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Subject animacy and underspecified meaning: The conceptual and cortical underpinnings

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ABSTRACT

We examine the distinction between animacy, a conceptual property, and agency, a conceptual and linguistic property involved in semantic role assignment. Are these two notions—agency and animacy—interchangeable in the mind/brain of the comprehender or are they distinct yet correlated? If the latter, does brain behavior show sensitivity to this distinction? Through a self-paced reading and an fMRI experiment we investigate the comprehension of sentences containing aspectual verbs (e.g., *begin, finish*) in composition with animate vs. inanimate-denoting subjects (e.g., *The noblewoman/prologue began the book*). Aspectual-verb sentences are ambiguous independently of subject denotation: whereas sentences with inanimate subjects engender a constitutive/subpart reading along one of multiple possible dimensions (e.g., the spatial vs. informational construal of the book), sentences with animate-denoting subjects can also engender a constitutive/subpart reading along one of several possible dimensions, *(The story about) the noblewoman began the book* (informational dimension), in addition to the *agentive* reading along the eventive dimension, *The noblewoman began (doing something with) the book*. So, both animate and inanimate subject-denotations can license the construal of the complement as a structured individual along mutually-exclusive conceptual dimensions (spatial, informational, eventive, etc.). During real-time comprehension such a situation calls for ambiguity resolution, and therefore computational cost, to settle on one interpretation. Therein lies the relevance of this construction: the final reading of the sentence depends on whether or not the subject can be interpreted as *agentive* independent of animacy. Results show that controlling for animacy, all aspectual-verb sentences (1) engender longer reading times, consistent with shared increased compositional cost and (2) exhibit overlapping cortical activity: left angular gyrus and left inferior frontal gyrus, consistent with the distinction between concept composition on the one hand, and ambiguity resolution processes on the other. This converging behavioral and neurological pattern thus suggests that sentence interpretation need not be determined by perception of animacy *per se* but by a more fundamental conceptual parameter that has, as by-product, agency but that more locally results from the control relationship between two participants of the situation denoted by the sentence. Finally, (3) sentences with animate-denoting subjects (> inanimate-subject counterparts) additionally recruited the posterior cortex; an activation pattern consistent with the construal of animate-denoting individuals as "default" controllers in the agentive reading. This suggests in turn a de-coupling of animacy and agency such that the former is an entity-level attribution that supports but does not determine an eventive interpretation, and the latter is the output of a control asymmetry evaluation in an eventive representation connecting two otherwise

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independent entities. Altogether, the findings are consistent with a neurocognitive model of sentence semantic comprehension whereby meaning construal and composition are carried out within a parametrized conceptual space that is only secondarily modulated by independent conceptual factors such as animacy.

1. Introduction

Even though a sentence's morpho-syntactic structure supports the way lexical meanings are combined, in many cases sentence meaning is lexically underspecified, yet must be obligatorily inferred by comprehenders for sentence comprehension to succeed. These cases of lexically underspecified meaning composition thus present an opportunity to observe the mechanisms of conceptual composition that are at least partly independent of the morphosyntax of the construction. That is the case of sentences with aspectual verbs (AspVs), such as *begin*, *continue*, and *finish*, in their transitive form. Specifically, this construction allows us to distinguish agency as a lexico-semantic property from animacy, the property of being "alive" as perceived/construed by comprehenders.

Composition of aspectual verbs with an entity-denoting complement like (1a) below can result in an interpretation like (1b) where the complement that can be interpreted as entity-denoting emerges instead as supporting an eventive interpretation.

(1) a. *The lady began the book.*
b. → The lady began [reading/writing/burning/restoring/etc.] the book.

In the interpretation (1b) the subject denotation (*the lady*) is construed as an initiator of some activity involving the complement denotation (*the book*) with the role of patient. We call this kind of interpretation the "**agentive reading**" of AspV sentences. Crucially, such an interpretation is presumably triggered by the animacy of the subject. While previous work has focused on this agentive reading for sentences with animate-denoting subjects (e.g., Katsika, Braze, Deo, & Piñango, 2012; McElree, Traxler, Pickering, Seely, & Jackendoff, 2001; Pustejovsky, 1995; Pylkkänen & McElree, 2007; Traxler, Pickering, & McElree, 2002), a key related configuration which has not been equally examined, reveals that the animacy of the subject is only one factor in the interpretation. The related configuration involves aspectual verbs + entity-denoting complements with **inanimate-denoting subjects**. That is the case of sentence (2a) below, interpreted as (2b). Here, the subject denotation is construed not as an agent, but as an initial subpart of the structured individual denoted by the complement. As (2b) illustrates, the structured individual can be construed along an informational or a physical dimension. We call this reading the "**constitutive reading**" of AspV sentences.

(2) a. *The chapter on global warming begins the book.*
b. → The chapter on global warming is the initial subpart of the book.

("the book" can be viewed as a body of informational content or a physical entity)

Examples (1) and (2) thus illustrate what appear as two semantically distinct configurations: with an animate-denoting subject and with an inanimate-denoting subject; both involve meaning underspecification of the sort described above but lead to distinct readings—readings that correlate with the perceived animacy of the subject.

Previous studies have shown increased processing cost for sentences with an animate-denoting subject and an entity-denoting complement like (1a) and have attributed the associated cost to the generation of an agentive reading (Traxler, McElree, Williams, & Pickering, 2005, 2002; McElree, Pylkkänen, Pickering, & Traxler, 2006; Pickering, McElree, & Traxler, 2005; Frisson & McElree, 2008; Katsika et al., 2012; Kuperberg, Choi, Cohn, Paczynski, & Jackendoff, 2010; Baggio, Choma, Van Lambalgen, & Hagoort, 2010; Husband, Kelly, & Zhu, 2011; Pylkkänen & McElree, 2007; Piñango & Zurif, 2001). We reason that if the perception of animacy is crucial to determining the agentive reading and therefore to the observed computational cost, no such cost should result from processing sentences like (2a) which disallow such an interpretation. Specifically, if the previous observations regarding the processing cost for aspectual-verb sentences are valid, could the cost be attributed to the determination of animacy on the subject? Or is it instead rooted in the generalized compositional demands of aspectual verbs independent of the subject denotation? An answer to this question allows us to examine the bigger issue of the extent to which animacy, understood as perceived biological sentience, interacts with the determination of agency, a lexico-conceptual property.

The remainder of the paper is structured as follows: Section 1 presents the conceptual components proposed to support the comprehension of AspV sentences. It presents the processing implications of this conceptual approach, captured under the Structured Individual Hypothesis (SIH) and which allows us to formulate the experimental predictions. Sections 2 and 3 present the two experiments, respectively. Experiment 1 compares the processing cost of AspV sentences with animate and inanimate subjects through a self-paced reading task, and Experiment 2 examines the cortical correlates for the same two contrasting conditions and as compared to a minimally differing control counterpart. Section 4 explicates the findings in connection to the conceptual components proposed to support meaning composition. Section 5 concludes the paper.

1.1. Subject animacy and the conceptual composition of sentences with underspecified meaning

Animacy has traditionally been viewed as a feature of particular thematic roles (e.g., Agent, Experiencer) and licensed by verbal predicates (Dowty, 1991, pp. 547–619; Jackendoff, 1972). From a sentence processing perspective, previous work has shown that it plays a role in syntactic ambiguity resolution (e.g., MacDonald et al., 1994; Tanenhaus & Carlson, 1989; Trueswell, Tanenhaus, & Garnsey, 1994). For example, Trueswell et al. (1994) report that sentences with an animate-denoting subject, as compared to an inanimate-denoting subject, elicit longer reading times in reduced relative clauses (e.g., *The defendant/evidence examined by the lawyer* …), suggesting that the effect results from an animate-denoting subject being a representative *Agent* —while an inanimate-denoting one being a representative *Patient* —and such thematic fit favors a main-clause analysis, thereby inducing greater cost when it turns out to be a reduced relative clause. In an ERP study, Kuperberg, Kreher, Sitnikova, Caplan, and Holcomb (2007) find that comprehension of sentences with animacy violation of thematic roles (e.g., *For breakfast the eggs would eat* …) elicit a P600 effect (but no N400). The findings are interpreted as consistent with the view that animacy constraints associated with thematic relation of verbs carry impact on real-time sentence processing.

Animacy also appears to interact with linear order. That is shown through a real-time comprehension preference for animate initial argument over an inanimate one in the context of an Actor-Undergoer linearization (Bornkessel-Schlesewsky & Schlesewsky, 2009; Bornkessel, Zysset, Friederici, Von Cramon, & Schlesewsky, 2005; Bornkessel & Schlesewsky, 2006; Grewe et al., 2006; Kuperberg et al., 2007, 2008; Paczynski & Kuperberg, 2011). Regarding cortical organization, previous neuroimaging work reports increased activation in the left posterior superior temporal sulcus (pSTS) for sentences without animacy contrast between arguments over sentences with animacy contrast (animate subject + inanimate object) (Grewe et al., 2007). The increased pSTS activity is attributed to deviations from an unmarked order of relational animacy for transitive sentences, which is proposed to encode a preference for an animate subject and an inanimate object. Relatedly, Grewe et al. (2006) report that sentences with an *inanimate* nominative subject and a dative *animate* object engender additional activity in the left pars opercularis as compared to the sentential counterparts with an animate subject. Grewe et al. suggest that this region responds to linguistic prominence in terms of animacy hierarchy, i.e. a preference for animate arguments to precede inanimate ones. In a similar line, Chen, West, Waters, and Caplan (2006) report results from a fMRI-based comparison of object relative clauses with an animacy contrast comparing inanimate—animate vs. animate—inanimate orderings between matrix subject-head and object relative-subject head denotations (e.g., *The wood that the man chopped heated the cabin* vs. *The golfer that the lightning struck survived the incident*). Results show increased activity in several brain regions, involving left inferior frontal and dorsolateral frontal region as well as left inferior parietal regions, leading again to an interpretation focusing on animacy as the determinant factor in the preferential cortical recruitment. In contrast, Wallentin, Østergaard, Lund, Østergaard, & Roepstorff, 2005 report no increased brain activation in response to subject animacy contrasts in sentences like "*The man/trail goes through the house.*" suggesting instead that animacy *per se* does not seem to encode neural categorical specificity at the sentence level.

In contrast to previous work on animacy and sentence comprehension, in which animacy manipulation involves violations of selectional restrictions of the verbs, aspectual-verb sentences are compatible with both animate and inanimate-denoting subjects. This means in turn that subject animacy may not be associated with thematic or meaning well-formedness violations. Aspectual-verb sentences thus represent a viable space to determine whether, and if so how, animacy comes into play in the processing of predicates that are ambiguous between agentive and non-agentive readings. Indeed, the animacy effect shown in previous studies is typically tied to Agency, a lexico-semantic construct indicating a relation between participants of an event (Carey, 2009; Pinker, 1989). Crucially, however, when composing with aspectual verbs, an agent or actor need not be an animate entity. For example, in the sentence "*The rocket began the journey to the moon*," *the rocket* is an inanimate entity that is nonetheless construable as an agent. Directly below we describe how agentivity and animacy come apart in the behavior of aspectual-verb sentence composition.

Examples (1) and (2) above show that aspectual verbs can be composed with an animate-denoting subject or with an inanimate-denoting subject, giving rise to an agentive or a constitutive reading respectively. The two readings stem from the following analysis of Piñango and Deo (2012; 2015): aspectual verbs (e.g., *begin, finish*) select for *structured individuals* as their complements. Structured individuals are defined as entities that can be mapped onto a directed path structure (3)—an axis—along some ontological dimension (e.g., spatial, informational, eventive, temporal).

(3) Directed path structure

In this way, sentences with aspectual verbs express a parthood relationship between the verb's arguments. They map the subject denotation onto a specific subpart of the structured individual denoted by the complement.[1]

Not only can animate subjects give rise to *agentive* readings, they can also give rise to *constitutive* readings. That is the case of (4) below, which is ambiguous between agentive and constitutive readings and which we term [animate-denoting subject + AspV]—**the "AspV-Animate" configuration** henceforth.

[1] The proposed lexical entry for *begin*, as an example, is as follows (Piñango & Deo, 2015, p. 20):[[begin]] = $\lambda x_{\tau} \lambda y_{\sigma}$: **struct-ind** $_{fc}$ (x). $\exists f'[f'(y) <_{small-init} f_c(x)]$. The lexical entry states that *begin*$(x)(y)$ is true if and only if the complement of the verb (x) is construed as a structured individual via the function f_c in context, and, once this condition is met, there is a function ($\exists f'$) that maps the subject denotation (y) to a small initial part ($<_{small-init}$) of the axis given by $f_c(x)$. Compositionally the lexical item takes the subject denotation and maps it onto a subpart of the complement denotation which has been construed as a structured individual along a dimension and mapped onto the directed path structure or axis.

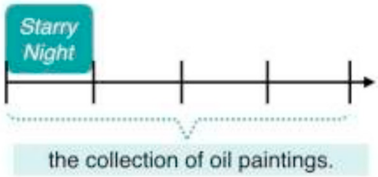

Fig. 1. The constitutive reading of [*Starry Night began the collection of oil paintings*].

(4) Van Gogh began the collection of oil paintings.

Sentence (4) engenders an agentive reading, such as "Van Gogh began browsing/editing/etc. the collection of oil paintings." In this reading, the complement is construed as a structured individual along the *eventive* dimension, and the subject is construed as an Agent. In the constitutive reading, such as "Van Gogh's painting was the initial subpart of the collection.", the complement is construed as a structured individual along one of several possible dimensions. If the complement is construed along the *spatial* dimension, "the collection of oil paintings" is construed as a structured spatial entity, such as a book consisting of *X* number of pages. Along this spatial dimension, the subject denotation (Van Gogh's painting) is printed on the first page of this collection. If the complement is construed along the *informational* dimension, the collection will be construed as a structured body of informational content involving a series of *X* number of paintings, where each painting is a piece of informational content. Along the informational dimension, the sentence is understood to convey that Van Gogh's painting was the first painting of this collection, regardless of which page it is printed on. As we can see then, sentences in the AspV-Animate configuration are semantically ambiguous between an agentive and a constitutive reading. Moreover, arriving at one interpretation requires dealing with *dimension ambiguity* given that the complement can be construed along multiple mutually exclusive dimensions, as shown in (5).

(5) a. *Eventive dimension (agentive reading)*: Van Gogh began browsing/editing/etc. the collection of oil paintings (as an event).
b. *Spatial dimension (constitutive reading)*: Van Gogh's painting was printed on the first page of the collection of oil paintings (as a physical entity).
c. *Informational dimension (constitutive reading)*: Van Gogh's painting was the first painting of the collection of oil paintings (as a body of informational content).

As mentioned, aspectual verbs can also combine with an *inanimate*-denoting subject naturally as in (6). Crucially, such sentences typically do not yield an agentive reading. The constitutive reading can be visualized as in Fig. 1. Such configuration—[inanimate-denoting subject + AspV]—will henceforth be termed **the "AspV-Inanimate" configuration**.

(6) *"Starry Night" began the collection of oil paintings.*

Like the constitutive reading of AspV-Animate sentences above, the constitutive reading of the AspV-Inanimate configuration is also underspecified with respect to the exact dimension along which the complement denotation is construed as a structured individual. Dimension *specification*, that is, which dimension will ultimately be chosen, depends on the context of the utterance, including the intended dimension that the hearer perceives of the speaker. In (6), the collection of oil paintings can be conceived as a physical entity along the spatial dimension or as a structured body of informational content along the informational dimension as in (5b-c). Therefore, a constitutive reading of an AspV-Inanimate sentence can also be interpreted along more than one dimension, resulting again in dimension ambiguity.

The compositional requirements of aspectual verbs, that is, the meaning-building functions that map the structured individual denoted by the complement to an axis are encoded as lexical functions in the lexical entry of each of the verbs. Each one of the lexical functions is associated with a specific dimension (e.g., f_{space}, f_{time}, f_{info}). At the same time, and to meet the selectional restrictions of the verbal functions, the complement denotation also needs to be able to be construed as a structured individual along one of a set of conceptually available dimensions associated with the complement denotation. The availability of multiple dimensions along which the structured individual can be construed inevitably leads to dimension ambiguity which must be resolved. Successful verb-complement composition thus depends on choosing a specific dimension, which in turn determines the function in the verb that will map the complement denotation onto the directed path structure.[2] This Structured Individual analysis captures the agentive and constitutive readings of AspV sentences in a unified fashion. Regardless of reading, AspV sentences establish a structural relation between two entities denoted by the subject and complement. The complement's potential multiple dimensions (e.g., spatial, information, eventive, temporal) percolate to the sentence level, leading to sentence-level ambiguity. In this sense, AspV sentences, regardless of subject animacy, involve *dimension ambiguity*, being underspecified for dimension without disambiguating context.

Nevertheless, there could be one possible way in which subject animacy may interact with sentence interpretation. Recall that while the AspV-Animate configuration gives rise to both an agentive reading and a constitutive reading, the AspV-Inanimate

[2] Interested readers are referred to Piñango and Deo (2015) for the linguistic motivation and full semantic implementation of this analysis.

configuration gives rise to a constitutive reading primarily *without supporting context*. This means that out of context the set of interpretations available in the AspV-Animate configuration is a *superset* of those available in the AspV-Inanimate configuration. Thus, AspV-Animate ⊇ AspV-Inanimate in terms of available interpretations (Fig. 2). Notice that this relation is independent of the presence of dimension ambiguity, because the constitutive reading, available from both configurations, can emerge via the complement's construal along more than one dimension. This supports the generalization that the source of the complexity in AspV sentence composition is found not entirely in the availability of the agentive reading but more in the presence of multiple dimensions along which the structured individual (denoted by the complement) is construed. That is, both configurations involve a semantic ambiguity in terms of *multiple dimension readings*, and therefore this part of processing effort is comparable for both. Where the two configurations differ is in subject animacy: in the absence of context, an animate-denoting subject supports the agentive reading along the eventive dimension given that all else being equal, an animate entity is more likely to serve as an agent.

1.2. Conceptual components that capture sentence interpretations regardless of subject animacy

AspV sentences combine with both animate and inanimate subject referents. Yet, subject animacy is dissociated from the type of reading it can give rise to: agentive (in which the subject is construed as an Agent) vs. constitutive (in which the subject is construed as a subpart of the complement's denotation) of the sentences. Specifically, AspV-Animate sentences can give rise to a constitutive reading along the spatial or informational dimension as shown in (7).

(7) *The girl began the line in front of the famous bakery.*

By contrast, AspV-Inanimate sentences can also give rise to an agentive reading. This is demonstrated in (8) below, in which the subject denotes an inanimate referent that is nevertheless interpretable as an Agent.

(8) The printer started my paper finally.

If subject animacy does not determine the agentive vs. constitutive reading, what non-lexical factors could be determining the sentence interpretation? Here is a possibility which is grounded on our assumptions about real-time conceptual composition.

When composing meaning based on linguistic input, conceptual composition is also taking place. The composition of lexical meanings is thus also a composition of lexicalized concepts and the semantic representation of a sentence is in fact ultimately a conceptual representation. Concept composition, we propose, is what we are ultimately measuring in the experiments to be presented below. It is at this level where the de-coupling of agentivity and animacy, two conceptual constructs, can be observed. In what follows we sketch a model that captures this dissociation. The distinction between agency and animacy can be understood within the Multi-Dimensional Space (MdS). The MdS was originally proposed in Piñango (2018) to describe the meaning distribution of English *have* and the unified cost of circumstantial and systematic metonymy (Piñango et al., 2017). The MdS is the organized mental space where conceptual units i.e. situation-episodes, are stored and combined into larger conceptual structures. Situation-episodes are memory-based situations (i.e. eventualities) involving participants in some functional relation. Linguistically, they take the form of predicate-argument structures. Even though a full presentation of the MdS is beyond the scope of this paper, here we provide the general sketch of the model which allows us to introduce the specific component that affords the distinction at issue between agency and animacy. From a real-time comprehension perspective, the MdS serves as a space of *meaning evaluation* that is constrained by at least two parameters: (i) **Control Asymmetry**—the degree of asymmetric control power between the participants in a situation, and (ii) **Connectedness**—the structural or functional relation between the participants (ranging from incidental proximity to non-coincidental parthood relation). Comprehension of a situation results from the evaluation of the participants in the situation along these two parameters in the context of a given predicate (see Piñango (2018) for specific examples of how this determination comes to be).

From the model, **Control Asymmetry** is the component that gives rise to the dissociation between agency and animacy. It allows the comprehender to predict the *relative* role of participants in a situation given the salient inherent properties of the participants.

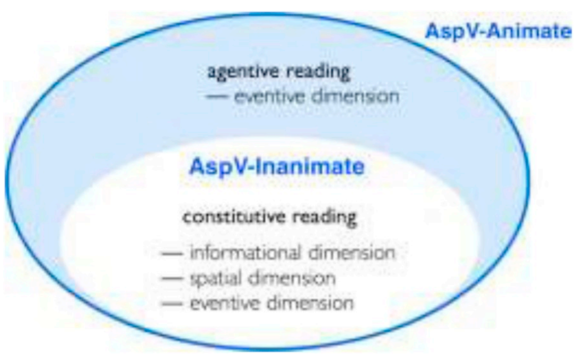

Fig. 2. Superset relationship: AspV-Animate ⊇ AspV-Inanimate in terms of available readings in the absence of context.

This means that all else being equal, if in a two-participant situation one participant is perceived as typically having more control over the other participant, the control relation between the two participants is deemed *asymmetric*. If the participants are perceived as similar in control power, then the relation is of low control asymmetry or more symmetric. Crucially, the evaluation of control asymmetry is co-participant dependent; that is, an entity will be deemed more or less "controlling" in relation to the other participants in that situation. It is this contextually-based evaluation that ultimately affords the de-coupling between agency and animacy at play in aspectual-verb constructions.

As mentioned, aspectual-verb sentences yield two possible mutually exclusive readings: agentive and constitutive. When analyzed within the MdS, we observe that these two mutually exclusive readings are distinguishable not by animacy, but by the control relation between the participants denoted by the subject and complement. As shown in Table 1, an evaluation of high control asymmetry between the participants supports an agentive reading, whereas control symmetry supports a constitutive reading, again, regardless of the participants' animacy.

Support for the viability of control asymmetry as a conceptual parameter of evaluation is found in Lai and Piñango (2019). They report the results of a questionnaire study containing aspectual-verb sentences with the AspV-Animate configuration, and preceded by three contextual types: (i) with bias towards high control asymmetry of the subject-object relation, (ii) with bias towards low control asymmetry (or, control symmetry), and (iii) with no bias (i.e. neutral). Results show that when subject and object arguments are perceived as having *high control asymmetry* in context, such that the subject participant is conceived as having greater control over the object participant, comprehenders report an agentive reading for the target aspectual-verb sentence. This is, for example, how "*Van Gogh began the collection of oil paintings*" is interpreted as "Van Gogh began browsing/editing/etc. the collection of oil paintings." By contrast, if the subject and object arguments are evaluated as having control *symmetry*, comprehenders report a constitutive reading, such as "Van Gogh's painting was the first piece of the collection." In the neutral context, the comprehenders report both agentive and constitutive readings. These findings are consistent with a control asymmetry evaluation. Crucially, they show that this evaluation is arguably independent of subject animacy, because all aspectual-verb sentences tested in Lai & Piñango's study contained an animate-denoting subject.

In this way, animacy emerges not as an independent category but as a bi-product of the accumulation of control asymmetry evaluations over the experience of an individual. That is, an animate referent is more likely to be construed (more often) as a controller or an actor in the context of an agentive reading. This would be because, as noted throughout the literature like Dowty (1991, pp. 547–619), an animate referent is more likely to be sentient, willful, causing changes, and therefore linguistically more Agent-like. However, as demonstrated above, an animate-denoting subject does not seem to be causally correlated with an agentive reading. Indeed, Jackendoff (1983, p.181) notes that animacy is in fact too strong for specifying sentence meaning; instead, other primitive concepts such as autonomy and willfulness, are more suitable to de/encode agency. For example, the properties contributing to what Dowty terms "Agent Proto-Role" are associated with the control power argued here. This relation has been independently suggested in Bornkessel-Schlesewsky & Schlesewsky (2009) and Primus (2010) for example, for the determination of actorhood. Finally, studies in developmental psychology have shown that even preverbal infants are able to construe self-controlling entities (e.g., squares, circles) as agents in contrast to physically identical but inert counterparts (Carey, 2009; Saxe, Tenenbaum, & Carey, 2005, 2007). From these observations, we conclude that at least for language comprehension purposes, animacy is neither a necessary nor sufficient semantic feature in the determination of agency. And that instead, agency can be viewed as a by-product of a high control asymmetry evaluation in the context of a given situation-episode as comprehension unfolds. With the conceptual ground established, and before delving into the experimental component, we present the analysis of the real-time processing implementation of the aspectual-verb construction, the basis for motivating our experimental predictions.

1.3. The real-time processing of underspecified meaning

We follow Lai et al.'s (2017) Structured Individual Hypothesis (SIH) for the comprehension of semantically underspecified sentences as in AspV sentences. It is derived from Piñango and Deo's (2015) semantic analysis described above coupled with minimal assumptions of sentence processing. On the SIH, the comprehension of a semantically underspecified sentence is hypothesized to proceed as follows. When the processor encounters the verb, it retrieves all lexical functions encoded in the verb irrespective of context (*cf.* Onifer & Swinney, 1981; Shapiro, Zurif, & Grimshaw, 1989; Swinney, 1979); each function is defined by the dimension with which it is associated (e.g., f_{space}, f_{time}, f_{info}). Aspectual verbs select for structured individuals. This means that in order to compose with the predicate, their complement must be construed as a structured individual along a dimension. Normally, a complement is associated with more than one dimension, so more than one dimensional representation is ultimately construed (see (5) above). One key distinction is between agentive and constitutive readings. Facing such semantic ambiguity, information from the

Table 1
Control relation between the participants and sentence reading.

Configuration	Control relation (Subject ⇔ Complement)	Reading	Example
AspV-Animate	Asymmetric	Agentive	*Van Gogh began the collection.*
AspV-Inanimate			*The printer started my paper.*
AspV-Animate	Symmetric	Constitutive	*The little girl began the queue.*
AspV-Inanimate			*The acknowledgement section ends the paper.*

subject is brought into the interpretive process by evaluating the degree of control asymmetry of the participants denoted by the subject and the complement. This leads to a reading disambiguation. The whole process is illustrated in Fig. 3.

As can be seen, processing of the aspectual-verb construction involves exhaustive lexical retrieval of dimension-functions encoded in the verbs, the composition of multiple dimension representations, and the resolution of dimension ambiguity (i.e. choosing the contextually-relevant interpretation) after the complement is encountered. These processes have been independently shown to underlie processing cost (e.g., DiNardo, 2015; Frazier & Rayner, 1990; Katsika et al., 2012; Lai, Lacadie, Constable, Deo, & Piñango, 2017; Shapiro et al., 1989; Swinney, 1979). The SIH simply leverages those robust and generalized empirical observations, doing away in the process with any additional phenomenon-specific stipulations. Therein lies its independent validity. Finally, we note that while the SIH captures the agentive reading as resulting from control asymmetry evaluation between participants as comprehension unfolds, animacy is instead an independent conceptual construct connecting to agentivity only correlationally, as a by-product of a high control asymmetry evaluation e.g., high controller entity → sentient, volitional entity.

With the processing analysis in place we are able to formulate the experimental question. We **hypothesize** that regardless of animacy considerations, all AspV sentences involve exhaustive lexical retrieval of the verbs, the composition of multiple structured individuals along mutually exclusive dimensions, and the resolution of dimension ambiguity. This **predicts** (1) that AspV-Animate and AspV-Inanimate sentences will engender longer reading times and similar additional cortical recruitment, as compared to non-AspV, the semantically explicit counterparts, and (2) if an interpretation of animacy (although independent) is correlated with an agentive reading interpretation, we should see it reflected in non-linguistic cortical regions when comparing from AspV-Animate to AspV-Inanimate regions. On the other hand, if subject animacy is the key factor in the determination of interpretation and therefore the trigger of the processing cost, then distinct, non-overlapping processing profiles are expected for each of the configurations.

In this way, examining the processing of underspecified meaning as manifested in AspV sentences presents an opportunity to establish whether the cost long-associated with this predicate class is due to the more local factor of subject animacy or whether it is due to the compositional implementation of dimension representations that is independent of animacy. This investigation thus has implications that generalize to an understanding of the semantico-conceptual underpinnings of real-time comprehension and their cortical correlates.

1.3.1. Linkage to previous work: challenges and possible solutions

We note five observations that separate the present study from the considerable body of work on the processing and neurological implementation of aspectual-verb composition. The first two speak to problems that the SIH solves; the second two speak to related observations that it successfully accounts for. The last one presents the conflicting neurological evidence associated with this phenomenon and presents the questions we raise in this respect. We discuss each of the observations in turn.

First, previous work has attributed the agentive reading of AspV sentences to a process that generates an event from the entity-denoting complement (McElree et al., 2001; Traxler et al., 2005, 2002; Pickering et al., 2005; Frisson & McElree, 2008; Pylkkänen & McElree, 2007; Kuperberg et al., 2010; Baggio et al., 2010; Husband et al., 2011; Zarcone, McRae, Lenci, & Padó, 2017). Yet, recent work has pointed out crucial theoretical and empirical challenges that make this idea untenable (DiNardo, 2015; Katsika et al., 2012; Lai, Lacadie, Constable, Deo, & Piñango, 2014, 2017; Utt, Lenci, Padó, & Zarcone, 2013). Specifically, sentences with aspectual verbs do not necessarily give rise to an agentive reading in which the complement refers to an event, and that even though such reading does reliably originate from the behavior of aspectual verbs, not all agentive readings arise from the same linguistic basis (Piñango & Deo, 2015). Before this was observed, the agentive reading diagnostic misled some of the previous work into mixing together aspectual verbs with other semantic classes, particularly psychological verbs (e.g., *enjoy, prefer*). This was in turn problematic because aspectual verbs have been shown to have a distinct processing profile from psychological verbs during comprehension, rooted in their distinct semantic representations. The two verb classes differ in the reading time measurements as shown by eye-tracking (Katsika et al., 2012), self-paced reading (Lai et al., 2017, Exp. 1), and also in brain activity as shown by ERP (DiNardo, 2015) and fMRI (Lai et al., 2017, Exp. 2).

Second, in considering the constitutive reading we provide a robust and parsimonious account for the source of the cost. A key point is that the ambiguity invoked by AspV sentences is specific to available *dimensions* associated with the complement and

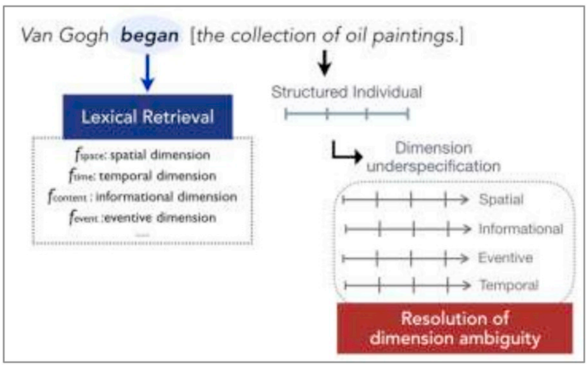

Fig. 3. Structured Individual Hypothesis for processing AspV sentences.

crucially distinct from the ambiguity among various *activities* in which the subject referent can participate as an Agent (as in sentences like (4)). The possible activities (e.g., browsing, editing) in the agentive reading of AspV sentences are all subsumed under the eventive dimension (5a). The constitutive reading (with either an animate subject in (4) or an inanimate subject in (6)) still involves dimension ambiguity (e.g., spatial, informational). So, as presented, for AspV transitive sentences there is only one possible source of ambiguity, dimension ambiguity, and therefore only one potential source of cost.[3] Notably, the observation that activity type may not be a source of cost has already been shown in previous work. Traxler et al. (2005) and Frisson and McElree (2008) show that the cost associated with sentences like "*The author began the book*" is not eliminated by specifying an activity (among many possible others) in context. This suggests that the cost associated with AspVs is not caused by disambiguating the activity in which an animate-denoting subject participates as an Agent.

Third, contextual information can be relevant in modulating cost if it addresses dimension ambiguity. Traxler et al. (2005) (Exp. 3 & 4) report cost associated with processing expressions like "*Sue started the book*" and attenuated by a prior context sentence containing either the same expression or an eventive expression ("*Sue read the book*"). This finding which had yet to receive a satisfactory explanation follows naturally from our account, which states that the processing cost arises from the resolution of dimension ambiguity. By presenting the intended dimension along which the complement denotation will be construed in the context sentence, the processor has been cued into a possible dimension to choose for the target sentence. This is predicted to attenuate cost because the dimension cue alleviates the effort of ambiguity resolution, which is what Traxler et al. (2005) observed.

Fourth, Traxler et al. (2002) show that entity-denoting complements (e.g., *puzzle*) engender longer reading times than event-denoting complements (e.g., *fight*). This again is also compatible with the current view: event-denoting complements bias towards the eventive dimension by their lexical semantic representations and hence facilitate dimension resolution, thus reducing the cost to unobservable levels as argued by Lai et al. (2017).

With respect to neural activity, sentences with aspectual verbs (examined along with those containing psychological verbs and other classes) have been associated with distinct brain regions. In a lesion study, Piñango and Zurif (2001) report that Wernicke's aphasics have difficulty understanding such sentences. More recently, Husband et al.'s (2011) fMRI study reveals activation in left Brodmann area (BA) 45, part of left inferior frontal gyrus (LIFG). However, Pylkkänen & McElree (2007) found stronger activity in ventral medial prefrontal cortex (vmPFC) in an MEG study. Dissociating aspectual verbs from psychological verbs by their distinct semantics, Lai et al. (2017) found activity in both Wernicke's area and LIFG for AspV sentences with animate-denoting subjects. Nevertheless, whether or not AspV sentences with an inanimate-denoting subject would reveal a privileged cortical pattern and if so, whether it could be connectable to the animate-denoting subject counterpart remains unknown. At this point we note that sentences with inanimate-denoting subjects have yet to be considered at the level of detail we do here. As shown in previous sections, such sentences are semantically well-formed and involve semantic ambiguity not unlike that observed for the animate-subject counterparts. The comparison between AspV sentences with animate- versus inanimate-denoting subject is thus not only important because it allows us to tease apart the effect of subject animacy (more local scope) and that of compositional demands resulted from multiple semantic representations (more global scope), it is important because it allows us to deepen our understanding of this fundamental meaning domain, and the connection between its linguistic and conceptual representations at all levels of realization: representational, processing and neurological. We turn to these studies directly below.

In sum, whereas previous studies show processing cost associated with the agentive interpretation of AspV sentences in composition of animate-denoting subjects, the linguistic assumptions on which some of those results have been based wrongly predict the non-existence of the constitutive reading of AspV sentences and fail to explain why the distinct semantic and processing patterns observed would be specific to aspectual verbs. Here we address these issues and make further testable predictions regarding inanimate-denoting subjects, which had not been explored before, and which allow us to showcase aspectual-verb composition as a window of opportunity for the possible dissociation between agentivity and animacy.

2. Experiment 1: Self-paced reading

This study investigates the time-course of the cost associated with processing the two AspV configurations—with in/animate-denoting subjects. Two of the conditions tested are reported in Lai et al., (2017), the critical condition addressing animacy was tested in that context but not reported. That is the focus of the present effort.

2.1. Methods

2.1.1. Materials

We created fifty sets of the following conditions as exemplified in Table 2.

The first two conditions contained sentences with an aspectual verb followed by an entity-denoting complement. The subject in the first condition refers to an animate entity (AspV-Animate), while the subject in the second condition refers to an inanimate entity (AspV-Inanimate) typically. For the AspV-Inanimate condition, the verbs appeared in their present tense for most of the items to

[3] It could be that some activity is more preferable than others due to predictability, typicality (Delogu, Crocker, & Drenhaus, 2017; Zarcone, McRae, Lenci, & Padó, 2017), or the relevant saliency in a given context. However, this difference in possible activities is not involved in dimension ambiguity. As shown by these studies, predictability or typicality alone does not fully explain the observed processing cost. See also DiNardo's (2015) arguments regarding AspV composition as distinct from surprisal.

Table 2
Conditions and sample sentences.

Condition		Verb	Comp.Head	Comp.Head + 1	Comp.Head + 2	
AspV-Animate	*Van Gogh*	*started*	*the collection*	*of*	*impressionist*	*oil paintings.*
AspV-Inanimate	*"Starry Night"*	*starts*	. . .	. . .	. . .	. . .
Control	*Van Gogh*	*loved*	. . .	. . .	. . .	. . .

further facilitate the constitutive reading. These two AspV conditions were contrasted with a Control condition that involved no dimension ambiguity; this contained psychological verbs such as "*love*" and "*hate*." Again, two conditions, AspV-Animate and Control, are reported in Lai et al. (2017); they represent the baseline for the new critical condition, AspV-Inanimate. All conditions, however, underwent the same norming treatment.

We further examined the frequencies of aspectual verbs and the control verbs using the Corpus of Contemporary American English (COCA). Results of item-analysis by ANOVA revealed that aspectual verbs did not differ from control verbs in the lemma forms ($Mean_{AspV}$ = 65014.28 (range = 15,873~101,524); $Mean_{Control}$ = 78731.6 (range = 26~210,252); $F(1,148) = 2.05$, $p = .15$). Yet aspectual verbs showed significantly higher frequencies than the control verbs in the exact verb forms (inflected forms) as shown in sentences ($Mean_{AspV}$ = 62069.69 (range = 1329~139,583); $Mean_{Control}$ = 20752.72 (range = 405~34,930); $F(1,148) = 31.77$, $p < .001$). Suppose that words with higher frequencies are easier to process (Inhoff & Rayner, 1986; Just & Carpenter, 1980; Kliegl, Grabner, Rolfs, & Engbert, 2004; Rayner & Duffy, 1986; Rayner, Sereno, & Raney, 1996; Rayner & Raney, 1996), the pattern that the aspectual verbs are more frequent than the control verbs, if anything, went against our hypothesis that comprehending AspV sentences would be more costly due to exhaustive lexical retrieval of the verbs, the composition of multiple conceptual representations, and the resolution of dimension ambiguity. The aspectual verbs and the control verbs did not differ in word length neither ($F(1,148) = 2.40$, $p = .124$). Moreover, the critical verbs have been examined independently by DiNardo (2015), whose results of a lexical decision study showed no difference between the verb types in response times, suggesting that they match in lexical accessing time.

Pretest. The stimuli were evaluated for acceptability via a rating questionnaire. The questionnaire pretest included 50 sets of the 3 critical conditions mentioned above plus 150 fillers (50 of which being nonsensical), yielding a total of three hundred sentences. These stimuli were distributed in a fully counterbalanced fashion into two scripts; each was randomly assigned to a participant. We recruited forty native speakers of American English (21 females), who participated in the experiment for monetary compensation, via advertisement postings around the campus. The participants were all college students between the ages of 18~30 and without reading disabilities by self-report. They were asked to read each sentence, rate its sensicality from a scale 1~5 (1 = does NOT make sense; 5 = makes sense) and answer a comprehension question afterwards.

The comprehension questions queried the participants' interpretations of the given sentences. The template, exemplified by an AspV-Animate sentence, was as below: [If "*The celebrated florist finished the last row of the flower exhibition*", what did the celebrated florist finish?] Five answer options were provided: (i) bare complement-NP (*the last row of the flower exhibition*), (ii) preferred eventive reading (*viewing the last row of the flower exhibition*), (iii) dispreferred eventive reading (*moving the last row of the flower exhibition*), (iv) distraction, to screen if the participants were paying attention to the task (*the celebration*), and (v) nonsensical (*The sentence does NOT make sense*). The preferred and the dispreferred readings were randomized across the trials. Multiple choices were allowed. The participants were expected to select mostly the bare complement-NP and the eventive readings for AspV-Animate and Control conditions, and select the bare complement-NP for the AspV-Inanimate condition. Data were collected via the Survey Monkey software on a lab computer in a quiet room. Participants' informed consent was obtained prior to the experiment.

The data of three participants were discarded due to technical issues during the administration of the protocol. The rating scores of the remaining 37 participants were transformed by the z-score transformation for scale-based data (Schütze and Sprouse, 2014). The z-scores were then analyzed in the R statistical environment (R Core Team, 2015) using mixed-effects models by the *lmer* function of the *lme4* package (Bates, Mächler, Bolker, & Walker, 2015). The models incorporated random intercepts for subject and item as well as by-subject random slopes for the fixed factor, simplified from the maximal models that failed to converge. An effect of condition was assessed by comparing the model with the fixed factor of condition against a base model without it. Pairwise comparisons between conditions were corrected by Tukey tests for *p*-values.

Results of rating scores showed that the critical conditions were within the sensical range in average, i.e. > 3.7 (AspV-Animate: mean = 4.13, se = 0.04; AspV-Inanimate: mean = 3.73, se = 0.05, Control: mean = 4.80, se = 0.02) while each significantly differing from the nonsensical fillers (all $ps < .001$, corrected). A significant effect of condition was found ($\chi^2(2) = 48.45$, $p < .001$), with significant pairwise comparisons among the three conditions (AspV-Animate vs. Control: $z = 6.789$, $p < .001$; AspV-Inanimate vs. Control: $z = 9.998$, $p < .001$; AspV-Animate vs. AspV-Inanimate: $z = -4.904$, $p < .001$).

We interpret the lower rating scores of AspV sentences as compared to Control as resulting from the presence of dimension ambiguity, which would require more effort from the comprehenders for determining the intended interpretation (Lai & Piñango, 2019). In other words, lower sentence acceptability results from lower comprehensibility; and lower comprehensibility results from unresolved ambiguity. On the other hand, AspV-Inanimate sentences received lower rating scores than AspV-Animate sentences; we believe that this reflects that relatively speaking aspectual verbs combine with inanimate-denoting subjects less often than with animate-denoting subjects. Indeed, this observation is supported by a corpus-based evaluation using the Corpus of Contemporary American English (COCA). In it we found that two representative aspectual verbs, "*begin*" and "*finish,*" combine with animate-denoting subjects for 68.57% of the occurrences and with inanimate-denoting subjects for 24.27% of the occurrences, supporting the conclusion that in usage the constitutive reading occurs less frequently than the agentive reading. If this asymmetry generalizes to our participants' everyday usage, it would have the consequence of systematically lowering, even if slightly, the sensicality scores. The reason is that when comprehending an inanimate-denoting subject with an aspectual verb, comprehenders need to find an appropriate context which would guide them in dimension disambiguation; if this is something that they do less often it will take them longer and more effort to carry out the process which would incline them to grant less than full sensicality for those sentences.

In terms of the comprehension task, results showed that the participants selected mostly the bare complement-NP (> 70%) and the eventive interpretations around 50% of the time for the AspV-Animate and Control condition. For the AspV-Inanimate condition, the participants selected mostly the bare complement-NP interpretation (> 80%). Results are reported in Table 3.

The stimuli of the critical conditions tested in the questionnaire were adopted in the following experiments, with a different set fillers introduced. Each sentence was segmented into several windows, shown by the cells of Table 2. Our windows of interest were the verb, the complement head, and the two segments following the complement head (Comp.Head + 1, Comp.Head + 2).

2.1.2. Participants

We recruited twenty-eight native speakers of American English (18 females) via advertisement postings around the campus. All participants were college students between the ages of 18~30, with normal vision and without history of reading disabilities. They received monetary payment for participation and their written informed consent was obtained prior to the experiment.

2.1.3. Procedure

Sentences were visually presented segment-by-segment on a computer screen via the E-Prime software. The participants were instructed to read the sentences at their own pace. Every trial began with a series of dashes corresponding to the lengths of the sentences on the screen, with a plus sign (+) appearing on the left-most edge to mark the beginning of the sentence. The participants began each trial by pressing the spacebar, causing the first segment to show up. With the subsequent pressing, the next segment appeared and the previous segment was replaced by a set of dashes. The whole set of experimental sentences were read by every participant. At the end of the sentence, the participants were presented a comprehension statement for which they were asked to judge whether it was true or false. The purpose of this comprehension task was to ensure that the participants were paying attention during the reading task; the content of this task was unrelated to the research questions at issue. A practice session was given beforehand for which the participants had to reach 80% accuracy before proceeding to real trials. The experiment was approved by the Institutional Review Boards of Yale University.

2.2. Data analysis

The reading time (RT) measurements of the four windows of interest were analyzed: the main verb, the complement head, and the two segments following the complement head (Comp.Head + 1, Comp.Head + 2). The data of all 28 participants were included in data analysis. Reading times (in milliseconds) were analyzed using linear mixed-effects models via the *lmer* function of the *lme4* packages in the R statistical environment (Bates, Mächler, Bolker, & Walker, 2015; Baayen, Davidson, & Bates, 2008; R Core Team, 2015). The models included a fixed factor of Condition (3 levels: AspV-Animate, AspV-Inanimate, Control), incorporating random intercepts for participant and item, simplified from more complicated models that failed to converge. A significant effect was assessed by contrasting a model with the fixed factor of Condition against a base model without it. Pairwise comparisons were corrected by Tukey tests for *p*-values.

2.3. Results

Results of the comprehension task achieved 94.73% accuracy in average (ranging between 87~99.33%, SD = 3.63% across participants), indicating that the participants fully comprehended the sentences and were paying attention during the reading task. Regarding reading times (RTs), the Verb region showed an effect of Condition, such that aspectual verbs engendered longer RTs than controls ($\chi^2(2) = 6.41, p = .04$), mainly driven by the contrast Control < AspV-Inanimate ($z = -2.42, p = .04$) as revealed by pairwise comparisons. The Complement Head region showed no significant effect. A significant effect of Condition was found at the Comp.Head + 1 region ($\chi^2(2) = 13.19, p = .001$) and the Comp.Head + 2 region ($\chi^2(2) = 18.83, p < .001$). At these two regions, the two AspV conditions engendered longer RTs than the Control condition. Pairwise comparisons showed that at the Comp.Head + 1 region, the Control condition engendered shorter RTs than the AspV-Animate condition ($z = -3.53, p = .001$) and the AspV-

Table 3
Results of comprehension questions in the Pretest questionnaire.

	AspVanimate	AspVinanimate	Control
bare complement NP	71.56%	84.28%	87.31%
preferred eventive reading	51.51%	2.33%	54.77%
dispreferred eventive reading	15.64%	1.57%	7.38%
distraction	0.99%	1.48%	1.19%
nonsensical	9.09%	14.63%	1.41%

Inanimate condition ($z = -2.52$, $p = .031$) respectively. At the Comp.Head + 2 region, the Control condition elicited shorter RTs than both the AspV-Animate condition ($z = -2.64$, $p = .02$) and the AspV-Inanimate condition ($z = -4.31$, $p < .001$). In the latter two regions, AspV-Animate and AspV-Inanimate did not differ from each other (Comp.Head + 1: $z = -1.008$, $p = .57$; Comp.Head + 2: $z = 1.67$, $p = .22$). Results are summarized in Table 4 and Fig. 4.

Given that aspectual verbs had higher frequencies than the control verbs in the exact forms (though not in the lemma forms) and that they did not differ in word length, the additional cost engendered by AspV sentences at Comp.Head + 1, Comp.Head + 2 is unlikely due to verb frequency or length. Importantly, reading times showed that subject animacy did not cause a difference in processing AspV sentences. Rather, the cost of AspV sentences is more likely due to the compositional load associated with dimension ambiguity resolution.

Overall, results show that sentences with aspectual verbs engendered longer RTs than the control counterparts at the two segments following the complement head noun. Crucially, the two AspV conditions patterned alike in spite of their difference in subject animacy. On the other hand, this pattern is inconsistent with the an animacy-based approach, and consistent with the concept composition approach, which holds that all sentences with aspectual verbs involve semantic ambiguity along multiple dimension-readings (e.g., spatial, informational). In Section 1.1 and Fig. 2, we show that sentences of the AspV-Animate and AspV-Inanimate conditions are construable along more than one dimension, giving rise to dimension ambiguity. Processing AspV sentences is therefore costlier than semantically unambiguous controls because upon encountering dimension ambiguity the processor must wait to resolve it to obtain an appropriate sentence interpretation. This involvement of dimension ambiguity, we suggest, captures the RT pattern {AspV-Animate = AspV-Inanimate} > Control.

3. Experiment 2: fMRI

This study investigates the neural correlates associated with the comprehension of AspV-sentences that differ by subject animacy. In this way we seek to determine the extent to which the brain is sensitive to the animacy vs. agency distinction. As with the self-paced reading experiment, conditions AspV-Animate and Control were reported in Lai et al. (2017) as part of another experiment; they represent the baseline for the critical, previously unreported condition AspV-Inanimate. All conditions received the same norming (as described above) and imaging treatment (as described below).

3.1. Methods

3.1.1. Materials

The fifty critical sets of the stimuli remained the same as in Exp.1 (50 items for each condition), and 150 filler sentences were introduced. The whole set of stimuli consisted of 300 sentences in total, read by each participant during fMRI imaging.

3.1.2. Participants

Sixteen native speakers of American English (6 females) were recruited. All participants were college students between the ages of 18~30, right-handed, with no reading disability or history of neurological disorders by self-report. Written informed consent was obtained from the participants, who received monetary compensation for participating in the experiment.

3.1.3. Paradigm

The set of three-hundred sentences were divided into ten runs; the order of the runs was randomized for each participant. Each run contained thirty sentences, lasting for 5 min 33 s with the inclusion of device connection delay. Within each run, the sentences were pseudo-randomized such that no successive sentences were of the same condition. Each sentence was visually presented segment-by-segment by the E-Prime software; each segment lasted for 500 ms. The participants received a comprehension question after reading the sentence for 3/4 of the trials to ensure that they were paying attention to the reading task. The content of the questions was unrelated to the phenomenon at issue. Each question remained on the screen for 4000 ms, and there was a 500 ms interval between the sentence-final word and the question. The experiment was approved by the Institutional Review Boards of Yale University.

3.1.4. Imaging acquisition

Anatomical measurements. The fMRI experiment was carried out on a Siemens Sonata; 3T whole body MRI scanner. Each session began with a 3-plane localizer followed by a sagittal localizer, and an inversion recovery T1 weighted scan (TE/TR = 2.61/285 ms, matrix 192 × 192, FOV = 220 mm, flip angle = 70°, bandwidth = 501 Hz/pix, 51 slices with 2.5 mm thickness). The AC-PC

Table 4
Results of reading times (in ms), standard errors in parentheses.

Condition	Verb	Complement Head	Comp. Head +1	Comp. Head +2
AspV-Animate	553.45 (7.30)	608.01 (8.70)	502.08 (7.13)	538.99 (9.07)
AspV-Inanimate	558.28 (6.98)	613.86 (8.81)	494.20 (6.29)	556.45 (10.01)
Control	537.93 (6.58)	598.98 (9.34)	474.50 (5.28)	511.49 (7.59)

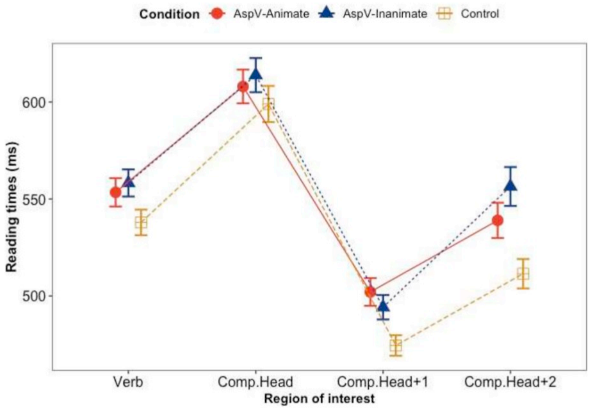

Fig. 4. Results of reading times (in milliseconds).

(anterior and posterior commissure) line was defined by this acquisition for prescription of the anatomic T1 images and functional images in the following series.

Functional measurements. We conducted event-related functional MRI using gradient echo-planar imaging (EPI) blood oxygenation level dependent (BOLD) contrast, with TE = 30 ms, TR = 956 ms, matrix 84 × 84, FOV = 210 mm, flip angle = 62°, bandwidth = 2289 Hz/pixel, slice thickness = 2.5 mm, with 321 measurements (images per slice). The scanner was set to trigger the stimulus presentation program, which enabled the image acquisition to be synchronized with the stimulus presentation. At the end of the functional imaging, a high-resolution 3D Magnetization Prepared Rapid Gradient Echo (MPRAGE) was used to acquire sagittal images for multi-subject registration, with TE = 2.77 ms, TR = 2530 ms, acquisition matrix 256 × 256, FOV = 256 mm, bandwidth = 179 Hz/pix, flip angle = 7°, 176 slices with slice thickness = 1 mm. The fMRI data within subjects was registered to this brain volume, which was then registered across subjects into a common 3D brain space by the Yale BioImage Suite software package (Papademetris et al., 2006).

3.2. fMRI data analysis

The data were converted from Digital Imaging and Communication in Medicine (DICOM) format to analyze format using XMedCon (Nolfe, Voet, Jacobs, Dierckx, & Lemahieu, 2003). The first 6 images at the beginning of each of the 10 functional runs were discarded during the process to enable the signal to achieve steady-state equilibrium between radio frequency pulsing and relaxation, leaving 315 images per slice per run for analysis. Functional images were motion-corrected with the Statistical Parametric Mapping (SPM) 5 algorithm (www.fil.ion.ucl.ac.uk/spm/software/spm5) for three translational directions (x, y, z) and three possible rotations (pitch, yaw, roll). Trials with linear motion that had a displacement exceeding 1.5 mm or rotation exceeding 2° were rejected. The data from one participant were excluded because of severe head movements. All further analyses were performed using BioImage Suite (Papademetris et al., 2006).

We analyzed individual subject data by using a General Linear Model (GLM) on each voxel in the entire brain volume with regressors specific for each task. In data analysis, each sentence was segmented into two events (i.e. two regressors), which correspond to the hypothesized processing stages involved in the comprehension of AspV sentences. **Event 1** included the onset of the subject noun phrase until the offset of the main verb (ranging between 1000~1500 ms, depending on the length of subject noun phrase). **Event 2** included the onset of the complement noun phrase until the offset of the sentence-final word (ranging between 1500~3500 ms, depending on the length of the phrase). During this time window (i.e. after encountering the complement), readers were hypothesized to resolve dimension ambiguity out of those functions retrieved from the verb's lexical representation so as to determine the dimension along which the complement is construed as a structured individual and mapped onto the directed path structure.

The resulting beta images of each task were spatially smoothed with a 6 mm Gaussian kernel to account for variations in the location of activation across subjects. The output maps were normalized beta-maps, which were in the acquired space (2.5 mm × 2.5 mm × 2.5 mm). We then calculated three registrations within the BioImage Suite software package to map the data onto a common reference space. The first registration carried out a linear registration between the individual subject raw functional image and that subject's 2D anatomical image. Then the 2D anatomical image was linearly registered to the individual's 3D anatomical image. The 3D differs from the 2D in that it has a 1 × 1×1 mm resolution whereas the 2D z-dimension is set by slice-thickness and its x-y dimensions are set by voxel size. Finally, we computed a non-linear registration between the individual 3D anatomical image and a reference 3D image. The reference brain used was the Colin27 Brain (Holmes et al., 1998) in Montreal Neurological Institute (MNI) space (Evans et al., 1993). All three registrations were applied sequentially to the individual normalized beta-maps to bring all data into the common reference space.

Using BioImage Suite, two-tailed paired *t*-test maps were generated to examine the differences between tasks. Family-wise error (FWE) correction for multiple comparisons was conducted with 3dClustSim from AFNI (version 18.0.09) using the autocorrelation function option and 10,000 iterations. Input smoothness for these simulations was estimated from the residuals of the *t*-tests. Results are shown at $p < .05$ corrected with an initial p threshold of $p < .01$.

3.3. Imaging results

The comprehension task showed 90.53% accuracy (ranging between 75.11~96.86%, SD = 6.17% across participants), suggesting that the participants attended to the reading task. Regarding the imaging results, we report the findings of each event below (Table 5).

At *Event 1* (Subject + Verb composition), no significant activation was found. At *Event 2* (Complement Head~Sentence-final), the AspV-Animate condition preferentially recruited left inferior frontal gyrus (LIFG, including Broca's area: BA 44, 47, left insula), left Angular Gyrus (AG, BA 39), and precuneus (BA 7) as compared to the Control condition (Fig. 5). Similarly, the AspV-Inanimate condition preferentially recruited left BA 44 (pars opercularis) of the LIFG as compared to Control (Fig. 6). We further consolidated both AspV conditions into one general AspV condition (AspV-All) and compared them to the Control condition; this revealed stronger activation for the AspV-All in left frontal cortex (LFC), including left BA44, 45, left insula, as well as left AG (BA 39), precuneus (BA7), and medial BA 8 (Fig. 7). Regarding the animacy contrast of AspV sentences, preferential activation was observed for AspV-Animate (> AspV-Inanimate), also only at Event 2, in posterior cingulate region, precuneus, visual cortex, and part of the orbitofrontal cortex (medial BA 11) (Fig. 8).

In short, both the AspV-Animate and AspV-Inanimate conditions engendered preferential activity in left inferior frontal gyrus—left pars opercularis in particular—associated with AspV-complement composition (Event 2). Beyond the shared activation, the AspV-Animate condition induced preferential activity in the posterior cingulate region and visual cortex as compared to the AspV-Inanimate condition.

4. Discussion

To summarize the results: Exp. 1 (self-paced reading) shows that both the AspV-Animate and AspV-Inanimate conditions engender longer RTs than the control counterparts. This comprehension cost is observable right after the complement head noun is encountered. Exp. 2 (fMRI) reveals that AspV-Animate condition shows greater activity in left AG, left frontal cortex (LFC), and the precuneus than Controls. Importantly, both AspV conditions, when compared to the control counterpart, preferentially recruit left frontal cortex (LFC), and only when the complement head is encountered. Furthermore, the AspV-Animate condition, while sharing the same activation pattern with the AspV-Inanimate condition, additionally recruits the posterior cingulate cortex. These results evidence that comprehension of not only AspV-Animate but also of AspV-Inanimate sentences require additional processing effort, and that they have overlapping activation patterns both preferentially recruiting the left frontal areas. This highly converging behavioral and neurological pattern involving the two configurations is consistent with a unified analysis of aspectual verbs that gives rise to two readings depending on context. It is inconsistent with a view that treats the two readings as two separate verb meanings. Finally, the fMRI pattern of results separates the behavior of animacy from that of agency, consistent with the analysis that the former is not necessarily a linguistic feature but a correlated conceptual property.

In what follows, we first explicate how the behavioral and neurological results of the two AspV configurations are captured by the conceptual approach instantiated by the SIH 1.2 & 1 as well as the implications of the findings. We then ask the question of how the apparent cost-free nature of animacy composition can be reconciled with the correlation with the kind of reading, agentive vs. constitutive, an AspV sentence may have, and provide an explanation within the context of the SIH and control asymmetry.

Table 5
Imaging results: region activation for each contrast (Note: BA = Brodmann areas).

Contrast	Region	Volume (mm^3)	Mean T-value	Max T-value	Max MNI coordinate [x, y, z]
AspV-Animate > Control	Left BA47, Insula	2091	3.93	6.84	[-36, 18, −1]
	Left BA44	1322	3.47	4.90	[-51, 14, 21]
	Left BA39, BA7	1421	3.65	5.53	[-27, −61, 42]
AspV-Inanimate > Control	Left BA44	2581	3.64	5.90	[-45, 21, 21]
AspV-All > Control	Left BA44, BA45, Insula	6460	3.65	7.67	[-36, 18, 0]
	Left BA39, BA7	2124	3.53	5.14	[-26, −63, 40]
	Medial BA8	2277	3.72	6.39	[-6, 32, 42]
AspV-Animate > AspV-Inanimate	Medial BA11	1328	3.48	6.77	[-7, 36, −18]
	Left BA19	2584	3.57	6.07	[-9, −54, −3]
	Medial BA17, BA18	8391	3.45	6.27	[-14, −93, 18]
	Medial PostCing, BA7	4615	3.60	5.70	[-3, −64, 41]
	Right white matter (near BA40)	1389	3.78	6.46	[30, −21, 37]

Note: In Fig. 5~8, the color bar represents the positive activation strength for the former condition as compared to the latter in each contrast. All figures show activation of positive differences only. The coordinates are in MNI space.

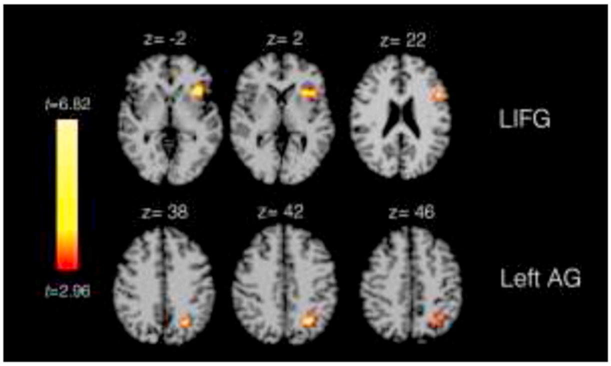

Fig. 5. Activation for AspV-Animate > Control at Event 2.

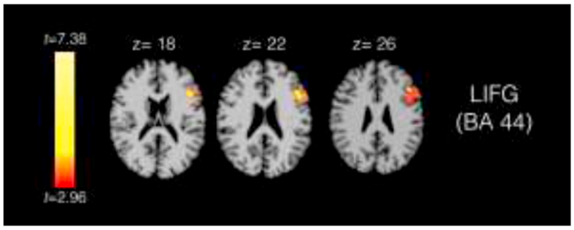

Fig. 6. Activation for AspV-Inanimate > Control at Event 2.

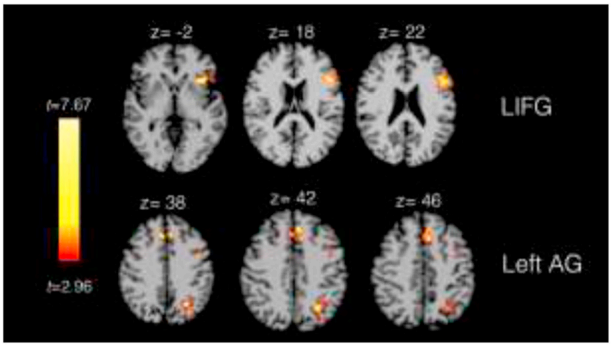

Fig. 7. Activation for AspV-All$_{\{animate,\ inanimate\}}$ > Control at Event 2.

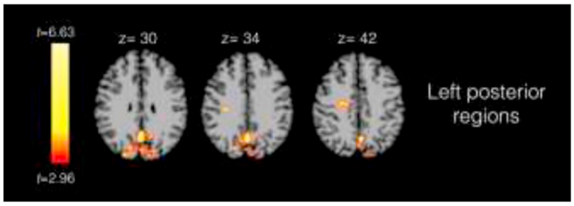

Fig. 8. Activation for AspV-Animate > AspV-Inanimate at Event 2.

4.1. Results support the concept composition approach

We begin with the discussion of the behavioral results whereby the processing cost previously observed in aspectual-verb composition with animate-denoting subjects and entity-denoting complements emerges (e.g., *Sue begins the book*). Our results further show that comparable cost also emerges in aspectual-verb composition with inanimate-denoting subjects and entity-denoting complements (e.g., *Chapter 1 begins the book*). This overlap in processing cost across the two AspV conditions is consistent with previous findings (DiNardo, 2015) and capturable by the SIH, according to which the cost of processing AspV sentences is rooted in the lexico-conceptual compositional demands of the verb with its complement, irrespective of the animacy of the subject. Concretely, processing cost emerges from the ambiguity resolution triggered by the need to select a dimension-function out of the set available from the verb so that the complement, once construed as a structured individual along a dimension, can properly compose with it. As pointed out in Section 1.1, both the AspV-Animate and AspV-Inanimate configurations involve a constitutive reading along various dimensions, with the AspV-Animate configuration additionally licensing an agentive reading along the eventive dimension in the absence of context. From the processing perspective, this predicts that all transitive sentences with aspectual verbs will exhibit dimension ambiguity (e.g., spatial, informational, eventive) and subsequent ambiguity resolution, leading to increased cost, and that this will be the case regardless of the animacy of the subject denotation. This is precisely what we observed.

With respect to the neurological findings, two key findings are reported during verb-complement composition (Event 2): (i) overlapping preferential activation of left frontal cortex (centered around the traditional Broca's area) and left angular gyrus associated with the two AspV conditions, as compared to controls, (ii) additional preferential recruitment of posterior cingulate region, precuneus, and the visual cortex associated with the AspV-Animate condition vs. AspV-Inanimate condition. We discuss each in turn.

4.1.1. Verb-complement composition: general pattern

We hypothesize that aspectual verbs require their complement to denote a structured individual, which can be construed as an axis along various possible dimensions afforded by the complement's conceptual representations (e.g., spatial, informational, eventive, temporal). Processing AspV sentences thus requires the retrieval of dimension functions encoded in the verbs, the construal of the complement as a structured individual, and the ultimate ambiguity resolution that the construal along more than one dimension generates. For Event 2, two loci of activation are reported involving the language network: left angular gyrus (AG) and left frontal cortex (LIFG). We propose that they correspond to distinct language processing mechanisms respectively: conceptual composition and ambiguity resolution. We provide independent justification below.

Left Angular Gyrus and conceptual composition. In line with previous work on the cortical localization of conceptual integration processes, we propose that the process of compositing dimension representations, involving mapping structured individuals to various dimensions via AspV's lexical functions, is what results in the observed recruitment of the angular gyrus (AG, BA 39, part of Wernicke's area). The recruitment of left AG for conceptual-semantic integration has already been suggested independently (Badre, Poldrack, Paré-Blagoev, Insler, & Wagner, 2005; Binder, Desai, Graves, & Conant, 2009; Damasio, Grabowski, Tranel, Hichwa, & Damasio, 1996; Humphries, Binder, Medler, & Liebenthal, 2007; Lau, Phillips, & Poeppel, 2008). The AG has been proposed to support the integration of conceptual-semantic information or the process of conceptual combination (Boylan, Trueswell, & Thompson-Schill, 2015; Price, Bonner, Peelle, & Grossman, 2015). This body of work suggests some level of consensus regarding the role that left posterior cortex plays in lexical retrieval and conceptual composition, in line with our hypothesis regarding the dimension-function retrieval and composition for AspV sentences.

Left frontal cortex and ambiguity resolution. The other recruitment locus observed for Event 2 is that of the left frontal cortex (LFC), including left BA 44, 45, 47, and left insula. We argue that the preferential recruitment of this substantial frontal cortical region corresponds to the resolution of dimension ambiguity necessary for the composition of the verb and its complement (Ardila, Bernal, & Rosselli, 2014; Hoenig & Scheef, 2009; Price, 2010). The connection between LFC recruitment and ambiguity resolution has been well documented in the literature (Badre, Poldrack, Paré-Blagoev, Insler, & Wagner, 2005; Krain, Wilson, Arbuckle, Castellanos, & Milham, 2006; Lau et al., 2008; McMillan, Clark, Gunawardena, Ryant, & Grossman, 2012; Rodd, Longe, Randall, & Tyler, 2010, 2011). For example, Rodd et al. (2010) show that the contrast between sentences with high vs. low semantic ambiguity elicited left inferior frontal gyrus (LIFG) including BA 44, 45, and 47. The subsequent study further evidences that LIFG is activated both by ambiguous words and by the subsequent disambiguating information, suggesting that this area is involved in semantic ambiguity resolution (Rodd, Johnsrude, & Davis, 2011). Likewise, in the study of Badre, Poldrack, Paré-Blagoev, Insler, & Wagner (2005) where the participants were asked to select the word that best matched the cue in semantic features, the number of target options (4 vs. 2) and the associative strength between the cue and the target modulated activation in left mid ventral-lateral prefrontal cortex. As we can see, the pattern of recruitment observed here overlaps with previous ones attributed to ambiguity resolution. What the current study also shows is that the resolution is true for both the AspV-Animate and AspV-Inanimate condition (centered in left pars opercularis), further evidencing that what is at issue is a general process of ambiguity resolution triggered by verb-complement semantic composition, independent of subject animacy.

In our experimental design, the two AspV conditions, which differ in subject animacy, contrast with the Control condition in the involvement of dimension ambiguity (see Section 1.1). What the imaging results show is that AspV-Animate and AspV-Inanimate patterned alike in preferentially recruiting left AG and LFC, as compared to the Control condition. This suggests that subject animacy *per se* does not contribute significantly to the neural correlates at the compositional level. Rather, we suggest the observed neural network in the frontal-parietal regions is associated with processing multiple dimension compositions required for all AspV sentences in the absence of disambiguating context, while not required for the Control condition, hence the contrast.

4.1.2. Recruitment associated with animacy

While AspV-Animate and AspV-Inanimate sentences induced comparable RTs and overlapping cortical recruitment in LFC, they show a neurological difference in the posterior cingulate area, leading us to conclude that this area may have specific involvement regarding subject animacy. Interestingly, this area has been associated with the retrieval of episodic memory, autobiographical memory, and event recall (Addis, Wong, & Schacter, 2007; Binder et al., 2009; Graham, Lee, Brett, & Patterson, 2003; Hassabis & Maguire, 2007; Summerfield, Hassabis, & Maguire, 2009). This connects very much with the conceptual role that animacy plays in the interpretation of AspV sentences. Specifically, while in a context-neutral situation animacy *per se* does not predict the agentive vs. constitutive reading, an animate interpretation of the subject correlates with the eventive dimension for the complement—the only configuration that supports the agentive reading in addition to the constitutive reading (see Fig. 2). That is not the case with the

AspV-Inanimate configuration which can yield a constitutive reading along more than one dimension. Given the current experimental contrast, the preferential recruitment of the posterior cingulate region for the AspV-Animate condition is considered to reflect the sensitivity of the mapping between the subject-complement relation and the underspecified sentence interpretation. Since the AspV-Animate sentences engender an additional agentive reading as compared to the AspV-Inanimate ones, this recruitment is likely associated with animate-based or agency-based functions such as autobiographical memory and event recall, in which an animate subject is perceived as an agent/controller of an event (*cf.* Wallentin, Østergaard, Lund, Østergaard, & Roepstorff, 2005). The superset relation in cortical activation between the two configurations, i.e. AspV-Animate ⊇ AspV-Inanimate, supports this interpretation. The pattern suggests that the two conditions are in almost complete overlap differing only by the availability of the agentive reading, in the absence of discourse context.

In fact, Grewe et al. (2007) found that left posterior cingulate cortex was activated more for sentences without animacy contrast between arguments (both being animate) as compared to sentence with animacy contrast (one being animate and the other, inanimate, though they did not discuss this region further). They also found increased activity in left posterior superior temporal sulcus (pSTS) for this contrast; the authors argue that left pSTS was engaged in processing the animacy relation at the sentence level. On the other hand, Wallentin et al.'s (2005) fMRI study reports no significant neural activity for subject-animacy contrasts in sentences like "*The man/trail goes through the house.*", suggesting that animacy *per se* is not a good categorical indicator for neural specificity.

While the role of animacy in sentence comprehension has been examined in many previous neurolinguistic studies, most of which manipulate animacy-thematic anomalies with respect to verbs' selectional restrictions, mainly manipulating the Agent-Patient semantic fit or animacy reversal in relative clauses (e.g., Chen et al., 2006; Kim & Osterhout, 2005; Kuperberg et al., 2007, 2008; Paczynski & Kuperberg, 2011; Weckerly & Kutas, 1999). The different findings reported in literature regarding argument animacy could be due to different constructions used. At the same time, the impact of subject animacy in comprehending underspecified meaning remains unclear. The current study differs from previous studies in that in the AspV sentences used here, there is no animacy restriction for this class of verbs; therefore, the effect observed could not be due to animacy violation. What is at play is the evaluation of argument relation denoted by the sentences—i.e. the control asymmetry between subject and complement participants in the denoted situation, and this likely underlies the differential neural recruitment. As Grewe et al. (2007) argues, animacy should be considered as a relational property at the sentence level rather than an isolated feature in terms of sentence processing. Our findings contribute to clarify the role of argument relation in the meaning computation in simple active sentences where the structure remains constant while interpretations differ. We suggest that it is the control a/symmetry between sentence arguments as perceived in situation that factors into sentence interpretation, reflected in neural correlates.

Visual cortex recruitment for language tasks: evidence of generalized processing load. Moreover, the contrast between the two AspV conditions engendered differential activity in the visual areas at Event 2 (Complement head ~ sentence-final). We interpret this activity as reflecting greater processing load involved in the comprehension of AspV-Animate sentences as compared to AspV-Inanimate sentences due to more available dimension representations of the former. Specifically, and in line with previous interpretations of similar cortical activation patterns, we believe that the visual cortex activity observed is due not to some language-specific process necessarily, but to the general memory and attention demands correlated with the language task which in this case result in a systematically heavier load (Bedny, Pascual-Leone, Dodell-Feder, Fedorenko, & Saxe, 2011; Kastner & Ungerleider, 2001; Nobre, Allison, & McCarthy, 1998; Petersen & Posner, 2012; Piñango, Finn, Lacadie, & Constable, 2016).

In brief, the findings of Exp. 1 and Exp. 2 confirm that (i) all AspV sentences require additional processing effort regardless of subject animacy, (ii) the subset relation between the two AspV configurations in terms of available dimension readings, AspV-Animate readings ⊇ AspV-Inanimate readings, parallels their embedded neural recruitment. Furthermore, (iii) the processes associated with comprehending AspV sentences recruit localizable cortical regions in left AG and LFC, consistent with the concept composition approach as instantiated by the Structured Individual Hypothesis. The general pattern of both AspV conditions implicates a connectivity network of left AG and LFC for the processing of underspecified sentence meaning, involving concept composition guided by lexico-semantic representations and ambiguity resolution.

In addition, in the current study we incorporated both the behavioral and imaging methodologies, which provide complementary insights on real-time semantic processing. It is worth noting that the difference in subject animacy between the AspV-Animate and AspV-Inanimate condition appeared only neurologically at Event 2 (see Section 4.1.2) but was not observed in the behavioral data, though the similar pattern of the two AspV conditions appeared in both experiments. That is, the behavioral and imaging findings showed convergent patterns, but not completely, which could be in part due to the nature of different methodologies. The neural activations showed a fine-grained distinction—more posterior cingulate region for sentences with animate-denoting subjects—reflecting the tendency that an animate-denoting subject is conceived as an agent in an event more typically, as compared to an inanimate one. On the other hand, the compositional loads resulted from processing multiple semantic representations are reflected in both behavioral and neurological measurements, both showing that sentences with underspecified semantic ambiguity require additional effort than those without. Evaluating different types of measurements informs which aspects of language processing are tapped by human neural and cognitive systems, implicating a more detailed picture of sentence meaning comprehension.

4.2. The conceptual perspective of processing underspecified meaning

In Section 1.2, we argue that the distinction between the agentive vs. constitutive readings of AspV sentences is determined, not by subject animacy, but by the control relation between the participants denoted by the subject and the complement, respectively. This conceptual parameter thus reconciles the seemingly cost-free process of animacy composition with aspectual verbs observed in Exp.1 (self-paced reading). We suggest that what underlies the animacy categorization is not a distinct binary system but a *conceptual* *gradient*, control asymmetry, a metric that enables the comprehender to evaluate, as it were, the specific degree of control differential between the participants in a sentential meaning given a contextual expectation. It is this evaluation along the conceptual metric continuum that determines the ultimate reading of the sentence; the greater the control asymmetry between subject and complement referents, the greater the perceived "animacy" of the subject referent for instance. Crucially, calculating the control asymmetry between participants in the continuum must be done for each subject-complement pair encountered regardless of where the relation will lie in the continuum, hence the absence of observable cost difference between the animate-denoting and inanimate-denoting subject composition.

With respect to the imaging findings (Exp.2), a preferential activation of the posterior cingulate area is observed for the AspV-Animate over the AspV-Inanimate configuration. We conjecture that the additional cortical involvement for the AspV-Animate configuration might be associated more specifically with the perceived greater control ability of the subject referent, likely due to the bias introduced by the animate-denoting subject. Although more research will be needed to flesh out the neural underpinnings linked to the calculation of control asymmetry between participants during sentence processing and even non-linguistic environments, we note that expressing animacy considerations in terms of control asymmetry calculation over situation participants is a move in a fruitful direction, as it allows us to separate the entities themselves from the contextual constraints (functional and cultural) that lead to attributions of sentience to those entities by a perceiver.

The control asymmetry parameter (Piñango, 2018) not only distinguishes the two readings of AspV sentences but also differentiates between the meanings of AspV and the control psychological-verb (PsychV) sentences. On the conceptual approach suggested here, the subject referent of AspV sentences in the agentive reading has higher control power than the subject referent of PsychV sentences; that is, regardless of subject animacy, control asymmetry is higher in the agentive reading of AspV sentences. To assess control asymmetry, we employ the "*What X do is .....*" test to first diagnose volitional involvement in actions, a property independently associated with the notion of control (Culicover & Jackendoff, 2005; Dowty, 1991, pp. 547–619).

(9) a. AspV-Animate in the Agentive reading:
✓ What John (*as an actor*) did was begin the book.
b. AspV-Inanimate in the Agentive reading:
✓ What the printer (*as an actor*) did was start the paper.
c. AspV-Animate in the Constitutive reading:
*What John (*as a story character*) did was begin the book.
d. AspV-Inanimate in the Constitutive reading:
*What the short prologue did was begin the book.
e. PsychV: *What John did was love the book.

As (9) reveals, only AspV sentences—regardless of animacy—in the agentive reading is perceived as having higher control asymmetry unequivocally; PsychV sentences do not seem to pass the test. The pattern lines up with Table 1, suggesting that the ultimate sentence interpretation corresponds to the control asymmetry calculation given the participants in a specific situation.

On a related note, the notion of control is often associated with *volitionality*. For instance, within the force-dynamics approach (Croft, 2012; Talmy, 1988), the concept of Agent is defined as an antagonist that has volitional intrinsic force tendency. Dowty (1991, pp. 547–619) lists the involvement of volition as a contributing property of the Agent Proto-Role. Jackendoff (1990, p.129) suggests the feature [± volitional] as one characteristic of Agent ("volitional Actor").[4] Here we do not distinguish between control and volition to the extent that an entity that has control over his/her behavior is volitional in performing the action. Using Jackendoff's test for volitionality—compatibility with *deliberately* (volitional) and *accidently* (non-volitional), we observe that [+volitional] is most compatible with the agentive reading of AspV sentences, a pattern similar to greater control asymmetry such that the subject referent has more control over the complement referent.

(10) a. AspV-Animate in the Agentive reading:
✓ The man (*as an actor*) began the book *deliberately*.
b. AspV-Animate in the Constitutive reading:
? The man (*as a story character*) began the book *accidentally/*deliberately*.
c. AspV-Inanimate in the Constitutive reading:
*The long prologue begins the book {*deliberately/accidentally*}.
d. PsychV:
?The man loved the book {*deliberately/accidently*}.

In sum, the control asymmetry calculation between participants outweighs their animacy and better predicts the final sentence interpretation. This conceptual parameter explains why there would be no cost to the animate subject-verb composition as compare to the inanimate subject counterpart, showing that animacy is epiphenomenal. In this regards, animacy is a label that we give to participants when they are conceived as controllers in situations of high control asymmetry. Yet, this calculation must be performed for every sentence regardless of semantic verb class, thus predicting no observable difference in processing cost between the

[4] For Jackendoff, Agent could be a doer of action, a volitional actor, or an extrinsic instigator.

configurations differing in subject animacy. We thus suggest that comprehenders make reference to the parameter of control relation in conceptual structure as they interpret the corresponding sentence meaning in context. This view is supported by the overlapping behavioral and neural patterns evoked by the AspV-Animate and AspV-Inanimate configurations. We end the section with the observation that the concept composition approach together with the empirical observations lead us to connect the specific linguistic analysis for aspectual-verb composition and the associated processing and neurological findings with a farther reaching model of conceptual composition; an approach that thus provides the necessary grounding connecting lexical-semantic constraints to generalized concept composition.

5. Conclusion

In this study, we examine how the lexico-semantic underspecification in aspectual verbs is resolved in composition with animate vs. inanimate-denoting subjects. While all previous studies examine sentences in composition with animate-denoting subjects, the current study clarifies that the processing cost is not due to subject animacy but better associated with the processing of concept composition rooted in lexical semantico-conceptual demands of the aspectual predicate. We show that AspV-sentence interpretation results at least in part from the calculation of control asymmetry between the participants denoted by the verb's arguments as perceived by the comprehender. This conceptual parameter, control asymmetry, provides a foundation for understanding the distinction between agency and animacy, as lexico-conceptual (linguistic) vs. conceptual properties respectively.

Finally, our results show that all transitive sentences with an aspectual verb, regardless of subject animacy, engender overlapping patterns in reading times and cortical recruitment. The findings are consistent with an account whereby during real-time comprehension, the processor retrieves the lexical-dimension function information encoded in the verb to guide the composition with the complement. It achieves successful interpretation once a dimension has been chosen along which the structured individual is to be construed and mapped onto the directed path structure (DPS). The construal of structured individuals along a dimension and subsequent mapping onto the DPS amounts to ambiguity resolution. The bias introduced by the subject denotation completes the conceptual representation associated with the whole sentential expression. Crucially, during such composition, the control asymmetry between the subject and complement denotations, and not the animacy of the subject denotation in isolation, biases interpretation towards either an agentive (high control asymmetry) or a constitutive (low control asymmetry) reading. Our results suggest that the degree of this control asymmetry, a relational parameter (vs. any single intrinsic property of the denotations), is the key conceptual interpretive factor that the brain appears sensitive to as comprehension unfolds.

Declaration of competing interest

The authors report no conflict of interest for this work.

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Appendix A. Supplementary data

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