Force dynamics in verbal semantics:
Verbs of maintaining

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A long-standing puzzle in the event-structure literature concerns the status of "maintaining" predicates like *keep* and *stay* (Jackendoff, 1972). They are clearly eventive, as diagnosed by the usual eventuality tests; for example, the progressive gets an 'ongoing-now' reading, as in *John is keeping the door open* or *The door is staying open*, while present tense is interpreted as habitual, as in *John keeps the door open* or *The door stays open*. However, it is difficult at first glance to understand what distinguishes these predicates from stative predicates such as *The door is open* and *John has the door open*. Both kinds of predicates refer to a situation in which the door's being open endures over time, so there is no obvious formal rationale for their distinct Aktionsart types. Yet at the same time, there is an intuition that the dynamicity of maintaining predicates is not an accident, as there is energy being put into the situation. It is not immediately obvious how to formally characterize a dynamic eventuality in which energy is put into the situation but nothing changes.

Within the framework of Montagovian formal semantics, we can imagine several neo-Davidsonian analyses for *keep*, but they are all unsatisfactory. We assume that *keep* and *stay* take a small clause complement p; in the case we are examining, p would be [the door open]). The problem with (1a) ("cause to be") and (1b) ("cause to become") is that it is possible to keep something in a location without strictly being the cause of its being there or coming to be there. On the other hand, *keep* might instead be "cause to stay," as in (1c). But for *stay* we run out of options: there can be no external argument or causing event, and there is no obvious way to combine the caused event e_2 and the small clause predicate p in such a way as to reflect the fact that *stay* is

not the same as *be*.

(1) a. keep =? $\text{AGENT}(x, e_1)$ & e_1 CAUSE e_2 & $\text{BE}(e_2, p)$

b. keep =? $\text{AGENT}(x, e_1)$ & e_1 CAUSE e_2 & $\text{BECOME}(e_2, p)$

c. keep =? $\text{AGENT}(x, e_1)$ & e_1 CAUSE e_2 & $\text{stay}(e_2, p)$

d. stay $\neq$ $\text{BE}(e_2, p)$

What is needed is some way to represent the idea that maintaining events involve the input of energy into a situation. Other kinds of events, of course, should also involve the input of energy; however, with these other kinds of events, the input of energy results in a different situation from the initial situation, while with maintaining events, the result of inputting energy is the same as the initial situation.

We propose to alter the neo-Davidsonian framework to view events—intuitively speaking—as inputs of energy into situations (Talmy, 1988, 2000), and—formally speaking—as forces that are functions from one situation to another, where the latter situation is the one that results provided that no other force intervenes. A situation s is a collection of individuals and their properties, a notion compatible with DRT-like theories (Kamp and Reyle, 1993) but also compatible with treatments of situations as partial worlds (Barwise and Perry, 1983; Kratzer, 1989). A force is a function f from situations to situations; i.e., it is type $\langle s, s \rangle$, which we will abbreviate as type f. The theorem in (2a) connects forces with situations, the definition of successor in (2b) links them into causal chains, and the terminology introduced in (2c) allows us to recover initial and final situations from a force.

(2) a. For any situation s_n, there is a

force f_n such that f_n is the net force of s_n.

b. For any situation s_n, its successor s_{n+1} is defined as $f_n(s_n)$.

c. For any force f_n which is a net force of a situation s_n, $\text{init}(f) =: s_n$ and $\text{fin}(f) =: s_{n+1}$.

By the formal object we call a "force," we mean to include not just contact forces that result in a change in the spatiotemporal properties of an object, i.e., where it is, whether it is moving or at rest, etc. In these cases, the situations init(f) and fin(f) differ only in the the spatiotemporal properties of objects. But in fact, any change could be represented abstractly as a function from one situation to another.[1] One robust category of such abstract forces is the category of what we may think of as "psychological forces." For example, just as we can speak of pushing or putting pressure on an object, we can also speak of pushing or putting pressure on someone, in a psychological sense, to accept an idea or to do an action. The idea that the conception of the physical world is co-opted for use in the psychological or psychosocial domain is present in Jackendoff (1987) and Lakoff and Johnson (1999), among many others (see, e.g., Bloom et al. (1999) for a representative sample). Talmy (1988, 2000) has extensively championed this view that force dynamics is the way to understand this link between the physical and the psychological. For example, while the sentence in (3a) (Talmy, 2000, (vol 1): 412) is "force-dynamically neutral," the sentence in (3b) conveys that some other force, whether physical or psychosocial, prevents John from going out of the house if he wants to.

(3) a. John doesn't go out of the house.
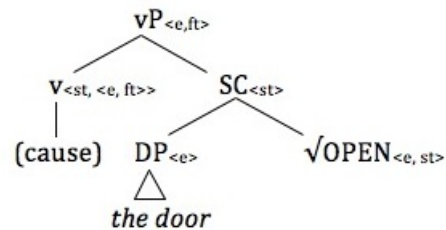   b. John can't go out of the house.

Wolff (2007), for one, has tested this idea experimentally, showing subjects a scene in which a pedestrian wants to go in a certain direction and a policeman directs her to go in a certain (possibly different) direction, and asking if the policeman *caused* the pedestrian to reach her dest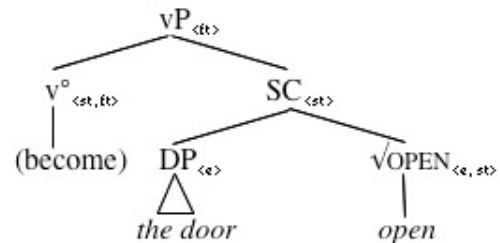ination, *helped* her reach her destination, or *prevented* her from reaching her destination. The results exactly parallel the results he obtains with inanimate objects exerting forces on each other. Based on such findings, it is not controversial to treat even non-spatiotemporal events as forces. So John can keep the door closed by pressing it closed, or he can keep Mary home by forbidding her to go out (and having the authority to make sure she obeys); in either case, he will be applying a maintaining force, whether physical or psychological in origin.[2]

To analyze *keep* and *stay* under a force-based framework, we first present logical forms for *cause* and *become*. *Cause* introduces an external argument (with a "source" role, similar to an agent role), while *become* does not. The initial situation is one where the small clause predicate p does not hold, and the final situation is one where p does hold (Jackendoff, 1972; Dowty, 1979; Pustejovsky, 1991). The event of someone opening the door (for *cause*) or the door opening (for *become*) is represented by the force f that effects the transition from door-not-open to door-open.

(4) $[\![\text{cause}]\!] = \lambda p\ \lambda x\ \lambda f\ .\quad \neg p(\text{init}(f))\ \&\ p(\text{fin}(f))\ \&\ \text{source}(x,f)$

(5) $[\![\text{become}]\!] = \lambda p\ \lambda f\ .\quad \neg p(\text{init}(f))\ \&\ p(\text{fin}(f))$

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[1]This abstraction is already present in Aristotle's *Physics* (V:1), although he does not extend the analysis to verbs of creation and destruction.

[2]We recognize that the notion of a psychological force is more complex than the notion of a physical force, in that it involves a belief of the entity desiring the outcome. We address the intensional character of psychological forces in Copley and Harley (2010).

For *keep* and *stay*, the intuition is that energy must be added to an initial situation to maintain identity between it and the final situation. This is true when the net force of an initial situation would, without the additional maintaining force, normally produce a transition to a different final situation. (Stative predicates such as *The door is open* characterize situations with a zero net force, where no energy need be inputted to maintain the situation). The predicates *keep* and *stay*, then, are very similar to the predicates *cause* and *become*. Both take a predicate-of-situations (that is, type $\langle$ s, t$\rangle$) complement. They require that this type $\langle$s, t$\rangle$ complement be true of both the initial situation and the final situation. *Keep* and *stay* will also be differentiated in the same way as *cause* and *become* in that *keep* introduces an external argument and *stay* does not. Thus, the logical forms of *keep* and *stay* are as follows:[3]

(6)   a. $[\![keep]\!] = \lambda p \ \lambda x \ \lambda f$. $p(\text{init}(f))$ and $p(\text{fin}(f))$ and $\text{source}(x,f)$

       b. $[\![stay]\!] = \lambda p \ \lambda f$. $p(\text{init}(f))$ and $p(\text{fin}(f))$

We assume that when *keep* or *stay* takes another eventive predicate as its complement, as in *John kept Bill running around all day*, the aspect represented by *-ing* has applied to map the type $\langle f,t \rangle$ constitutent [run around all day] to an appropriate $\langle s,t \rangle$ predicate. (This suggests, perhaps, that *Bill kept running around all day* involves a control structure with a PRO subject of the gerund in the lower constituent.) Predicates like *endure* and *preserve* consist of the *stay* and *keep* functions with null existence predicates in their complements.

Two issues that arise with verbs of maintaining deserve further attention. Firstly, certain uses of verbs of maintaining seem to involve "maintenance by prevention" as in the example in (7) (due to an anonymous reviewer):

(7)   The cattle grid kept the road clear of

animals.

In this case, the cattle grid prevents the animals' actions that would normally cause the road to not be clear of animals. We propose an analysis inspired by Wolff's (to appear) force-dynamic analysis of "causation by omission", in which the force-dynamic configurations for *A prevents B* and *B prevents C*, taken together, result in the force-dynamic configuration for *A causes C*.

The second issue that arises has to do with cases that seem to involve not physical forces, but behavior that is out of the ordinary for the agent. For example, (8) can indeed be uttered when John is not physically preventing the door from closing:

(8)   John is keeping his door open.

In that case, however, the hearer accommodates the idea that John does not typically have his door open. We suggest that the force being opposed in (8) is a force of John's typical tendency to close his door. This tendency can be compared to the tendency of an object to fall in the gravitational field of the earth; cf. the Aristotelian explanation (Physics, VIII:4) for gravity, in which heavy things (earth, etc.) have a tendency to descend, while light things (smoke, fire) have a tendency to ascend; Talmy (2000) as well uses this notion of tendency to understand forces. Just as the force of gravity on an object can be understood as the object's tendency to fall, so can John's tendency to close his door be understood as a force on John.

We will discuss some further implications of this proposal for argument structure, including for activities. Activity predicates have no associated result state; we treat such predicates (*sing,* etc.) as pure predicates of forces. Within this framework, their special ability to function as manner predicates in Accomplishment constructions such as *John whistled his way to the store* is unsurprising.

To the extent that this proposal captures the argument structure of verbs other than verbs of maintaining, but also captures other verbs such as *cause*, *become*, and Activity verbs, the import of this proposal goes beyond merely accounting for a backwater of ver-

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[3]A reviewer points out that there is a grammatical difference between *keep* and *cause*, namely that the former takes a bare VP (e.g., *John kept the door open*) and the latter takes an infinitival clause (e.g., *John caused the door to open*). We believe this difference to be orthogonal to the difference between *keep* and *cause*, as a verb very similar to *cause*, namely *make*, also takes a bare VP complement (e.g., *John made the door open*).

bal semantics. The understanding of events as forces could clarify the interface with the cognitive system, since its ontology–situations as arrangements of individuals with the forces on them—may be preferable to that of the event-based framework with its concatenated events that somehow cause one another. It should also be preferable to treatments of situations as partial worlds (Barwise and Perry, 1983; Kratzer, 1989), since it is not at all clear how to make cognitively plausible sense out of possible worlds.

Another advantage of our approach has to do with how arguments of the verb are composed in syntax. The particulars of the force-situation framework suggest that it is more straightforwardly compositional than is the event-based framework. In the latter, the constituents denoting subevents are related to each other by means of a stipulated "CAUSE" interpretive relation, imposed when a type mismatch is detected between the event-denoting subparts of the vP. In the force-situation framework, however, all components of the vP are composed via function application, just as other nodes in the structure are; the lower VP in John opened the door, for example, which we take to be a small clause [the door open] with denotation $\langle s,t \rangle$, is selected by a v^0 head of type $\langle \langle s, t \rangle, \langle e, \langle f,t \rangle \rangle \rangle$, such that the $\langle s, t \rangle$ predicate denoted by the VP is interpreted as the final state of the force introduced by the v^0 head.

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