SPATIAL = no

$$\text{look} = \left[\begin{array}{l} \text{ARGSTR} = \left[\begin{array}{l}\text{Arg1} = \text{human}\\ \text{Arg2} = \text{physical\_object}\end{array}\right] \\ \text{QUALIA} = \left[\begin{array}{l}\text{Formal} = \text{other}\\ \text{Telic} = \text{nil}\\ \text{Agentive} = \text{other}\end{array}\right] \end{array}\right]$$

“$\underline{\text{Adam}}_{\text{S}}$ *looked* at $\underline{\text{the pot}}_{\text{IO}}$”

Clausal segment: *the concierge called out to them*
Classified: SPATIAL = no
Actual: SPATIAL = no

$$\text{call} = \left[\begin{array}{l} \text{ARGSTR} = \left[\begin{array}{l}\text{Arg1} = \text{human}\\ \text{Arg2} = \text{human}\end{array}\right] \\ \\ \text{QUALIA} = \left[\begin{array}{l}\text{Formal} = \text{giver\_taker}\\ \text{Telic} = \text{“to”}\\ \text{Agentive} = \text{transaction}\end{array}\right] \end{array}\right]$$

“$\underline{\text{the concierge}}_{\text{S}}$ *called* out to $\underline{\text{them}}_{\text{IO}}$”

Clausal segment: *Galli arrived*
Classified: SPATIAL = yes
Actual: SPATIAL = yes

$$\text{arrive} = \left[\begin{array}{l} \text{ARGSTR} = \left[\begin{array}{l}\text{Arg1} = \text{human}\end{array}\right] \\ \\ \text{QUALIA} = \left[\begin{array}{l}\text{Formal} = \text{spatially\_proximal}\\ \text{Telic} = \text{“at”}\\ \text{Agentive} = \text{spatial\_overlap}\end{array}\right] \end{array}\right]$$

“$\underline{\text{Galli}}_{\text{S}}$ *arrived*”

Clausal segment: *his watch told him he was still early*
Classified: SPATIAL = no
Actual: SPATIAL = no

$$\text{tell} = \left[\begin{array}{l} \text{ARGSTR} = \left[\begin{array}{l} \text{Arg1} = \text{artifact}\bullet\text{physical\_object} \\ \text{Arg2} = \text{information} \end{array}\right] \\ \\ \text{QUALIA} = \left[\begin{array}{l} \text{Formal} = \text{giver\_given} \\ \text{Telic} = \text{nil} \\ \text{Agentive} = \text{transaction} \end{array}\right] \end{array}\right]$$

"his watch$_{\text{S}}$ *told* him he was still early$_{\text{DO}}$"

Clausal segment: *he can make you work papers*
Classified: SPATIAL = no
Actual: SPATIAL = no

$$\text{make} = \left[\begin{array}{l} \text{ARGSTR} = \left[\begin{array}{l} \text{Arg1} = \text{human} \\ \text{Arg2} = \text{physical\_object}\bullet\text{information} \end{array}\right] \\ \\ \text{QUALIA} = \left[\begin{array}{l} \text{Formal} = \text{taker\_taken} \\ \text{Telic} = \text{"for"} \\ \text{Agentive} = \text{transaction} \end{array}\right] \end{array}\right]$$

"he *can make* you$_{\text{IO}}$ work papers$_{\text{DO}}$"

Clausal segment: *he slept*
Classified: SPATIAL = no
Actual: SPATIAL = no

$$\text{sleep} = \left[\begin{array}{l} \text{ARGSTR} = \boxed{\text{Arg1} = \text{human}} \\ \\ \text{QUALIA} = \boxed{\begin{array}{l} \text{Formal} = \text{other} \\ \text{Telic} = \text{nil} \\ \text{Agentive} = \text{other} \end{array}} \end{array}\right]$$

"$\underline{\text{he}}_{\text{S}}$ *slept*"

Clausal segment: *he rose*
Classified: SPATIAL = yes
Actual: SPATIAL = yes

$$\text{rise} = \left[\begin{array}{l} \text{ARGSTR} = \boxed{\text{Arg1} = \text{human}} \\ \\ \text{QUALIA} = \boxed{\begin{array}{l} \text{Formal} = \text{orientation\_change} \\ \text{Telic} = \text{"up"} \\ \text{Agentive} = \text{motion\_initiation} \end{array}} \end{array}\right]$$

"$\underline{\text{he}}_{\text{S}}$ *rose*"

Clausal segment: *Hillman had ordered him not to leave the far bank*
Classified: SPATIAL = no
Actual: SPATIAL = no

$$\text{order} = \left[\begin{array}{l} \text{ARGSTR} = \left[\begin{array}{l} \text{Arg1} = \text{human} \\ \text{Arg2} = \text{human} \end{array}\right] \\ \text{QUALIA} = \left[\begin{array}{l} \text{Formal} = \text{giver\_taker} \\ \text{Telic} = \text{“to”} \\ \text{Agentive} = \text{transaction} \end{array}\right] \end{array}\right]$$

“$\underline{\text{Hillman}}_{\text{S}}$ *had ordered* $\underline{\text{him}}_{\text{DO}}$ not to leave the far bank”

Clausal segment: *he reached down*
Classified: SPATIAL = yes
Actual: SPATIAL = no

$$\text{reach} = \left[\begin{array}{l} \text{ARGSTR} = \left[\begin{array}{l} \text{Arg1} = \text{human} \end{array}\right] \\ \text{QUALIA} = \left[\begin{array}{l} \text{Formal} = \text{spatially\_altered} \\ \text{Telic} = \text{“down”} \\ \text{Agentive} = \text{motion\_cessation} \end{array}\right] \end{array}\right]$$

“$\underline{\text{he}}_{\text{S}}$ *reached* down”

Clausal segment: *he had not felt that*
Classified: SPATIAL = no
Actual: SPATIAL = no

$$\text{feel} = \left[\begin{array}{l} \text{ARGSTR} = \left[\begin{array}{l}\text{Arg1} = \text{human}\\ \text{Arg2} = \text{abstract}\end{array}\right] \\ \text{QUALIA} = \left[\begin{array}{l}\text{Formal} = \text{other}\\ \text{Telic} = \text{nil}\\ \text{Agentive} = \text{other}\end{array}\right] \end{array}\right]$$

"$\underline{\text{he}}_{\text{S}}$ *had not felt* $\underline{\text{that}}_{\text{DO}}$"

Clausal segment: *he enjoyed it*
Classified: SPATIAL = no
Actual: SPATIAL = no

$$\text{enjoy} = \left[\begin{array}{l} \text{ARGSTR} = \left[\begin{array}{l}\text{Arg1} = \text{human}\\ \text{Arg2} = \text{event}\end{array}\right] \\ \text{QUALIA} = \left[\begin{array}{l}\text{Formal} = \text{other}\\ \text{Telic} = \text{nil}\\ \text{Agentive} = \text{other}\end{array}\right] \end{array}\right]$$

"$\underline{\text{he}}_{\text{S}}$ *enjoyed* $\underline{\text{it}}_{\text{DO}}$"

Clausal segment: *she looked mighty interested*
Classified: SPATIAL = no
Actual: SPATIAL = no

look = [ARGSTR = [Arg1 = human]
QUALIA = [Formal = other
Telic = nil
Agentive = other]]

"$\underline{\text{she}}_{\text{S}}$ *looked* mighty interested"

Clausal segment: *he hurried to the living room*
Classified: SPATIAL = no
Actual: SPATIAL = no

hurry = [ARGSTR = [Arg1 = human
Arg2 = location]
QUALIA = [Formal = spatially_altered
Telic = "to"
Agentive = motion_initiation]]

"$\underline{\text{he}}_{\text{S}}$ *hurried* to $\underline{\text{the living room}}_{\text{IO}}$"

Clausal segment: *I never want to see her again*
Classified: SPATIAL = no
Actual: SPATIAL = no

$$\text{enjoy} = \left[\begin{array}{l} \text{ARGSTR} = \left[\begin{array}{l}\text{Arg1 = human}\\ \text{Arg2 = human}\end{array}\right] \\ \\ \text{QUALIA} = \left[\begin{array}{l}\text{Formal = other}\\ \text{Telic = nil}\\ \text{Agentive = other}\end{array}\right] \end{array}\right]$$

"$\underline{\text{I}}_{\text{S}}$ *never want to see* $\underline{\text{her}}_{\text{DO}}$ again"

Clausal segment: *Roberta and Dave began to back toward the door*
Classified: SPATIAL = yes
Actual: SPATIAL = yes

$$\text{enjoy} = \left[\begin{array}{l} \text{ARGSTR} = \left[\begin{array}{l}\text{Arg1 = human}\\ \text{Arg2 = location•physical\_object}\end{array}\right] \\ \\ \text{QUALIA} = \left[\begin{array}{l}\text{Formal = orientation\_change}\\ \text{Telic = "toward"}\\ \text{Agentive = motion\_initiation}\end{array}\right] \end{array}\right]$$

"$\underline{\text{Roberta and Dave}}_{\text{S}}$ *began to back* toward $\underline{\text{the door}}_{\text{IO}}$"

Clausal segment: *she pushed it back*
Classified: SPATIAL = yes
Actual: SPATIAL = yes

$$\text{push} = \left[\begin{array}{l} \text{ARGSTR} = \left[\begin{array}{l} \text{Arg1} = \text{human} \\ \text{Arg2} = \text{location} \bullet \text{physical\_object} \end{array}\right] \\ \text{QUALIA} = \left[\begin{array}{l} \text{Formal} = \text{spatially\_proximal} \\ \text{Telic} = \text{“back”} \\ \text{Agentive} = \text{motion\_initiation} \end{array}\right] \end{array}\right]$$

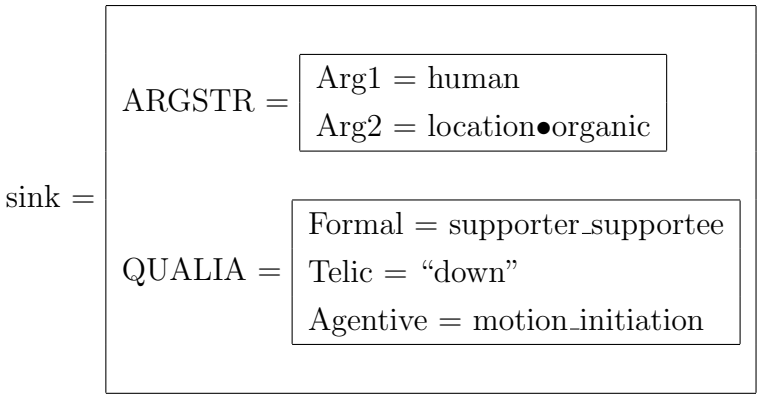
“$\underline{\text{she}}_{\text{S}}$ *pushed* $\underline{\text{it}}_{\text{IO}}$ back”

Clausal segment: *he looked straight at Marty*
Classified: SPATIAL = no
Actual: SPATIAL = no

$$\text{look} = \left[\begin{array}{l} \text{ARGSTR} = \left[\begin{array}{l} \text{Arg1} = \text{human} \\ \text{Arg2} = \text{human} \end{array}\right] \\ \text{QUALIA} = \left[\begin{array}{l} \text{Formal} = \text{other} \\ \text{Telic} = \text{nil} \\ \text{Agentive} = \text{other} \end{array}\right] \end{array}\right]$$

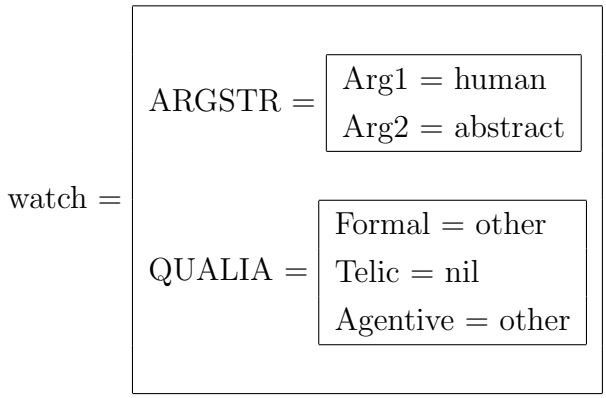
“$\underline{\text{he}}_{\text{S}}$ *looked* straight at $\underline{\text{Marty}}_{\text{IO}}$ back”

Clausal segment: *sank to his knees*
Classified: SPATIAL = yes
Actual: SPATIAL = yes



"[he]$_{\text{S}}$ *sank* to his knees$_{\text{IO}}$"

Clausal segment: *I was watching for numbers*
Classified: SPATIAL = no
Actual: SPATIAL = no



"I$_{\text{S}}$ *was watching* for numbers$_{\text{IO}}$"

Clausal segment: *the fingers curled*
Classified: SPATIAL = yes
Actual: SPATIAL = yes

$$\text{curl} = \left[\begin{array}{l} \text{ARGSTR} = \left[\text{Arg1} = \text{organic}\right] \\ \\ \text{QUALIA} = \left[\begin{array}{l} \text{Formal} = \text{orientation\_change} \\ \text{Telic} = \text{“around”} \\ \text{Agentive} = \text{motion\_cessation} \end{array}\right] \end{array}\right]$$

“the fingers$_{\text{S}}$ *curled*”

Clausal segment: *he found the razor*
Classified: SPATIAL = no
Actual: SPATIAL = no

$$\text{find} = \left[\begin{array}{l} \text{ARGSTR} = \left[\begin{array}{l} \text{Arg1} = \text{human} \\ \text{Arg2} = \text{physical\_object•artifact} \end{array}\right] \\ \\ \text{QUALIA} = \left[\begin{array}{l} \text{Formal} = \text{taker\_taken} \\ \text{Telic} = \text{nil} \\ \text{Agentive} = \text{other} \end{array}\right] \end{array}\right]$$

“he$_{\text{S}}$ *found* the razor$_{\text{DO}}$”

Clausal segment: *the body lay*
Classified: SPATIAL = yes
Actual: SPATIAL = yes

$$\text{find} = \left[\begin{array}{l} \text{ARGSTR} = \boxed{\text{Arg1} = \text{human}\bullet\text{organic}} \\ \\ \text{QUALIA} = \boxed{\begin{array}{l}\text{Formal} = \text{supporter\_supportee} \\ \text{Telic} = \text{“on”} \\ \text{Agentive} = \text{support}\end{array}} \end{array}\right]$$

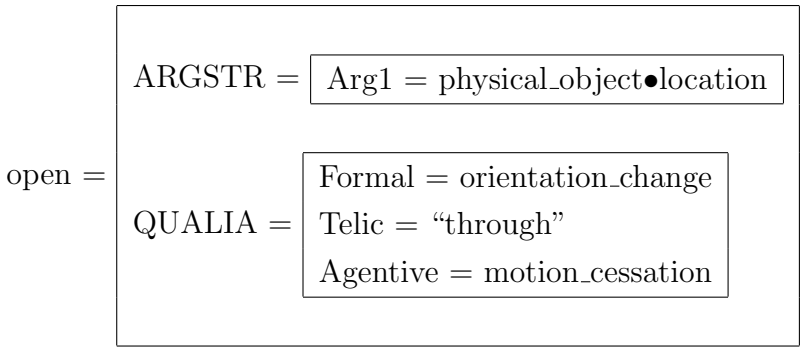
“the body$_{\text{S}}$ *lay*”

Clausal segment: *he put in a call to Cunningham*
Classified: SPATIAL = no
Actual: SPATIAL = no

$$\text{put} = \left[\begin{array}{l} \text{ARGSTR} = \boxed{\begin{array}{l}\text{Arg1} = \text{human} \\ \text{Arg2} = \text{human}\end{array}} \\ \\ \text{QUALIA} = \boxed{\begin{array}{l}\text{Formal} = \text{giver\_taker} \\ \text{Telic} = \text{“to”} \\ \text{Agentive} = \text{transaction}\end{array}} \end{array}\right]$$

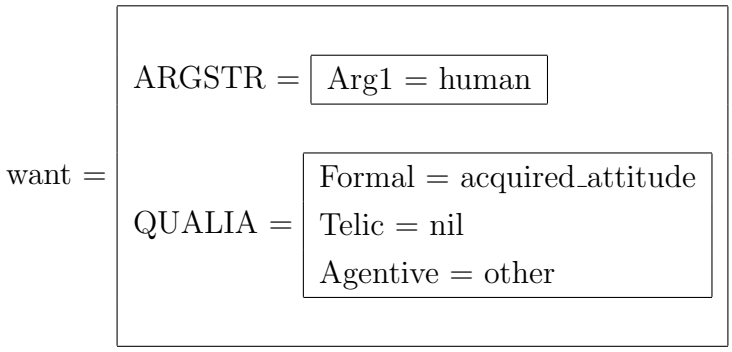
“he$_{\text{S}}$ *put* in a call to Cunningham$_{\text{IO}}$”

Clausal segment: *it won't open*
Classified: SPATIAL = yes
Actual: SPATIAL = yes



"$\underline{\text{it}}_{\text{S}}$ *won't open*"

Clausal segment: *she wanted much*
Classified: SPATIAL = no
Actual: SPATIAL = no



"$\underline{\text{she}}_{\text{S}}$ *wanted* much"

Clausal segment: *Rilly or Glendora had entered her room*
Classified: SPATIAL = yes
Actual: SPATIAL = yes

$$\text{enter} = \left[\begin{array}{l} \text{ARGSTR} = \left[\begin{array}{l}\text{Arg1} = \text{human}\\ \text{Arg2} = \text{location}\end{array}\right] \\ \\ \text{QUALIA} = \left[\begin{array}{l}\text{Formal} = \text{container\_containee}\\ \text{Telic} = \text{“in”}\\ \text{Agentive} = \text{spatial\_overlap}\end{array}\right] \end{array}\right]$$

“Rilly or Glendora$_{\text{S}}$ *had entered* her room$_{\text{DO}}$”

Clausal segment: *she told anyone of the opium*
Classified: SPATIAL = no
Actual: SPATIAL = no

$$\text{tell} = \left[\begin{array}{l} \text{ARGSTR} = \left[\begin{array}{l}\text{Arg1} = \text{human}\\ \text{Arg2} = \text{information}\end{array}\right] \\ \\ \text{QUALIA} = \left[\begin{array}{l}\text{Formal} = \text{taker\_taken}\\ \text{Telic} = \text{“to”}\\ \text{Agentive} = \text{transaction}\end{array}\right] \end{array}\right]$$

“she *told* anyone$_{\text{IO}}$ of the opium$_{\text{DO}}$”

Clausal segment: *he crossed the lobby*
Classified: SPATIAL = yes
Actual: SPATIAL = yes

$$\text{cross} = \left[\begin{array}{l} \text{ARGSTR} = \left[\begin{array}{l}\text{Arg1} = \text{human}\\ \text{Arg2} = \text{location}\end{array}\right] \\ \\ \text{QUALIA} = \left[\begin{array}{l}\text{Formal} = \text{spatially\_altered}\\ \text{Telic} = \text{“across”}\\ \text{Agentive} = \text{axial\_traversal}\end{array}\right] \end{array}\right]$$

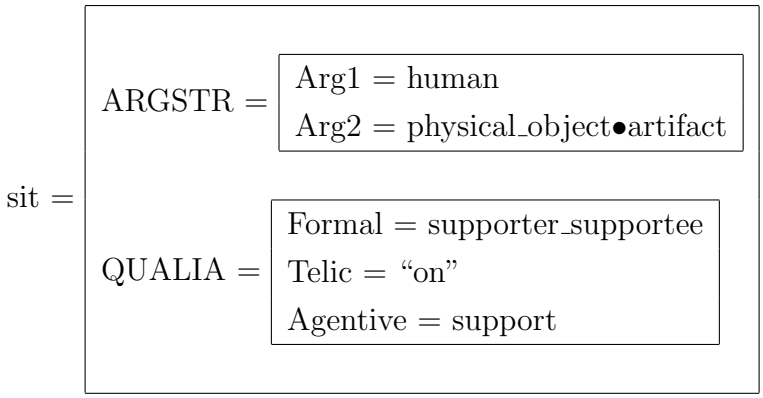
“$\underline{\text{he}}_{\text{S}}$ *crossed* $\underline{\text{the lobby}}_{\text{DO}}$”

Clausal segment: *he hadn't come back*
Classified: SPATIAL = no
Actual: SPATIAL = no

$$\text{come} = \left[\begin{array}{l} \text{ARGSTR} = \left[\begin{array}{l}\text{Arg1} = \text{human}\end{array}\right] \\ \\ \text{QUALIA} = \left[\begin{array}{l}\text{Formal} = \text{spatially\_altered}\\ \text{Telic} = \text{“back”}\\ \text{Agentive} = \text{motion\_cessation}\end{array}\right] \end{array}\right]$$

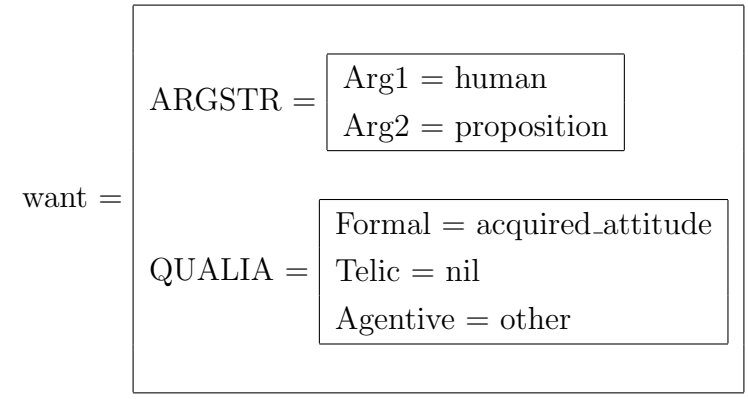
“$\underline{\text{he}}_{\text{S}}$ *hadn't come* back”

Clausal segment: *Hub was sitting in a chair*
Classified: SPATIAL = yes
Actual: SPATIAL = yes



"Hub$_{\text{S}}$ *was sitting* in a chair$_{\text{IO}}$"

Clausal segment: *he wants to ask you some questions*
Classified: SPATIAL = no
Actual: SPATIAL = no



"he$_{\text{S}}$ *wants* to ask you some questions$_{\text{DO}}$"

Clausal segment: *opened it*
Classified: SPATIAL = yes
Actual: SPATIAL = yes

$$\text{open} = \left[\begin{array}{l} \text{ARGSTR} = \left[\begin{array}{l} \text{Arg1} = \text{human} \\ \text{Arg2} = \text{physical\_object} \bullet \text{location} \end{array}\right] \\ \\ \text{QUALIA} = \left[\begin{array}{l} \text{Formal} = \text{orientation\_change} \\ \text{Telic} = \text{“through”} \\ \text{Agentive} = \text{motion\_cessation} \end{array}\right] \end{array}\right]$$

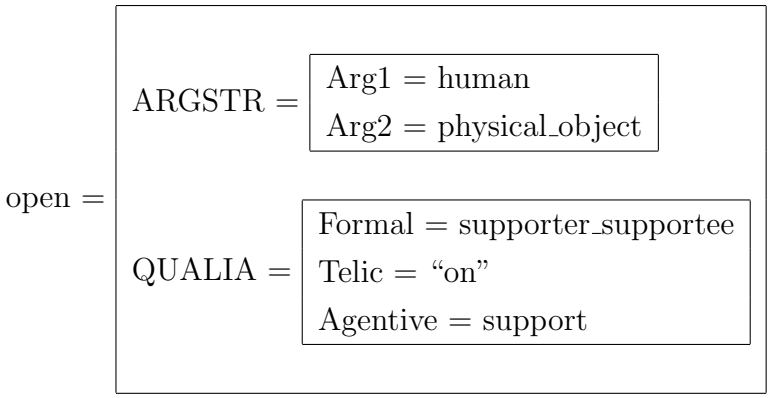
“[he]$_{\text{S}}$ *opened* it$_{\text{DO}}$”

Clausal segment: *a newspaper open at stock-market reports lay on one of them*
Classified: SPATIAL = yes
Actual: SPATIAL = yes

$$\text{lie} = \left[\begin{array}{l} \text{ARGSTR} = \left[\begin{array}{l} \text{Arg1} = \text{physical\_object} \\ \text{Arg2} = \text{physical\_object} \end{array}\right] \\ \\ \text{QUALIA} = \left[\begin{array}{l} \text{Formal} = \text{supporter\_supportee} \\ \text{Telic} = \text{“on”} \\ \text{Agentive} = \text{support} \end{array}\right] \end{array}\right]$$

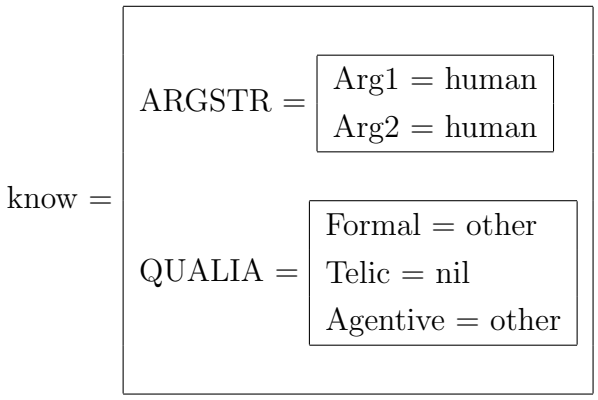
“a newspaper open at stock-market reports$_{\text{S}}$ *lay* on one of them$_{\text{IO}}$”

Clausal segment: *he climbed the steps*
Classified: SPATIAL = yes
Actual: SPATIAL = yes



"he$_{\text{S}}$ *climbed* the steps$_{\text{DO}}$"

Clausal segment: *you don't know me*
Classified: SPATIAL = no
Actual: SPATIAL = no



"you$_{\text{S}}$ *don't know* me$_{\text{DO}}$"

Clausal segment: *they rolled*
Classified: SPATIAL = yes
Actual: SPATIAL = yes

roll = [ARGSTR = [Arg1 = physical_object]
QUALIA = [Formal = orientation_change
Telic = "around"
Agentive = motion_repetition]

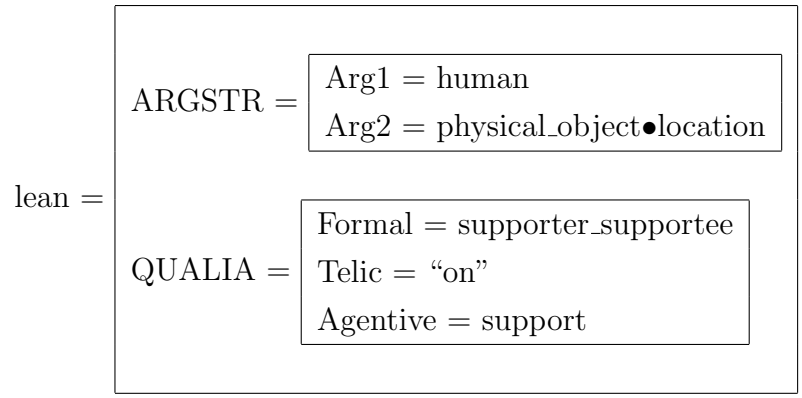
"they$_S$ *rolled*"

Clausal segment: *I dropped into the doctor's office*
Classified: SPATIAL = yes
Actual: SPATIAL = no

drop = [ARGSTR = [Arg1 = human
Arg2 = location•organization]
QUALIA = [Formal = container_containee
Telic = "into"
Agentive = motion_initiation]

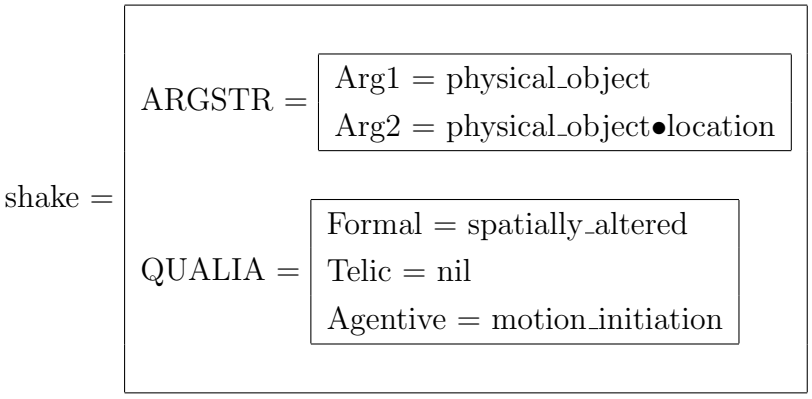
"I$_S$ *dropped* into the doctor's office$_{IO}$"

Clausal segment: *Alec leaned on the desk*
Classified: SPATIAL = yes
Actual: SPATIAL = yes



"Alec$_{\text{S}}$ *leaned* on the desk$_{\text{IO}}$"

Clausal segment: *something heavy shook the floor*
Classified: SPATIAL = no
Actual: SPATIAL = no



"something heavy$_{\text{S}}$ *shook* the floor$_{\text{DO}}$"

Clausal segment: *I'd told them a lot of it*
Classified: SPATIAL = no
Actual: SPATIAL = no

$$\text{tell} = \left[\begin{array}{l} \text{ARGSTR} = \left[\begin{array}{l}\text{Arg1} = \text{human}\\ \text{Arg2} = \text{human}\end{array}\right] \\ \\ \text{QUALIA} = \left[\begin{array}{l}\text{Formal} = \text{giver\_taker}\\ \text{Telic} = \text{“to”}\\ \text{Agentive} = \text{transaction}\end{array}\right] \end{array}\right]$$

“$\underline{\text{I}}_{\text{S}}$’d *told* $\underline{\text{them}}_{\text{DO}}$ a lot of it”

Clausal segment: *he went back to work*
Classified: SPATIAL = no
Actual: SPATIAL = no

$$\text{go} = \left[\begin{array}{l} \text{ARGSTR} = \left[\begin{array}{l}\text{Arg1} = \text{human}\\ \text{Arg2} = \text{human}\end{array}\right] \\ \\ \text{QUALIA} = \left[\begin{array}{l}\text{Formal} = \text{organization\_member}\\ \text{Telic} = \text{“in”}\\ \text{Agentive} = \text{joining}\end{array}\right] \end{array}\right]$$

“$\underline{\text{he}}_{\text{S}}$ *went* back to $\underline{\text{work}}_{\text{IO}}$”

Clausal segment: *we'll never know which*
Classified: SPATIAL = no
Actual: SPATIAL = no

$$\text{know} = \left[\begin{array}{l} \text{ARGSTR} = \left[\begin{array}{l}\text{Arg1} = \text{human}\\ \text{Arg2} = \text{unknown}\end{array}\right] \\ \text{QUALIA} = \left[\begin{array}{l}\text{Formal} = \text{other}\\ \text{Telic} = \text{nil}\\ \text{Agentive} = \text{other}\end{array}\right] \end{array}\right]$$

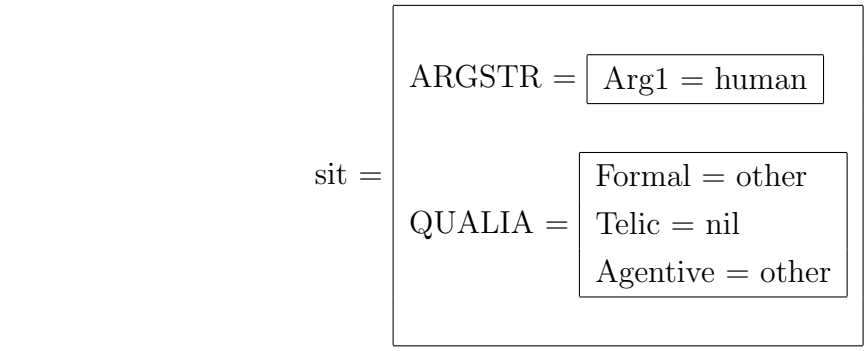
"$\underline{\text{we}}_{\text{S}}$'ll *never know* $\underline{\text{which}}_{\text{DO}}$"

Clausal segment: *he had lost his audience*
Classified: SPATIAL = no
Actual: SPATIAL = no

$$\text{lose} = \left[\begin{array}{l} \text{ARGSTR} = \left[\begin{array}{l}\text{Arg1} = \text{human}\\ \text{Arg2} = \text{human}\end{array}\right] \\ \text{QUALIA} = \left[\begin{array}{l}\text{Formal} = \text{acquired\_attitude}\\ \text{Telic} = \text{nil}\\ \text{Agentive} = \text{other}\end{array}\right] \end{array}\right]$$

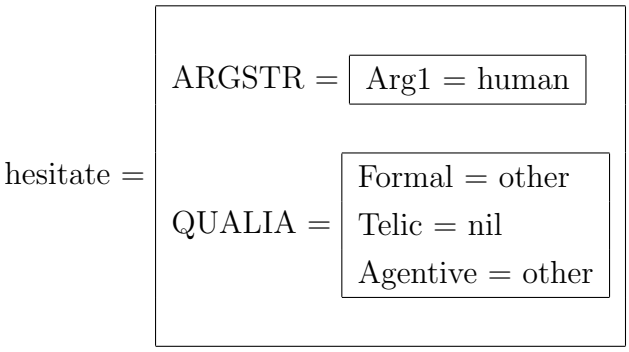
"$\underline{\text{he}}_{\text{S}}$ *had lost* $\underline{\text{his audience}}_{\text{DO}}$"

Clausal segment: *there were nine qualified scouts sitting around*
Classified: SPATIAL = no
Actual: SPATIAL = no



"there were nine qualified scouts$_S$ *sitting* around"

Clausal segment: *Morgan hesitated*
Classified: SPATIAL = no
Actual: SPATIAL = no



"Morgan$_S$ *hesitated*"

Clausal segment: *she stared*
Classified: SPATIAL = no
Actual: SPATIAL = no

$$\text{stare} = \left[\begin{array}{l} \text{ARGSTR} = \boxed{\text{Arg1} = \text{human}} \\ \\ \text{QUALIA} = \boxed{\begin{array}{l}\text{Formal} = \text{other} \\ \text{Telic} = \text{nil} \\ \text{Agentive} = \text{other}\end{array}} \end{array}\right]$$

"$\underline{\text{she}}_{\text{S}}$ *stared*"

Clausal segment: *Clayton lifted him*
Classified: SPATIAL = yes
Actual: SPATIAL = yes

$$\text{lift} = \left[\begin{array}{l} \text{ARGSTR} = \boxed{\begin{array}{l}\text{Arg1} = \text{human} \\ \text{Arg2} = \text{human}\end{array}} \\ \\ \text{QUALIA} = \boxed{\begin{array}{l}\text{Formal} = \text{supporter\_supportee} \\ \text{Telic} = \text{"up"} \\ \text{Agentive} = \text{support}\end{array}} \end{array}\right]$$

"$\underline{\text{Clayton}}_{\text{S}}$ *lifted* $\underline{\text{him}}_{\text{DO}}$"

B Clustering Results

B.1 Results with Six Means

Cluster 0

loom =

Formal = orientation_change
Agentive = continued_separation
Has telic
Telic = "over"
Subject = human
Indirect object = human

fall =

Formal = spatially_altered
Agentive = motion_initiation
Has telic
Telic = "down"
Subject = human

open =

Formal = orientation_change
Agentive = motion_cessation
Has telic
Telic = "through"
Subject = human
Direct object = location
Direct object = physical_object
Transitive

Cluster average Lin similarity according to WordNet: 0.243478644721

Cluster 1

turn =

Formal = orientation_change
Agentive = motion_cessation
Has telic
Telic = “toward”
Dynamic
Subject = human
Indirect object = location
Indirect object = physical_object
Transitive

spin =

Formal = orientation_change
Agentive = motion_cessation
Has telic
Telic = “around”
Dynamic
Subject = organic

lift =

Formal = spatially_altered
Agentive = motion_initiation
Has telic
Telic = “up”
Dynamic
Subject = human
Direct object = organic
Transitive

rise =

Formal = orientation_change
Agentive = motion_initiation
Has telic
Telic = “up”
Dynamic
Subject = human

back =

Formal = orientation_change
Agentive = motion_initiation
Has telic
Telic = “toward”
Subject = human
Indirect object = location
Indirect object = physical_object

curl =

Formal = orientation_change
Agentive = motion_initiation
Has telic
Telic = “around”
Dynamic
Subject = organic

Cluster average Lin similarity according to WordNet: 0.398089317372

Cluster 2

enter =

Formal = container_containee
Agentive = spatial_overlap
Has telic
Telic = “in”
Dynamic
Subject = human
Direct object = location
Transitive

enter =

Formal = container_containee
Agentive = spatial_overlap
Has telic
Telic = “in”
Dynamic
Subject = human
Direct object = location
Transitive

Cluster average Lin similarity according to WordNet: 1.0

Cluster 3

arrive =

Formal = spatially_proximal
Agentive = spatial_overlap
Has telic
Telic = “at”
Dynamic
Subject = human

sink =

Formal = supporter_supportee
Agentive = support
Has telic
Telic = “down”
Dynamic
Subject = human
Indirect object = location
Indirect object = organic

roll =

Formal = orientation_change
Agentive = motion_repetition
Has telic
Telic = “around”
Dynamic
Subject = human

lift =

Formal = supporter_supportee
Agentive = support
Has telic
Telic = “up”
Dynamic
Subject = human
Direct object = human
Transitive

Cluster average Lin similarity according to WordNet: 0.218120750636

Cluster 4

push =

Formal = spatially_proximal
Agentive = motion_initiation
Has telic
Telic = "back"
Subject = human
Direct object = location
Direct object = physical_object
Transitive

open =

Formal = orientation_change
Agentive = motion_cessation
Has telic
Telic = "through"
Dynamic
Subject = location
Subject = physical_object

cross =

Formal = spatially_altered
Agentive = axial_traversal
Has telic
Telic = "across"
Dynamic
Subject = human
Direct object = location

Cluster average Lin similarity according to WordNet: 0.225807290657

Cluster 5

lie =

Formal = supporter_supportee
Agentive = support
Has telic
Telic = “on”
Subject = human
Subject = organic

sit =

Formal = supporter_supportee
Agentive = support
Has telic
Telic = “on”
Subject = human
Indirect object = physical_object
Indirect object = artifact

lie =

Formal = supporter_supportee
Agentive = support
Has telic
Telic = “on”
Subject = physical_object
Indirect object = physical_object

climb =

Formal = supporter_supportee
Agentive = support
Has telic
Telic = “on”
Dynamic
Subject = human
Indirect object = physical_object
Transitive

lean =

Formal = supporter_supportee
Agentive = support
Has telic
Telic = “on”
Subject = human
Indirect object = location
Indirect object = physical_object

Cluster average Lin similarity according to WordNet: 0.535374188807

B.2 Results with Eight Means

Cluster 0

loom =

Formal = orientation_change
Agentive = continued_separation
Has telic
Telic = "over"
Subject = human
Indirect object = human

fall =

Formal = spatially_altered
Agentive = motion_initiation
Has telic
Telic = "down"
Subject = human

open =

Formal = orientation_change
Agentive = motion_cessation
Has telic
Telic = "through"
Subject = human
Direct object = location
Direct object = physical_object
Transitive

Cluster average Lin similarity according to WordNet: 0.243478644721

Cluster 1

turn =

Formal = orientation_change
Agentive = motion_cessation
Has telic
Telic = “toward”
Dynamic
Subject = human
Indirect object = location
Indirect object = physical_object
Transitive

back =

Formal = orientation_change
Agentive = motion_initiation
Has telic
Telic = “toward”
Subject = human
Indirect object = location
Indirect object = physical_object

Cluster average Lin similarity according to WordNet: 0.356146885997

Cluster 2

spin =

Formal = orientation_change
Agentive = motion_cessation
Has telic
Telic = “around”
Dynamic
Subject = organic

curl =

Formal = orientation_change
Agentive = motion_initiation
Has telic
Telic = “around”
Dynamic
Subject = organic

Cluster average Lin similarity according to WordNet: 0.522447569517

Cluster 3

lift =

Formal = spatially_altered
Agentive = motion_initiation
Has telic
Telic = “up”
Dynamic
Subject = human
Direct object = organic
Transitive

rise =

Formal = orientation_change
Agentive = motion_initiation
Has telic
Telic = “up”
Dynamic
Subject = human

Cluster average Lin similarity according to WordNet: 1.0

Cluster 4

enter =

Formal = container_containee
Agentive = spatial_overlap
Has telic
Telic = “in”
Dynamic
Subject = human
Direct object = location
Transitive

sink =

Formal = supporter_supportee
Agentive = support
Has telic
Telic = “down”
Dynamic
Subject = human
Indirect object = location
Indirect object = organic

enter =

Formal = container_containee
Agentive = spatial_overlap
Has telic
Telic = “in”
Dynamic
Subject = human
Direct object = location
Transitive

roll =

Formal = orientation_change
Agentive = motion_repetition
Has telic
Telic = “around”
Dynamic
Subject = human

lift =

Formal = supporter_supportee
Agentive = support
Has telic
Telic = “up”
Dynamic
Subject = human
Direct object = human
Transtive

Cluster average Lin similarity according to WordNet: 0.447945675492

Cluster 5

push =

Formal = spatially_proximal
Agentive = motion_initiation
Has telic
Telic = “back”
Subject = human
Direct object = location
Direct object = physical_object
Transitive

open =

Formal = orientation_change
Agentive = motion_cessation
Has telic
Telic = “through”
Dynamic
Subject = location
Subject = physical_object

cross =

Formal = spatially_altered
Agentive = axial_traversal
Has telic
Telic = “across”
Dynamic
Subject = human
Direct object = location

Cluster average Lin similarity according to WordNet: 0.225807290657

Cluster 6

arrive =

Formal = spatially_proximal
Agentive = spatial_overlap
Has telic
Telic = “at”
Dynamic
Subject = human

lie =

Formal = supporter_supportee
Agentive = support
Has telic
Telic = “on”
Subject = human
Subject = organic

lean =

Formal = supporter_supportee
Agentive = support
Has telic
Telic = “on”
Subject = human
Indirect object = location
Indirect object = physical_object

Cluster average Lin similarity according to WordNet: 0.122977690018

Cluster 7

sit =

Formal = supporter_supportee
Agentive = support
Has telic
Telic = “on”
Subject = human
Indirect object = physical_object
Indirect object = artifact

lie =

Formal = supporter_supportee
Agentive = support
Has telic
Telic = “on”
Subject = physical_object
Indirect object = physical_object

climb =

Formal = supporter_supportee
Agentive = support
Has telic
Telic = “on”
Dynamic
Subject = human
Indirect object = physical_object
Transitive

Cluster average Lin similarity according to WordNet: 0.529161923452

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