Interpretation and Representation: Testing the Embodied Conceptual Combination (ECCo) Theory

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Abstract

The Embodied Conceptual Combination (ECCo) theory differs from previous theories of conceptual combination in two key respects. First, ECCo proposes two basic interpretation types: destructive and nondestructive. Second, ECCo assumes complementary roles for linguistic distributional information and perceptual simulation information. Here, we empirically test these assumptions using a noun-noun compound interpretation task. We show that ECCo's destructive/nondestructive interpretation distinction is a significant predictor of people's successful interpretation times, while the traditional property/relation-based distinction is not. We also demonstrate that both linguistic and simulation systems make complementary contributions to the timecourse of successful and unsuccessful interpretation. Results support the ECCo theory's account of conceptual combination.

Keywords: conceptual combination; linguistic distributional information; embodied cognition; simulation.

Introduction

Conceptual combination is the process of creating and understanding new meanings from old referents. Our ability to understand novel word compounds, such as *octopus apartment* or *fame advantage*, is predicated upon the inherently constructive nature of cognition that allows us to represent new concepts by mentally manipulating old ones. Central to research into how people process such combinations is an understanding of what constitutes the representations of these concepts.

Recently, Lynott and Connell (2010a) proposed the Embodied Conceptual Combination (ECCo) theory, the core tenets of which lie contrary to traditional accounts of conceptual combination. Critically, ECCo abandons the traditional division of interpretation types into multiple categories based on assumptions of discrete features and relations, and instead argues for two categories based on the intactness of the constituent concepts. Furthermore, the ECCo theory argues for complementary, interacting roles for linguistic distributional information and perceptual-motor-affective simulation. This simulation-based representation has allowed ECCo to explain embodied effects in conceptual combination, such as visual occlusion (Wu & Barsalou, 2009) and modality switching costs (Connell & Lynott, in press), in a way that traditional theories cannot.

Interpretation Types

Broadly speaking, theorists have traditionally categorised interpretations that people produce for noun-noun compounds as either property-based (i.e., where the property of one concept is transferred or applied to the other concept e.g., a *cactus beetle* as a prickly beetle) or relation-based (i.e., where a relation is used to link both the head and modifier concepts e.g., a c*actus beetle* meaning a beetle that eats cacti). In some theories, these categories have been supplemented by less-frequent hybrid or conjunctive interpretation types (e.g., *singer songwriter* as a person who both sings and writes songs: Costello & Keane, 2000; Gagné, 2000; Wisniewski, 1997a), as well as allowing for a miscellaneous “other” category to contain valid interpretations that do not seem to fit the earlier descriptions (e.g., Gagné, 2000, Wisniewski & Love, 1998). Indeed, the hard distinction between property- and relation-based interpretations even extends to claims of distinctive processes: dual process theory (Wisniewski, 1997a, 1997b; Wisniewski & Love, 1998) holds that when a person attempts conceptual combination, discrete property and relational processes compete in parallel, with the winning process generating the specified interpretation.

To complicate matters further, the category of relation-based interpretations is often represented as a taxonomy containing numerous relations. This approach has most recently been exemplified by the CARIN theory (Competition Among Relations in Nominals), proposed by Gagné and colleagues (Gagné & Shoben, 1997; Gagné, 2000). CARIN includes a list of 16 different relations (e.g., has, made of, located etc.) that can be used to categorise interpretations, including the later addition of a “resembles” relation (Gagné, 2000) which subsumes property-based interpretations (e.g., a *coat shirt* meaning a thick shirt, because *shirt* resembles *coat* in some way). However, a problem for such taxonomies is that there is little empirical evidence for the number of relations specified: why 16 relations, and not 8 or 40? Furthermore, the psychological basis for the relational categories themselves is weak; there is no evidence to suggest that the descriptor of a relation such as “for” or “is” maps cleanly onto the representation of any particular relational function. Rather, it appears that this fractionation of interpretation types is merely a hangover from earlier linguistic research which used these labels as descriptors (e.g., Downing, 1977; Levi, 1978), rather than reflecting of any true cognitive or representational distinction between these types of combination. Many of the individual categories are often too abstract to be meaningful. For example, the "for" relation can be used to interpret *blueberry spoon* and *paint spoon*, yet their functions are markedly different: while the former might be a spoon used for serving, the latter is likely to be a spoon used for stirring (Wisniewski, 1997b). In a similar vein, Lynott and Connell (2010a) have shown how the same relation can refer either to a specific concept in the compound or simply to some feature or aspect of that concept. For example, in a *stone lion* there is no actual lion present, only a lion-shaped stone carving, while in a *stone wall*, there is both stone and a wall present. Thus, the same relations appear to represent very different content in an interpretation.

As an alternative to the traditional fragmented approach, the ECCo theory suggests two categories of interpretation: destructive and nondestructive. Destructive interpretations are those where one or both concepts are destructively reduced during the interpretation process. For example, interpreting a *zebra clam* as a clam with black and white stripes is destructive because the concept of *zebra* has been reduced solely to its constituent stripes. A nondestructive interpretation is one where both concepts remain relatively intact in the resultant representation of the compound. For example, interpreting an *octopus apartment* as an apartment where an octopus lives retains both an intact *octopus* and an intact *apartment* in the described situation. While most property-based interpretations appear to be destructive, interpretations previously classed as relation-based can be either destructive or nondestructive. For example, the combinations *stone wall* and *stone lion* would both be classified as relation-based (using a "made of" relation), but in ECCo, the former is classified as nondestructive (because both concepts are intact in the resulting interpretation), while the latter would be destructive (as there is no actual lion in the final interpretation).

Interacting Linguistic and Simulation Systems

So how do people generate destructive and nondestructive interpretations? In ECCo, interpretations are constructed when affordances of both concepts are successfully meshed in a coherent and stable situated simulation (i.e., the combined concepts do not exist in a representational vacuum, but rather incorporate a broader situational context: e.g., Barsalou, 1999). Affordances refer to the ways in which a particular object enables interaction (or meshing) with other entities (Gibson, 1979; Glenberg, 1997). In this way, ECCo views affordances as embodying much of what is often described as relational information, in that they refer to the ways in which concepts can interact (Estes, Golonka & Jones, in press), and that they extend to both concrete and abstract concepts (Lynott & Connell, 2010a). For example, the compound *elephant complaint* allows the concepts to mesh in a situation where either the complaint itself is large and important (i.e., *elephant* is destructively reduced to its size), or where the elephant is the originator or subject of the complaint (i.e., a nondestructive interpretation).

Affordance meshing takes place in the simulation system. In essence, the same neural systems that are responsible for representing information during perception, action, and introspection are also responsible for representing (or simulating) the same information during conceptual thought (e.g., Barsalou, 1999; Gibbs, 2006; Glenberg, 1997). In this respect, ECCo is distinguished from other theories of conceptual combination that are either agnostic regarding representational format (e.g., Costello & Keane, 2000; Gagné & Shoben, 1997) or adopt an explicitly amodal view (e.g., Estes & Glucksberg, 2000; Wisniewski, 1997a). However, the simulation system does not act alone. The linguistic system contains statistical distributional information that is powerful enough to support superficial strategies in a broad range of linguistic and conceptual tasks (e.g., Barsalou, Santos, Simmons & Wilson, 2008; Louwerse & Jeuniaux, 2008; Lynott & Connell, 2010a). During the conceptual combination process, both the linguistic and simulation systems interact to mutually constrain the affordances of the constituent concepts. Linguistic information can activate simulation information, which may in turn can activate further linguistic information, and so on.

For our present purposes, the essential difference between the two systems is that linguistic distributional information is best for "quick and dirty" judgements, while the simulation system is best for deeper conceptual processing. Supporting this view, Louwerse and Connell (2011) have shown that linguistic information (based on a corpus study) is capable of distinguishing words on the basis of their perceptual modality. However, this linguistic heuristic cannot distinguish vision from touch, nor smell from taste, and these three "linguistic modalities" are therefore a coarse-grained approximation of the perceptual reality of five modalities. Critically, in a property verification task that measured processing costs for switching between one modality and another (e.g., from visual to haptic), Louwerse and Connell found that this linguistic heuristic was the best predictor of fast responses, whereas perceptual simulation of five modalities was the best predictor of slow responses. Because their structures are both based on experience, the linguistic and simulation systems are, to some extent, partial reflections of each other. However, the linguistic system offers a fuzzy approximation that can provide an adequate heuristic in certain tasks, whereas the simulation system provides representational precision for more complex conceptual processing.

The Current Study

In the following experiment, we presented people with novel noun-noun compounds in a forced-choice interpretation task, where they press "yes" if they can think of a meaning for the compound, and press "no" if they cannot. This task allowed us to directly test the ECCo theory with regards to two of its primary tenets: the categorisation of interpretation types into destructive and nondestructive, and the complementary roles for the linguistic and simulations in the timecourse of processing.

Firstly, ECCo holds that, all things being equal, destructive combination is usually slower than nondestructive combination, because it is easier to leave two concepts intact than to destructively reduce one or both of them in a situationally-appropriate fashion. Traditional theories hold that property-based combination is slower than relation-based, either because the process of comparison and attribution is slower than inferring a relation (Estes, 2003; Wisniewski, 1997a), or because property resemblance is only employed as a last resort when other relations fail to produce an appropriate interpretation (Gagné, 2000). On the face of it, both ECCo and traditional approaches appear to make similar predictions. However, destructive and nondestructive categories do not map neatly onto property-based and relation-based categories, and thus make differential predictions. In the following study, we coded participants' interpretations twice: once according to ECCo's categories and once according to traditional categories. Since we believe ECCo's representational distinction between destructive and nondestructive interpretations to be a more accurate construct than traditional assumptions of relation and feature mappings, we expected the destructive / nondestructive distinction to be a better predictor of interpretation times than the relatively arbitrary property / relation-based distinction.

Secondly, ECCo describes distinct and complementary roles for the linguistic and simulations system during conceptual combination. Specifically, if the two nouns in a compound have little shared statistical, distributional history from language use, then the linguistic system offers people a reasonable heuristic for rejecting the compound as uninterpretable without expending much cognitive effort in attempting to combine the concepts. Traditional accounts of conceptual combination have little to say about the timecourse of compound rejection, and so do not provide any competing hypotheses. In the experiment below, as well as measuring interpretation times (i.e., how long it takes someone to create an interpretation for the compound), we also measured rejection times (i.e., how long it takes someone to decide the compound is uninterpretable). In support of ECCo's claim that the linguistic system is used for "quick and dirty" judgements, particularly in time-constrained situations, we expected rejection times to increase with linguistic distributional frequency.

Thus, in short, ECCo predicts inverse effects for interpretation and rejection times: the linguistic system (i.e., how frequently the two nouns have shared a context) should predict the time people take to reject a compound, while the simulation system (i.e., whether the interpretation is destructive or nondestructive) should predict how long it takes people to arrive at an interpretation.

Method

Materials Forty-one noun-noun compounds were used in this study: 14 lexicalised filler items and 27 novel test items. Filler items took the form of lexicalised noun-noun compounds (e.g., *hospital wing*, *guerrilla warfare*), with a British National Corpus frequency greater than 20 (BNC, 2001). Test items comprised novel noun-noun compounds (e.g., *octopus apartment*, *elephant complaint*) with a BNC phrase frequency of zero, and featured a range of concept types (i.e., artifacts, natural kinds, abstract concepts). All test compounds were easily interpretable: in an offline task (i.e., under no time constraints), this item set had an overall interpretation rate of 96% (Lynott & Connell, 2010b).

In order to approximate the linguistic distributional information available to these novel compounds, we carried out a corpus analysis using the Web 1T 5-gram corpus (Brants & Franz, 2006), which contains over a trillion tokens culled from Google indices and thus allows extensive analysis of linguistic distributional patterns. For each compound, we calculated the cumulative 5-gram frequency of occurrence between the modifier and head nouns (e.g., the summed count of *octopus … apartment* with zero, one, two and three intervening words: for a similar approach, see Louwerse & Connell, 2011). Finally, frequencies were log-transformed as ln $(f + c)$, where f is the raw frequency and c is a constant (minimum non-zero frequency) added to all values to enable log calculations of zero counts.

Participants Eighteen native speakers of English completed the experiment for a nominal sum. No participants needed to be excluded for rejecting a majority of lexicalised fillers.

Procedure Participants were told that they would be presented with two-word phrases onscreen; some of these phrases would be familiar to them, while others would not. They were instructed to press the key labelled "Yes" to indicate that "Yes, I can think of a meaning" or to press the key labelled "No" to indicate that "No, I cannot think of a meaning" (there was no response timeout). All responses were made with the participant's dominant hand. If participants pressed "Yes", a screen appeared where they then typed in the interpretation they had just generated.

Each trial began with the word "Ready" appearing on the screen for 2000ms, followed by the compound which remained onscreen until the participant made a decision. Response times were recorded from the onset of the compound until the participant's keypress ("Yes" or "No" button). There was a blank screen interval of 1000ms until the start of the next trial. Each participant saw all compounds, which were presented in random order. The experiment took approximately 20 minutes to complete and had a short, self-paced, break was halfway through.

Coding Overall, 64.1% of test trials were interpreted ("yes" responses) and 35.9% were rejected ("no" responses). Participant interpretations were considered invalid (5.2%) if they were unrelated to the compound (e.g., "I don't know")

Table 1: Example interpretations produced by participants in the current experiment and their coding according to ECCo and traditional views of conceptual combination.

Compound	Interpretation	ECCo coding	Traditional coding
octopus apartment	A place where an octopus might live	Nondestructive (there is still an intact *octopus* and *apartment*)	Relation-based (*octopus* links to *apartment* by thematic relation "lives in" or "location")
	An apartment with eight rooms	Destructive (*octopus* reduces to eight component parts)	Property-based (eight legs in *octopus* maps to eight rooms in *apartment*)
whale knife	A knife that has a picture of a whale on it	Destructive (*whale* reduces to a 2-dimensional visual representation)	Relation-based (*knife* links to *whale* by thematic relation "has" or "describes")
snail shark	A cross between a snail and a shark	Destructive (*snail* and *shar*k reductively merge to produce offspring)	Hybrid (*snail* and *shark* genetically hybridise)
whiskey giraffe	A cocktail	Destructive (*giraffe* reduces to little more than its name, analogous to other cocktails such as a *Moscow mule*).	Other (no evident linking relation, property mapping, or hybridisation)

or if they were merely typological definition of the head noun (*e.g., elephant comp*laint as "a type of complaint"), and were not analysed further. Valid interpretations were then classified by the authors according to two different accounts of conceptual combination (see Table 1). Consistent with ECCo, interpretations were coded as either destructive (where one or both concepts are destructively reduced in the described compound representation: 41.1%), or nondestructive (where both concepts remain relatively intact in the described compound representation: 58.9%). Consistent with traditional accounts of conceptual combination, interpretations were coded as one of four types: property-based (where a property of one concept is transferred to the other: 36.9%), relation-based (where a thematic relation is used to link the two concepts: 59.7%), hybrid (where the interpretation is an equivalent mixture of the two concepts: 0.7%) or other (2.8%). These low numbers of hybrid and other interpretations were not analysed further in tests of the traditional model. Coding agreement in both schemes was high (kappas > .8).

Overall, destructive interpretations comprised 86.7% property-based, 5.8% relation-based, 1.7% hybrid and 5.8% other interpretations, while nondestructive interpretations were composed of 98.2% relation-based and 1.8% other.

Design & Analysis Interpretation times ("yes" keypresses that resulted in valid interpretations) and rejection times ("no" keypresses) acted as dependent variables in separate analyses. Data were analysed in mixed-effects regression models with crossed random effects for participants and items (Baayen, Davidson & Bates, 2008; Locker, Hoffman & Bovaird, 2007), and fixed predictor variables of interpretation type and linguistic frequency (i.e., log 5-gram frequency per compound). The primary advantages of mixed effects analysis as regards the present experiment is that it can determine the effect of item-level predictors while simultaneously taking participant and item variability into account, and that it offers greater power than analysing aggregated responses over participants or item (Bayen et al., 2008). Effect size r for each predictor was calculated from t (Cohen, 1988).

For interpretation times, outliers more than 2.5 standard deviations from the mean of each interpretation type were removed (4.2% destructive and 2.3% nondestructive; 4.7% property-based and 1.7% relation-based). Separate regression models were created for each account of conceptual combination: interpretation type was dummy-coded as destructive (1) versus nondestructive (0) in the ECCo model, and as property-based (1) versus relation-based (0) in the traditional model.

For rejection times, outliers more than 2.5 standard deviations from the mean were removed (2.5% of data). Since traditional accounts of conceptual combination have not addressed the timecourse of rejection in compound interpretation, and hence have no explicit predictions to make regarding rejection times, we created a regression model only for the ECCo account of conceptual combination. However, because rejected compounds were not actually interpreted, it was not possible to associate each response with a dummy-coded discrete predictor of interpretation type. Instead, interpretation type was operationalised as the proportion of destructive interpretations for each compound. This variable therefore reflected the likelihood of a particular compound, had it been successfully interpreted, of giving rise to a destructive interpretation.

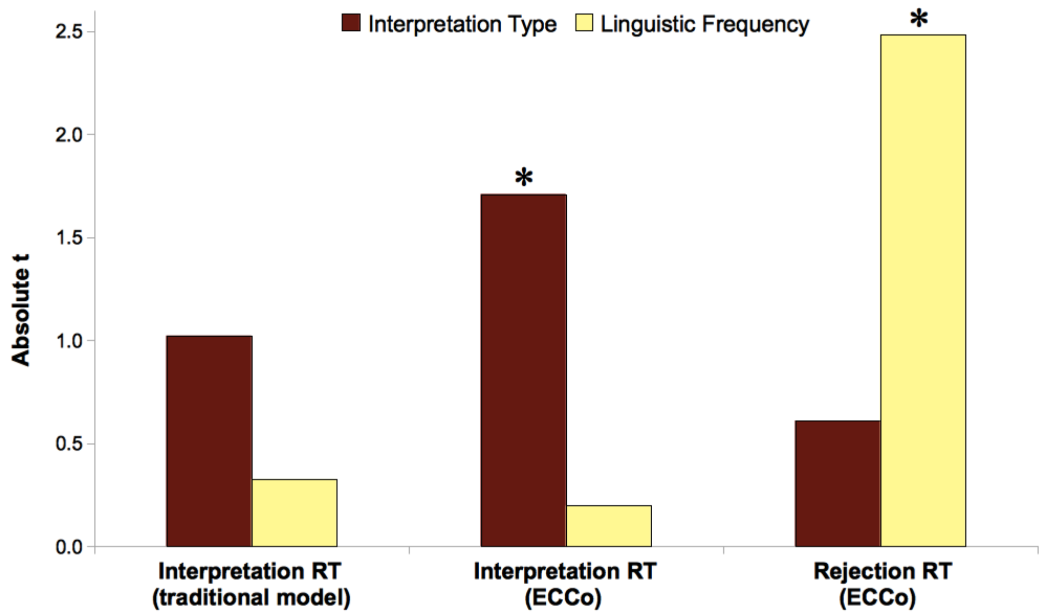

Figure 1: Absolute *t*-values for regression predictors of interpretation times according to the traditional categorisation of interpretation type as property- and relation-based, and the ECCo theory's categorisation as destructive and nondestructive. Rejection times are regressed for ECCo only because the traditional account makes no predictions.

Results

The absolute *t*-values corresponding to tests of predictor variables in the regression models of interpretation and rejection times are graphed in Figure 1.

ECCo Analysis As predicted by ECCo, interpretation times were explained by the simulation variable (interpretation type) but not by the linguistic variable (frequency). Specifically, destructive combination led to slower responses than nondestructive combination, $t(163.92) = 1.709$, $p = .045$, $r = .132$, while linguistic frequency had no effect, $t(17.65) = -0.197$, $p = .423$, $r = .047$.

Rejection times, again following ECCo predictions, showed the inverse pattern to interpretation times in being explained by the linguistic variable but not by the simulation variable. Time to reject a compound as uninterpretable increased with linguistic frequency (i.e., low frequency compounds were rejected quickly, high frequency compounds were not), $t(22.44) = 2.485$, $p = .010$, $r = .465$. The type of interpretation likely to result from a particular compound (i.e., the proportion of successful interpretations that were usually destructive) had no effect on rejection times, $t(21.10) = 0.610$, $p = .274$, $r = .132$.

Traditional Analysis In contrast to the ECCo analysis, the traditional model had little success in accounting for interpretation times as property-based interpretations were no slower than relation-based, $t(255.35) = 1.022$, $p = .154$, $r = .064$. Linguistic frequency also had no effect, $t(254.17) = -0.326$, $p = .372$, $r = .020$.

General Discussion

Overall, the traditional view was less successful than ECCo in accounting for the timecourse of conceptual combination. Interpretation times were successfully predicted by the ECCo model (destructive slower than nondestructive) but not by the traditional model, thus confirming that ECCo's representational distinction between destructive and nondestructive interpretations is a better reflection of conceptual combination processing than traditional assumptions of relation and feature mappings. Furthermore, rejection times were also successfully predicted by the ECCo model (the less often two words have appeared in shared contexts, the faster people reject their compound as uninterpretable), thus extending theories of conceptual combination into the timecourse of interpretation failure, an area that traditional accounts have not adequately addressed.

ECCo's separation of interpretation types into destructive and nondestructive has several advantages over the traditional fragmentation into relation-based, property-based, hybrid and others. Not only does it have superior predictive power regarding the timecourse of conceptual combination (as shown above), but it does not suffer from the same degree of coding ambiguity. Take, for example, an interpretation for *whale knife* as “a large knife used by whalers to cut up whales”. This interpretation could reasonably be classed as relation-based, since there is a linking relation “used for” between the concepts *knife* and *whale*. However, it could also be reasonably classed as property-based; the property of large size has been taken from *whale* and applied to *knife*. In ECCo, this argument is moot. There is an intact *knife* in the interpretation, and an intact *whale* (albeit a dead one in the process of being butchered), therefore the interpretation is nondestructive. The largeness of the knife is simply the result of the situated nature of the simulation (i.e., cutting up whales), because a tiny-bladed penknife cannot afford such an action.

Although we show in the present paper that people appear to use linguistic distributional information as a "quick and dirty" heuristic to reject compounds, the ECCo theory is clear that such information also plays an important role in the interpretation process itself (Lynott & Connell, 2010a). Both the linguistic and simulation systems play complementary and interactive roles in conceptual processing, where linguistic information can activate simulation information, which may in turn activate further linguistic information, and so on. The main difference between destructive and nondestructive processes lies in how the affordances are constrained and meshed. The destructive process seeks to mesh the head and modifier concepts together even if it means substantially reducing one of them, while the non-destructive process seeks to mesh the head and modifier affordances in a situation that allows both concepts to remain relatively intact. Importantly, the representation of a successful interpretation is always a situated simulation.

In this paper, we have provided the first empirical test of ECCo, a theory that brings together the fields of embodied representation and conceptual combination. Future work will further explore the embodied basis to this critical faculty of generative cognition.

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