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TALKING ABOUT CAUSING EVENTS

ABSTRACT: Questions about the nature of the relationship between language and extralinguistic cognition are old, but only recently has a new view emerged that allows for the systematic investigation of claims about linguistic structure, based on how it is understood or utilized outside of the language system. Our paper represents a case study for this interaction in the domain of event semantics. We adopt a *transparency thesis* about the relationship between linguistic structure and extralinguistic cognition, investigating whether different lexico-syntactic structures can differentially recruit the visual causal percept. A prominent analysis of causative verbs like *move* suggests reference to two distinct events and a causal relationship between them, whereas non-causative verbs like *push* do not so refer. In our study, we present English speakers with simple scenes that either do or do not support the perception of a causal link, and manipulate (between subjects) a one-sentence instruction for the evaluation of the scene. Preliminary results suggest that competent speakers of English are more likely to judge causative constructions than non-causative constructions as true of a scene where causal features are present in the scene. Implications for a new approach to the investigation of linguistic meanings and future directions are discussed.

1. INTRODUCTION

Since Davidson's (1967) classic treatment of action sentences as involving reference to the ontological category *event*, the "event analysis" has increased in popularity. And, in the face of new linguistic generalizations, it has also increased in complexity. As a result, sentences containing a causative verb like *move* in (1) are often analyzed as involving reference to not one, but two events: the causing event (e.g., Al's action), and the caused event (the table's movement).

(1) Al moved the table.

Correspondingly, since at least Michotte (1946) there has been a great deal of research investigating the psychological mechanisms employed in event perception. The emerging view in psychology is that there are event *percepts* that exist independently of how we think about "things that happen" — percepts that function to discretize the continuous flow of experience into useful units that feed further cognitive processes (Liverence & Scholl 2012). The perception of causality between two events has, in particular, been shown to be fast, automatic, irresistible, stimulus-driven, and independent of the perceived animacy of the causer (Scholl & Tremoulet 2000).

Here, we offer a demonstration of how these literatures might be brought together, by asking how event structure, as encoded in the logical forms of sentences, might interact with extralinguistic cognition and perception. If the meaning of a sentence tells speakers what the world must be like in order for that sentence to be true, then speakers must use their non-linguistic capacities to verify whether the world is that way. More precisely, if the logical forms posited by semanticists indicate the truth conditions for natural language expressions, competent speakers must have the means to identify whether those conditions are satisfied by making use of their extra-linguistic cognitive resources.

The simplest hypothesis, and that which we propose, is that the interface between the human language faculty and relevant aspects of cognition is *transparent*. The guiding idea is that the logical forms encoded by natural language are satisfied directly by representations in extralinguistic cognition. In particular, we hypothesize that the event variables appealed to in the logical analysis of sentences like (1) range over representations of events, and that event percepts, if structured appropriately, can represent the satisfiers of the structured predicates and propositions that such sentences denote. In our test case, we show how appeal to a two-place causal concept in the semantics of causative sentences can predict the recruitment of simple, visually-constructed causal percepts.

This paper thus represents a small contribution to a new and growing literature that uses well-understood properties of visual processing to attempt reverse inferences into the nature of natural logical form. Supposing that the interface between language and extralinguistic cognition is *natural* (Baker 1997) or *transparent* (Goldman 2007), examining the types of cognitive processes engaged when a sentence is evaluated for truth or falsity can lend insight into the representational format of the meaning that a sentence encodes. It has been shown, for example, that if the compositional semantics of a sentence specifies the computation of a greater-than relation, English speakers will evaluate such sentences using visual magnitude estimation and comparison, as opposed to e.g. a one-to-one matching procedure — even when the visual scene biases towards the latter strategy (Pietroski et al. 2009). The relevant linking hypothesis has been dubbed the Interface Transparency Thesis (ITT):

Interface Transparency Thesis: The verification procedures employed in understanding a declarative sentence are biased towards algorithms that directly compute the relations and operations expressed by the semantic representation of that sentence (Lidz et al. 2011, p, 233).

On our view, the compositional semantics of a sentence is a recursive specification of instructions to build complex concepts out of simpler ones (Pietroski 2010, in press). "Lexical concepts", novel to the language faculty, form the basis for this composition. Lexical concepts are introduced during language acquisition as a bridge between (arbitrary) phonological forms and (antecedently available) primitive concepts, which themselves imbue sentences with our sense of their meaning. On our view, to decide whether a given sentence is true, one must locate or construct an extralinguistic representation that is structured in the way demanded by the predicates and relations encoded in the sentence. Put another way, "meanings" can ground judgments of truth just in case the existential claims they express can be verified by correlative representations in perception or cognition.

Unlike other views on the nature of the relationship between language and extralinguistic perception and cognition, this view suggests an interdisciplinary arena in which philosophers, linguists, and psychologists can work together to gain new insight into the nature of language and the conceptual structures of the mind. In our case study, we consider the semantics of causal eventive sentences and the psychology of event perception. In §2, we generate novel predictions about how speakers understand sentences like (1), and we test these predictions experimentally in §3. Our aim is to gain insight into the nature of the logical forms that the language faculty assigns to expressions, construed mentalistically. The upshot is that, if slight variations in the linguistic forms used to describe a task result in quite different patterns of behavior, and if those patterns can be understood in the context of well-understood aspects of extralinguistic cognition, this can inform us about the aptness of the semantic analysis of those forms.

2. EVENT LANGUAGE

In this section, we review the history and development of what we will call the "bi-eventive" analysis of causative sentences. The question is, how best to capture the fact that certain verbs, like *move*, are capable of systematically appearing both in a transitive (2a) and intransitive frame (2b)? This pattern, dubbed the *causative-inchoative alternation*, is robust in English and many other languages. Importantly, whenever a verb so alternates, speakers understand that the intransitive form (2b) is *entailed* by the transitive form (2a).

(2) a. The red ball moved the blue ball.
b. The blue ball moved.

Such patterns are interesting insofar as there are other verbs whose meanings do not appear *prima facie* all that different, and yet do not show the alternation. The non-causative verb push is rigidly transitive — i.e., (3a) is grammatical, but (3b) is not. (A "*" preceding a sentence indicates ungrammaticality.)

(3) a. The red ball pushed the blue ball.
b. *The blue ball pushed.

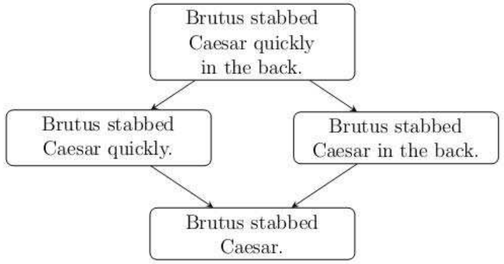
Historically, there has been a progression from semantic analyses that treat *move* and *push* as essentially interchangeable, to ones that explicitly encode the differences in the kinds of inferences they support. On classical approaches, nothing formally distinguishes CAUSATIVE (*move*) from NON-CAUSATIVE (*push*) verbs: both simply denote two-place predicates (4a-4b), where 'Red' and 'Blue' denote the "red/blue ball" respectively.

(4) CLASSICAL
a. MOVE(*Red,Blue*)
b. PUSH(*Red,Blue*)

The shift from classical to Davidsonian analyses involves augmenting forms like those in (4a-4b), having them appeal to an event variable e. This shift is motivated in part by the desirability of capturing certain "diamond-shaped" patterns of inferences between sentences containing adverbial modifiers and their unmodified counterparts. Competent speakers understand that the expressions in (5) admit to the patterns of inference in (6), where the arrows represent the direction of inference.

(5) a. Brutus stabbed Caesar quickly in the back.
b. Brutus stabbed Caesar quickly.
c. Brutus stabbed Caesar in the back.
d. Brutus stabbed Caesar.

(6)



Modeling speaker inference as logical entailment, the Davidsonian approach captures these patterns as follows. The logical forms in (5′) represent Davidsonian translations of the sentences in (5). Beginning with (5′a), these logical forms exhibit patterns of entailment isomorphic to the inferences observed for the sentences in (5), by simple conjunction reduction.

(5′) a. $\exists e[\text{STAB}(e,\mathit{Brutus},\mathit{Caesar})\ \&\ \text{QUICK}(e)\ \&\ \text{IN-THE-BACK}(e)]$
b. $\exists e[\text{STAB}(e,\mathit{Brutus},\mathit{Caesar})\ \&\ \text{QUICK}(e)]$
c. $\exists e[\text{STAB}(e,\mathit{Brutus},\mathit{Caesar})\ \&\ \text{IN-THE-BACK}(e)]$
d. $\exists e[\text{STAB}(e,\mathit{Brutus},\mathit{Caesar})]$

On this approach, the addition of the event variable as a component of the verb's satisfaction conditions permits those variables to act as a kind of 'pivot' for recursive adverbial modification. A consequence of this view is that the truth or falsity of sentences is determined not only based on whether a certain sort of relation obtains, but on whether a certain kind of event exists. The relevant events may be more or less elaborately specified, and the "diamond-shaped" inference patterns are explained via entailment relations between logical forms.

Crucially, however, on this analysis just as on the classical view, nothing in the logical form distinguishes causative and non-causative verbs. Their logical forms on the Davidsonian view are as in (7a-7b).

(7) DAVIDSONIAN
a. $\exists e[\text{MOVE}(e,\mathit{Red},\mathit{Blue})]$
b. $\exists e[\text{PUSH}(e,\mathit{Red},\mathit{Blue})]$

Parsons (1990) further articulated the event analysis, introducing what are now known as *Neo*davidsonian logical forms. On this account, all but the event argument is severed from the verb's denotation. Parsons' view is motivated in part because it allows for explicit labeling of the roles played by the participants in the events that sentences describe. On this account, the denotations of the subject and object of a sentence like (5) no longer serve as satisfiers of the verb, but instead satisfy thematic role relations that are themselves related to the verb via event predication.

This shift captures the fact that, while speakers endorse the inference from the sentence in (8a) to both of those in (8b) and (8c), speakers do *not* endorse the inference from the sentence in (8b) *alone* to the sentence in (8c).

(8) a. Brutus kicked Caesar.
 b. Brutus kicked.
 c. Brutus kicked something.

The first endorsement is expected on the Davidsonian account, in which the logical form of (8a), namely (8′a), entails the logical forms of (8b) and (8c), namely (8′b) and (8′c). However, the failure of speakers to endorse the inference from (8b) to (8c) is *unexpected*: the logical forms of these sentences, (8′b) and (8′c), are identical, and hence necessarily mutually entailing.

(8′) a. $\exists e[\textsc{kick}(e,Brutus,Caesar)]$
 b. $\exists e \exists e[\textsc{kick}(e,Brutus,x)]$
 c. $\exists e \exists e[\textsc{kick}(e,Brutus,x)]$

The issue is that (8b) has the interpretation that Brutus *fails* to kick anything at all, as when he kicks into the air. Parsons proposes that, if the event participants (those denoted by e.g. *Brutus* and *Caesar*) are introduced by separate “thematic predicates”, these patterns are expected. On his formulation,[1] Parsons suggests that the “external argument” of a verb, typically denoted by the subject of a sentence, is introduced by the thematic predicate Agent, and the “internal argument” is introduced by the thematic predicates Patient or Theme.

On Parsons’ proposal, (8a)–(8c) have the logical forms in (8″a)–(8″c). Here, (8″a) entails (8″b) by conjunction reduction and (8″c) by existential generalization; however, (8″b) fails to entail (8″c). Again, assuming that speakers’ inferences are well-modeled by entailments in logical forms, distinguishing the contribution of the names from that of the verbs in such forms explains the fact that speakers fail to infer (8c) from (8b).[2]

(8″) a. $\exists e[Agent(e,Brutus)\ \&\ \textsc{kick}(e)\ \&\ Patient(e,Caesar)]$
 b. $\exists e[Agent(e,Brutus)\ \&\ \textsc{kick}(e)]$
 c. $\exists e \exists e[Agent(e,Brutus)\ \&\ \textsc{kick}(e)\ \&\ Patient(e,x)]$

To explain the inference from sentences like (2a) to sentences like (2b) Parsons further articulates logical form. He posits that the translation of causative sentences contains the element CAUSE, a relation between events. Formally, appeal to CAUSE allows for the reference to the inchoative event to be contained within the reference to the causative event as in (9): it is clear that (9a) entails (9b).[3] In causative sentences, the Agent and Patient roles are related to distinct events, here e and e', respectively.

(2) a. The red ball moved the blue ball.
 b. The blue ball moved.

(9) a. $\exists e[Agent(e,Red)\ \&\ \exists e'[\textsc{move}(e')\ \&\ Theme(e',Blue)\ \&\ \textsc{cause}(e,e')]]$
 b. $\exists e[Agent(e,Red)\ \&\ \textsc{push}(e)\ \&\ Theme(e,Blue)]$

Thomson (1987) (see also Fodor & Lepore 1998; Pietroski 2005) expresses skepticism towards appeal to an element like CAUSE in the logical form of transitive sentences, offering the following kind of case. Imagine a situation in which Al sets his house on fire, and as a consequence, some water sitting in a pot on the stove boils. Speakers will assent to (11b) as an accurate description of what happened in such a situation, but not to (11a). (11a) intuitively implies a more direct relation between Al and the boiling event than is satisfied by such circumstances.

(11) a. Al boiled the water.
 b. Al caused the water to boil.

A related objection can be drawn from Fodor (1970). On a Parsons-style analysis, non-synonymous sentences are assigned the same meaning, since as Parsons’ claims, any causative verb construction is synonymous with a construction with the overt use of *cause* (Fodor 1970, p. 109). Fodor highlights a problem for this kind of paraphrastic commitment with examples like (12). This pair illustrates that the expression *cause* admits of more temporal flexibility than the causative construction *per se*, insofar as the latter expression seems infelicitous (as indicated by the question marks).

(12) a. John caused the house to burn on Sunday, by lighting a fuse on Saturday.

b. ??John burned the house on Sunday, by lighting a fuse on Saturday.

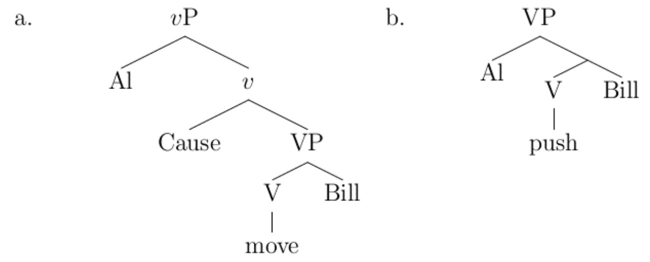
Such arguments assume that both (11a–11b) and (12a–12b) invoke CAUSE, the predicate that links causative and inchoative events in logical form; if they do, the sentences should be synonymous, contrary to fact. Parsons addresses both of these counterexamples by insisting on a distinction between two notions of ‘cause’, one direct and the other indirect. A causative sentence makes use of a direct sense of ‘cause’, while sentences with the word *cause* can make use of an indirect sense. In the proposed counterexamples, the interpretation of cause is clearly the indirect one. Thus, Parsons claims, they fail to apply to his proposal because each pair of expressions contain different notions of ‘cause.’

We think there is a better reply in defense of the event analysis. The purported counterexamples (and at times, Parsons’ own analysis) rely on a presumed identity between an implicit predicate in logical form, and an explicit predicate in English. However, these predicates differ at least as much as open and closed class lexical items do. The meanings, characterized extensionally for the moment, of open class words like *dog, cat, run, red*, and *happy* may vary widely from person-to-person even within a given language, while the meanings of closed class words like *of, the, a*, etc. are apparently uniform, constituting core grammatical knowledge.

The open class is not fixed in an individual’s youth, as evidenced by the fact that normal speakers update the “contentful” subset of their lexicons regularly throughout their life. In contrast, the “functional” subset is rarely (if ever) updated past the critical period in language acquisition. The English word *cause* is, if anything, part of the “open-class” vocabulary; we have no indication that the covert relational predicate Parsons proposed is anything of the sort. Thus, we can make the distinction clear formally, representing the open class word *cause* as CAUSE( ) (on analogy with DOG( ) or PUSH( )), and the covert relational predicate as Cause( ).

There is nothing implausible to the claim that the causal predicate introduced reflexively in the syntax of certain constructions has a different interpretation than what underlies the interpretation of the English word *cause*. While Parsons argues that the open class CAUSE is ambiguous (as it might very well be), our contention is that the predicate relevant for the bi-eventive analysis is not an open class term at all, but has a distinct (and fixed) meaning not necessarily tied to the English term. Indeed, as Thomson herself suggests, the semantic relation between a verb and its external argument (the subject of a transitive clause) seems to be primitive in some sense, and the interpretation of the English word *cause* likely being somewhat derivative.

Following Folli & Ramchand (2005), we propose that sentences with causative verbs like *move* have a structural analysis at least as complex as those in (13a), and sentences with non-causative verbs like *push* have an analysis like that in (13b).[4] The interpretation of Cause is given in (14) (cf. Pylkkänen 2002): its semantic function is to bind the open event argument introduced by the verb *move*, and introduce a new argument for the causing event.



(13)

(14) Cause $=\lambda P\lambda e'[\exists e[P(e) \;\&\; \underline{Cause}(e',e)]]$

Thus, the interpretation of (13a) is as in (15a) and (13b) as in (15b). On what we will call the “cognitive interpretation” of such forms, the predicate Cause is true of pairs of event *representations* $<e,e'>$, such that the first bears the (cognitive) relation Cause to the second. Here, (15a) will be verified by an event representation with two component events, one in which an Agent acts such that a Theme is Caused to move, and (15b) by an event representation with only one event component, one in which an Agent acts on a Theme.

(15) a. $\exists e'[Agent(e',Al) \;\&\; \exists e[\textsc{move}(e) \;\&\; \underline{Cause}(e',e) \;\&\; Theme(e,Bill)]]$

b. $\exists e[Agent(e,Al) \;\&\; \exists e[\textsc{push}(e) \;\&\; Theme(e,Bill)]]$

3. EXPERIMENTS AT THE INTERFACE

In the previous section we discussed the analysis of small linguistic structures, some of which refer to multiple events and a causal relation between them, and others referring to only one event. In the introduction, we discussed the hypothesis that the satisfiers of logical forms are representations in extralinguistic cognition. The question now is, how could we find evidence that something like Parsonian logical forms are good representations for how speakers understand causative as opposed to non-causative sentences?

It is often true that seemingly high level concepts are influenced by perception, e.g. causality and animacy (Scholl & Tremoulet 2000). The classic example of this phenomenon is present in displays like those from Heider & Simmel (1944). There, participants were asked to describe short scenes involving the interaction of geometrical shapes, that moved in accordance with linear trajectories in and around a rectangular space. By manipulating the trajectories and orientations of these shapes, Heider & Simmel found that participants would often attribute high-level motives such as cooperation and duplicity to the geometric shapes.

Likewise, manipulating low-level properties of visually-presented information can give rise to cognitive representations involving high-level properties like causation. In the paradigm developed in Michotte (1946), low-level incremental manipulations of simple shape interactions give rise to causal judgments in subjects. In his stimuli, a ball of one color moves across the screen to come into contact with a ball of a different color, as shown schematically in Figure 1. Michotte reported that, within a certain temporal window between the moment of contact between two balls, subjects will report perceiving that the second movement was caused by the first. That is, as the first ball moves toward and contacts the second (stationary) ball, there is a well-defined window of time after this contact in which the second ball's movement is seen as being caused by the movement of the first.

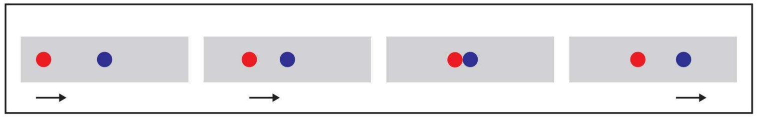


Figure 1: Michotte-type stimuli

In more contemporary experiments (see Scholl & Tremoulet 2000 for review), it has been shown that *spatial* parameters can be varied and still evoke causal percepts, showing that contact between the balls is not necessary. Restated, this perceived causal relationship between the movement of the two balls is not dependent on the two balls contacting each other. So long as the first ball comes within a well-defined distance of the second ball, participants still judge the movement of the second ball as caused by the movement of the first, so long as the movement occurs within the well-defined temporal window.

In designing our study, we used simple (Michotte-type) stimuli that have been shown in past studies to give rise to causal percepts. The stimuli consisted of a red circle (or "ball") and a blue circle (or "ball") on a gray background. In all conditions, the red ball moved toward the blue ball from the left side of the screen, as in Figure 1. We manipulated the movement of the two objects in one of two ways: by either changing the LAG (the delay between the termination of movement of the red ball, and the commencement of movement by the blue ball), or GAP (the distance from the blue ball at which the movement of the red ball terminated). We created five temporal LAG levels, ranging from 0ms to 200ms (0ms, 50ms, 100ms, 150ms, 200ms), and five spatial GAP levels, ranging from 0cm to 2cm (0cm, .5cm, 1cm, 1.5cm, 2cm). For every combination of LAG and GAP settings, subjects were presented with 8 trials, for a total of 250 trials/subject. The balls moved at a rate of 40 degrees of visual angle a second, a velocity that reliably produces causal percepts (cf. Scholl & Nakayama 2002). Both manipulations are known to alter the causal percept of observers; in particular, greater levels of LAG and GAP tend to reduce subjects' perception of causality (Scholl & Tremoulet 2000).

Previous studies investigating causal perception have often given subjects overt instructions (and training) regarding whether stimuli are to judged as causal (e.g. Schlottmann & Anderson 1993). In past studies investigating the parameters of causal judgments, subjects were given extensive numbers of training trials and overt instructions regarding what types of scenes do and do not count as causal. Because we are interested in the implicit relationship between the language faculty and extralinguistic cognition, we avoided providing such explicit training. We reasoned that the event structure subjects infer from a target sentence's meaning would guide their performance in the task.

Our experiment had four conditions, each corresponding to a change in a target sentence of the instructions (16A-D). Subjects were told that they would be presented with short animated scenes and asked to evaluate, for each scene, whether the TARGET was true of that scene. In addition to *push* (non-causative) and *move* (causative), we used sentences containing the "indirect" causative *cause to move* and the causative verb *launch*.[5]

(16) **Experimental conditions by target sentence and "cause level"**

CONDITION	TARGET	CAUSE LEVEL
A	The red ball **pushed** the blue ball.	low
B	The red ball **caused** the blue ball **to move**.	mid-low
C	The red ball **moved** the blue ball.	high
D	The red ball launched the blue ball.	high

"Cause level" in (16) should be understood as labeling the predicted frequency of recruitment of the causal percept upon evaluating the sentence. The word *push*, since it is non-causative in the sense we're exploring, should show the lowest frequency of recruitment of the causal percept. In contrast, *move* and *launch*, being causative verbs, should show the highest. Given that explicit mention of *cause* leads to looser standards for the directness of the causative relation, we expected an intermediate response with such constructions.

In a pilot study, we evaluated responses to an intransitive sentence containing the (non-causative) verb *touch* (i.e., *the red ball and the blue ball touched*). Pilot data revealed a pattern of responses in which the only trials that were judged 'true' were ones in which contact was made between the red and blue ball. Based on these data, and combined with the results from the causal perception literature, we posited two possible interpretations of the TARGETs that would give rise to 'true' answers: CONTACT, or CAUSE (cf. Young & Sutherland 2009, p. 733). The (idealized) patterns of responses if subjects choose one or the other interpretation for our experiment are shown in Figure 2.

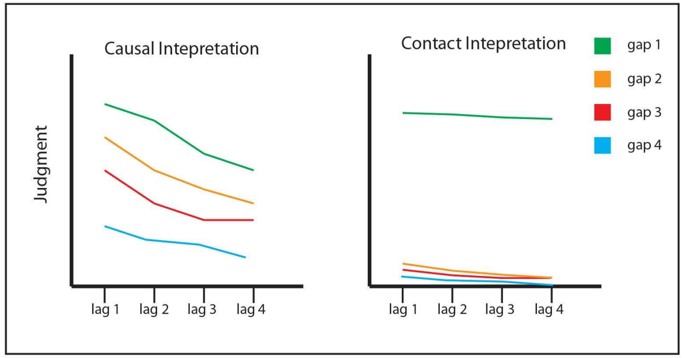


Figure 2: Idealized plots reflecting two interpretations of Michotte-type stimuli

It appeared to us, intuitively, that any of the sentences in (16A-D) might require contact, and deliver the graph on the right in Figure 2. After all, real-world interactions described by these verbs all tend to require that the interacting object come into contact. For example, to push a door open one must usually make contact with the door. Thus, if subjects' responses to the task were based on the intuitive meanings of the relevant verbs based on their experience with real-world objects, subjects would judge any non-contact scene as not satisfying the open class (e.g. English) predicate CAUSE.

However, if any subjects invoked a causal interpretation for determining the felicity of the linguistic description, we would expect the graph on the left. Importantly, the latter result would imply a non-trivial relationship between the sentence and recruitment of the causal percept. In terms of "Cause level" in (16), we reasoned that as *push* is not a causal verb, it need not recruit the causal percept. In contrast, (B-D) are all 'causal' constructions to varying degrees, and thus should recruit the causal percept. The *cause to X* construction is ranked lower on expected causality given that it allows for the "indirect" interpretation discussed in the previous section.

We tested thirty(30) undergraduates who received either course credit or $10 for participating, all of which were native speakers of American English as determined in a pre-test questionnaire. Eight(8) subjects were run in the A and B conditions and seven(7) were run in the C and D conditions. The experiment was approved by the Institutional Review Board at the University of Maryland.

Results. In this section, we present an overview of the results in light of the preceding discussion (for a summary of the statistical analyses, see the Appendix).

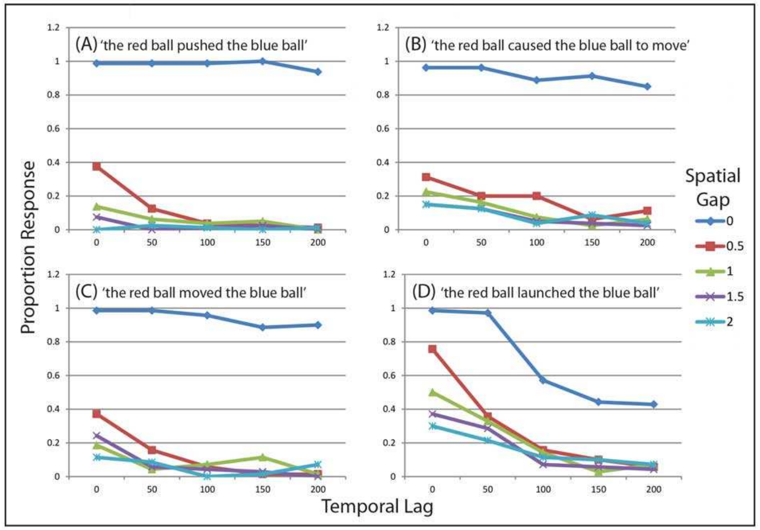


Figure 3: Results of the present study by instruction condition

The results presented in Figure 3 are supportive of the predicted effects. Overall, causative *launch* showed the highest correspondence to the expected causal graph, with levels of LAG and GAP together determining a clear declination in its acceptance as a good descriptor of a given scene. The other conditions were not as clear, though analyses reveal interesting differences. The condition with the non-causative verb *push* gave rise to the least CAUSE-based responses, whereas constructions with *move* and *cause to move* were roughly identical, and gave rise to a somewhat more CAUSE-based pattern of responses.

LAG was a marginal predictor for all but (D) *launch*. Indeed, when both LAG and GAP are included in the analysis, almost all the predictive power (i.e., model fit) in (A-C) is done by GAP. To get a better sense of the data, we conducted analyses over just the trials where GAP was set to 0 to see if there were differences between the targets for LAG (as in Michotte's original experiments). When analyzed separately in this manner, LAG is indeed a significant predictor in some but not all conditions, see Table 1. Only (A), *push*, fails to show an effect of lag with zero gap.

Since subjects' responses were binary, the influence of LAG, GAP and INSTRUCTION on performance was analyzed by logistic regression using SPSS (SPSS Inc, Chicago, IL). In addition to LAG and GAP, INSTRUCTION condition provided significant model improvement in predicting the likelihood of the data, ($\chi 2(1) = 33.462$, $df=3$, $p < .001$). Further, interaction terms for LAG-by-condition and GAP-by-condition were also significant based on model improvement, LAG-by-condition: ($\chi 2(1) = 24.809$, $p < .001$); GAP-by-condition: ($\chi 2(1) = 89.151$, $p < .001$). Together, these results warranted investigating the influence of LAG and GAP on the individual instruction conditions.

Table 2 in the appendix summarizes the results of regressing subjects' judgments on LAG and GAP for each of the four INSTRUCTION conditions. In all conditions LAG and GAP were both significant predictors of response (i.e. both increased the likelihood of the data). However, as can be seen from the tests of model improvement, GAP was a far better predictor than LAG in conditions (A), (B) and (C), while LAG and GAP were similar in terms of producing model improvement for condition (D). Across all four INSTRUCTION conditions, the negative coefficients show that increased GAPs and LAGs made subjects less likely to respond that the instruction sentence was true of the scene — and this was especially true for GAP.

Inspecting the distribution of response proportions in Figure 3, conditions (A), (B) and (C) have distributions somewhat similar to the CONTACT interpretation (especially (A)), while in (D) subjects clearly took the CAUSE interpretation. However, no condition was purely CONTACT. For example, in (A) LAG was not a significant predictor when there was no GAP ($\chi 2(1) = 3.27$, p= .071), in line with CONTACT, but LAG was a significant predictor across all GAP distances ($\chi 2(1) = 62.99$, p < .001).[6] Also, in (B) and (C), the slight decrease in proportion of responses with zero GAP was significant, respectively: $\chi 2(1) = 7.98$, p < .01, $\chi 2(1) = 10.12$, p < .01. Further, the steep decrease in (D) under the no GAP trials was highly significant, $\chi 2(1) = 96.163$, p < .0001 (see Appendix).

Given the similarity of the response proportions for (B) and (C) (they are virtually indistinguishable in Figure 3), we tested whether they were significantly different. After LAG and GAP, the addition of instruction condition as a predictor did not provide significant model improvement for the (B) and (C) data: $\chi 2(1) = 2.248$, $p = .134$. This suggests (B) and (C) were comparable in terms of the interpretations adopted by the subjects.

Table 1: **Effect of temporal LAG on data likelihood, when GAP = 0cm**

(A)	PUSH	$\chi 2(1) = 3.27$, p = .071	n.s.
(B)	CAUSE TO MOVE	$\chi 2(1) = 7.98$, p < .01	*
(C)	MOVE	$\chi 2(1) = 10.12$, p < .01	*
(D)	LAUNCH	$\chi 2(1) = 96.16$, p < .001	**

Discussion. The data presented in the graph for condition (D) aligns with the predictions outlined in the discussion above. This finding is compelling given that, unlike previous experiments on the perception of causality, subjects were given no instruction regarding how the scenes should pair with the displayed linguistic expressions. Yet, the subjects' judgments of felicity for the causative construction *The red ball launched the blue ball* tracked the conditions that give rise to the causal percept. However, this pattern was not present for the causative construction *The red ball moved the blue ball*, as we had lower overall cause-based responses in condition (C) *move*. Manually inspecting the results by individual subjects, our impression is that 2/7 subjects chose CAUSE in (C) whereas 5/7 did in (D) *launch*.[7]

However, this discrepancy has a possible explanation, which we are currently testing. In Michotte's original experiments, a ratio of 3.6:1 for Red:Blue velocity was determined ideal for evoking the causal percept. That is, subjects' causal percepts were most strongly reported when the movement of the first ball (prior to contact) was 3.6 times faster than the movement of the second ball (after contact). However, in our experiments the velocity ratio between the two balls was always 1:1 (the first ball always moved at the same velocity as the second ball). The strong effect we found for (D) *launch* (and the weak effect we found for (C) *move*) could thus be a product of that ratio. In normal situations, if something caused another thing to move by force, it is unlikely that the force of the causer's movement would wholly transfer into the movement evoked in the causee. In our scenes, there was always equal strength of movement, which is natural for the (presumably lexical) requirements of *launch*, but unnatural for those of *move*.

4. CONCLUSION

We presented data suggesting that English speakers' behavior in a simple task is sensitive to subtle semantic features of the sentences used in the instructions. We gave subjects sentences that differed little in their surface meaning (*move/push* on the one hand, and *push/launch* on the other), yet they differ in their underlying syntax/logical form. The verbs *move* and *launch* participate in the syntactic causative-inchoative alternation, but *push* does not. Our results so far are novel in that we gave subjects nearly no explicit instruction. Construing logical forms as cognitive objects that are used to guide comprehension, we found preliminary support for the idea that linguistic analyses differentially, and correctly, predict behavior in an essentially non-linguistic task.

These data suggest intriguing possibilities for future work. "Syntactic bootstrapping" approaches posit that speakers (young and old) of a language have knowledge of systematic relationships between syntactic and semantic form, which they can use to restrict the range of possible meanings for a novel word (Gleitman 1990). Past work has shown (e.g. Naigles 1990; Fisher et al. 1994; Yuan & Fisher 2009) that children can infer aspects of an event described by a novel verb based on the number of arguments it appears with, even on first exposure. However, it is not known whether children would make judgments corresponding to adults' based on simple, Michotte-type stimuli after hearing sentences that do/do not support Cause.

The most pertinent future direction we foresee is in event segmentation. The logical forms discussed in this paper suggest that two event representations contribute to the interpretation of a causative sentence.

Zacks et al. (2001) asked subjects to segment a continuous stream of complex action into either fine- or coarse-grained units, with the resultant pattern that fine-grained units are nested within coarse-grained units. This suggests that event representations are hierarchical, with smaller events contained within and constituting larger events. We hypothesize that, if a continuous stream of Michotte-type stimuli were created, different instructions could give rise to different segmentation patterns as a function of the instructions' semantics. Since the movement of multiple objects in a scene can be characterized at differing granularities, individuals can view those scenes as either few coarse-grained events, or many fine-grained events. Subtle differences in linguistic constructions might well influence the manner in which individuals represent the events in those scenes. This segmentation methodology could similarly be extended to children, since we know infants as young as 6 months (Sharon & Wynn 1998) or 10 months (Baldwin et al. 2001) are sensitive to the number of iterations in an event or to the boundaries of an event, respectively.

Finally, our results support the particular interpretation we offered as to the nature of the interaction between language and mind. Core language includes a functional vocabulary which must be related to representations in extralinguistic cognition to be qualitatively comprehended. An expression of the language can only be evaluated for truth when the predicates and relations comprising it find correlates outside of the language faculty in other areas of cognition. Some of these satisfiers may be perceptually-based, as in the data we report. The moral of this story, so far, is that the "new view", which proposes a cognitive interpretation of logical form, has great potential for fruitful, future interdisciplinary work.

Notes

[1] See Dowty (1991) for discussion of 'proto-roles'; he understands 'Agents' in events to be the entities that have the most Agent-like properties, and so on for other thematic roles. See Fillmore (1970) for early discussion.

[2] Note that the Neodavidsonian analysis has also been invoked to explain inference patterns involving nominalizations (*the kicking of Caesar by Brutus*; Higginbotham 1985; Parsons 1990, and to characterize the interpretation of sentences with multiple, quantified participants (Schein 2002).

[3] For example, by existential instantiation applied to the outer event quantification, and conjunction reduction applied to the conjunct containing the CAUSE relation.

[4] "Little-v" is a functional verbal category headed by Cause; see *ibid.*, and references therein, for relevant crosslinguistic evidence.

[5] Recall that we are defining 'causative' as 'displays the causative-inchoative alternation', which *launch* does: witness *The red ball launched the blue ball; so, the blue ball launched*. We included *launch* as this verb is often used to describe Michotte-type stimuli (see Scholl & Tremoulet 2000).

[6] That LAG was a significant predictor does not appear to be a result of the difference in sample size. Restricting ourselves to the first GAP of 0.5 cm, LAG is still a significant predictor ($\chi 2(1) = 62.628$, $p < .001$).

[7] There were only 1/8 subjects that appeared to have chosen CAUSE with each of (A) *push* and (B) *cause to move*. This inspection was of course purely qualitative, however individual subject data really did seem to conform to either a CAUSE or a CONTACT pattern like those in Figure 2.

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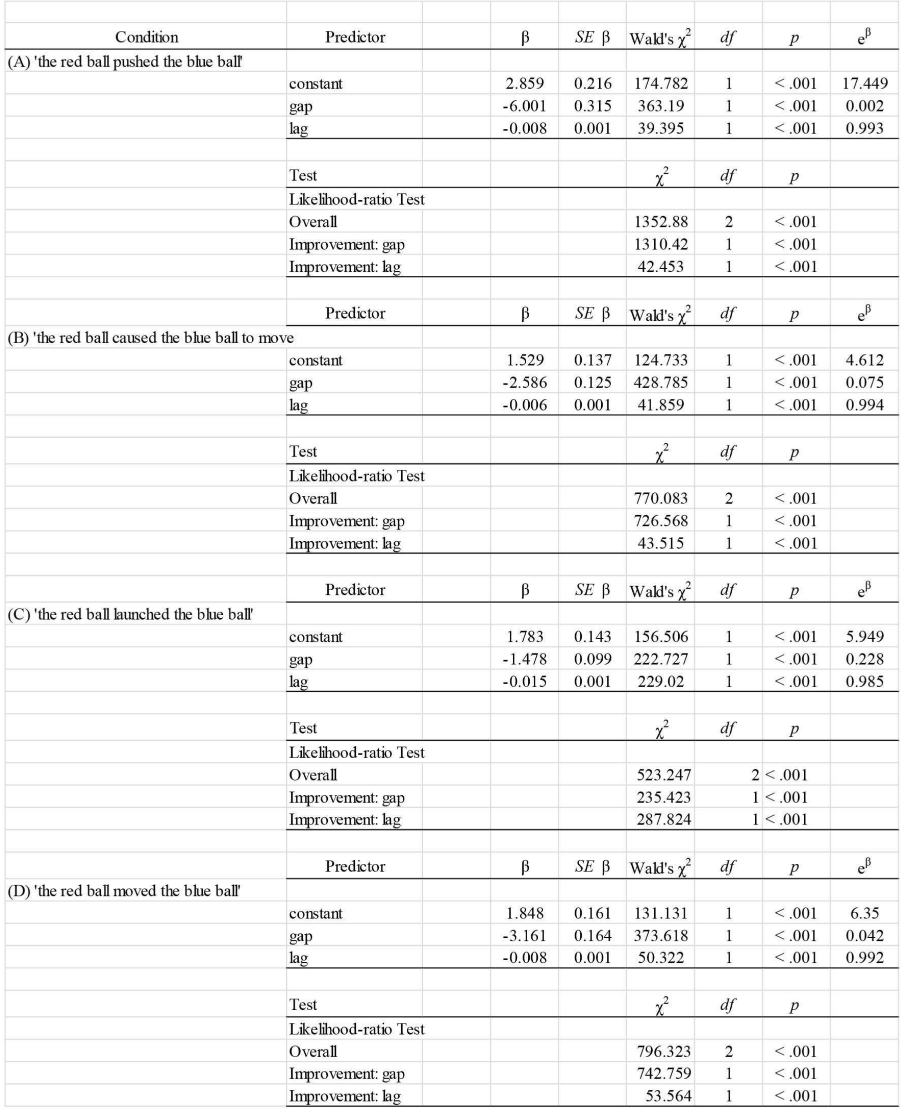
APPENDIX

Table 2: Statistical analysis of experimental results



Condition	Predictor	β	*SE* β	Wald's χ^2	*df*	*p*	e^β
(A) 'the red ball pushed the blue ball'							
	constant	2.859	0.216	174.782	1	< .001	17.449
	gap	-6.001	0.315	363.19	1	< .001	0.002
	lag	-0.008	0.001	39.395	1	< .001	0.993
	Test			χ^2	*df*	*p*	
	Likelihood-ratio Test						
	Overall			1352.88	2	< .001	
	Improvement: gap			1310.42	1	< .001	
	Improvement: lag			42.453	1	< .001	
	Predictor	β	*SE* β	Wald's χ^2	*df*	*p*	e^β
(B) 'the red ball caused the blue ball to move							
	constant	1.529	0.137	124.733	1	< .001	4.612
	gap	-2.586	0.125	428.785	1	< .001	0.075
	lag	-0.006	0.001	41.859	1	< .001	0.994
	Test			χ^2	*df*	*p*	
	Likelihood-ratio Test						
	Overall			770.083	2	< .001	
	Improvement: gap			726.568	1	< .001	
	Improvement: lag			43.515	1	< .001	
	Predictor	β	*SE* β	Wald's χ^2	*df*	*p*	e^β
(C) 'the red ball launched the blue ball'							
	constant	1.783	0.143	156.506	1	< .001	5.949
	gap	-1.478	0.099	222.727	1	< .001	0.228
	lag	-0.015	0.001	229.02	1	< .001	0.985
	Test			χ^2	*df*	*p*	
	Likelihood-ratio Test						
	Overall			523.247	2	< .001	
	Improvement: gap			235.423	1	< .001	
	Improvement: lag			287.824	1	< .001	
	Predictor	β	*SE* β	Wald's χ^2	*df*	*p*	e^β
(D) 'the red ball moved the blue ball'							
	constant	1.848	0.161	131.131	1	< .001	6.35
	gap	-3.161	0.164	373.618	1	< .001	0.042
	lag	-0.008	0.001	50.322	1	< .001	0.992
	Test			χ^2	*df*	*p*	
	Likelihood-ratio Test						
	Overall			796.323	2	< .001	
	Improvement: gap			742.759	1	< .001	
	Improvement: lag			53.564	1	< .001	