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Factors Influencing the Interpretation of Noun-Noun Compounds

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Abstract

The Competition Among Relation in Nominals theory (Gagné & Shoben, 1997) asserts that the relation frequency of the modifying noun is the primary determinant of ease of interpretation for noun-noun compounds. It also assumes that the influence of this variable is independent of the head noun. However, we suggest that both constituents exert an influence and that this influence depends on the pairing of nouns as well as the context. We present an experiment that investigates if the influence of the modifier's relation frequency is fixed or whether it is affected by the head noun. Our results reveal that modifier relation frequency *per se* is not an accurate predictor of ease of interpretation: low modifier relation frequency combinations were easily interpreted in cases where the modifier's general bias was overruled by the semantics of the head noun. As a result, we suggest that models predicting ease of interpretation must take into account the interaction of both constituents. The implications for models of conceptual combination are discussed.

Keywords: Conceptual combination; noun-noun compounds; CARIN theory; modifier primacy; context.

Introduction

The combination of two words is a technique commonly adopted by speakers in order to refer to novel concepts and ideas (e.g. *penguin film*, *handbag dog*). Although people have a well developed means of understanding these novel compounds, the associated comprehension process is not trivial, requiring many levels of understanding. Accordingly, the study of conceptual combination is important, both because it is intimately associated with the generativity and comprehension of natural language and because it is important for understanding how people represent concepts. In English, a language in which compounding is particularly productive, combinations consist of a modifier noun followed by a head noun. Usually, the head noun denotes the main category while the modifier implies a relevant subcategory or a modification of that set's typical members. In this way, a *kitchen chair* is interpreted as a particular type of chair, and more precisely as the type that is located in kitchens.

In order to understand a combination, people have to be able to relate the two concepts in a meaningful way. Gagné and Shoben's (1997) Competition Among Relations In Nominals (CARIN) theory focuses primarily on the relation linking the constituent nouns in a combination. This theory maintains that there is a fixed, relatively small taxonomy of standard relations that can be used to link the modifier and head noun concepts. One of the most notable aspects of the CARIN theory is its proposed mechanism for how constituent nouns affect relation availability. Gagné and Shoben (1997) contend that a noun's influence on relation availability is not a function of that noun's conceptual content; rather, its influence is a function of how that noun has been experienced in previous combinations. In other words, "people possess distributional knowledge about how often particular relations are used" (p. 74) and this knowledge affects the ease with which two constituents are combined. For example, Gagné and Shoben propose that *mountain goat* should be easier to interpret than *mountain magazine* by virtue of the fact that *mountain* is more frequently used with the <located> relation than it is with the <made of> relation. Here, *mountain goat* can be described as having a high modifier relation frequency while *mountain magazine* can be described as having a low modifier relation frequency. Thus, according to the CARIN theory, relation frequency should be positively correlated with ease of interpretation.

In a speeded sensibility task, Gagné and Shoben (1997) found that differences in ease of interpretation (response time and accuracy) were associated with differences in modifier relation frequency but not with differences in head relation frequency. This they interpreted as evidence that people store distributional knowledge for modifiers but not for heads. Accordingly, the CARIN theory provides an account of conceptual combination which views the influence of the modifier as being separate and independent to that of the head noun. The structure of Gagné and Shoben's model implies that the influence exerted by a modifier should remain constant across every situation.

This seems surprising as one would expect the significance of a modifier to vary depending on the head with which it is paired. Other theories of conceptual combination have proposed that the influence of both constituents is a joint interactive one. For example, Estes and Glucksberg (2000) point out that *feather luggage* can be interpreted as light luggage because feathers have the salient property of being light and luggage has weight as a relevant dimension. On the other hand, the use of the modifier *feather* in a combination such as *feather storage* is unlikely to have the same effect since storage does not have weight as a relevant dimension. If the significance of the modifier depends on how it is used, then its influence on the interpretative process will not be a constant one.

Maguire and Cater (2005) demonstrated that the relation bias of the head noun can be shown to exert a significant effect once the influence of the modifier is properly controlled. For example, *turnip soup* was interpreted more quickly and more reliably than *turnip field* because the head noun *soup* is more strongly suggestive of the <has> relation than *field*. This finding suggests that the relation bias of both constituents can influence the interpretation process. An important question is therefore whether the influence of both constituents is constant and independent or interactional and context-sensitive.

Interactional Influence

In their analysis of noun compounds in the British National Corpus, Maguire, Wisniewski and Storms (2007) found that different permutations of head and modifier types were strongly associated with particular relations. For example, [animal-body part] (e.g. *chicken feathers*) combinations predominantly used the <Modifier has Head> relation whereas [animal-food] (e.g. *chicken pie*) combinations predominantly used the <Head contains Modifier> relation. The influence of a modifier of type [animal] therefore strongly depended on the nature of the head. A measure averaging the relation incidence of such modifiers over a varied set of combinations (e.g. relation frequency) would not preserve this kind of information. Based on their findings, Maguire et al. (2007) suggested that people are sensitive to the interaction of both concepts and use this knowledge to 'home in' on the correct interpretation (e.g. knowing that patterns such as [substance-artifact] are associated with the <made of> relation). This implies that relation availability is best modeled by taking into account the interactional influence of both constituents as opposed to treating them separately.

A study by Maguire, Maguire and Cater (2007) supported the idea that people are aware of the interactional influence of the modifier and head. They found that combinations like *frog tail* which matched a productive modifier-head category (e.g. <animal-body part>) took longer to reject as implausible than combinations like *daffodil tail*, which did not match a productive category. Participants responded to the productivity of the overall modifier-head category rather than the productivity of either constituent in isolation. Maguire et al. (2007) suggested that knowledge about a concept is activated according to the situation in which it is used. In the case of noun-noun compounds, each constituent should exert a strong influence on the way the opposite constituent is interpreted. The idea that conceptual knowledge is activated in a context-appropriate manner is supported by converging evidence from numerous studies (cf. Barsalou, 2005).

If the significance of a noun varies depending on how it is used, then the influence of that noun cannot be modeled by averaging its influence over a wide variety of different combinations. Gagné and Shoben's (1997) variable of relation frequency reflects the association between a noun and a relation as averaged over every combination in which that noun has been previously encountered. Consequently, the CARIN model does not allow for any interactional influence between the modifier and head nouns. If the interactional hypothesis is correct, then relation frequency cannot provide an accurate reflection of relation availability.

Rationale

The following experiment investigates whether the influence of the modifier and head is an interactional one. Specifically, it examines whether the influence of Gagné and Shoben's (1997) variable of modifier relation frequency is affected by the head noun. If people are sensitive to the interaction of noun properties, then modifier relation frequency should only be associated with differences in ease of interpretation in cases where the head does not affect the influence of the modifier. In other words, a low relation frequency modifier should only increase interpretation difficulty when the properties of the head fail to rule out inappropriate relations of higher availability.

Gagné and Shoben showed that combinations involving a modifier such as *chocolate* are more difficult to interpret when they use relations other than <made of> (e.g. *chocolate factory*). Since most combinations involving the *chocolate* modifier use this relation (e.g. *chocolate cake*, *chocolate bar*, *chocolate biscuit* etc.) then it seems intuitive that people should be predisposed to selecting it based on their prior experience. However, our hypothesis is that subjective relation availability reflects the interaction of modifier and head properties. In the example *chocolate factory*, the head is an artifact. Since artifacts have a constitution, the head noun *factory* fails to preclude the use of the <made of> relation suggested by the modifier *chocolate*. However, for a combination such as *chocolate taste*, the head is an intangible abstract entity and therefore cannot have a constitution. This rules out the possibility of the <made of> relation: combinations of type [substance – attribute] are never interpreted in this way. If people are aware that the head noun *taste* rules out the bias of the modifier *chocolate*, as our interactional hypothesis predicts, then the ease of interpretation should be unaffected: *chocolate taste* should be no more difficult to interpret than *chocolate cake* or *chocolate bar*. It might even be easier to interpret, given the strong constraints on the range of interpretation. The following experiment examines whether the association between modifier relation frequency and ease of interpretation observed by Gagné and Shoben (1997) is affected by the potential of the head to overrule the modifier's bias.

Experiment

Although Gagné and Shoben (1997) observed a weak association between ease of interpretation and historical combination use, this may simply reflect part of a much stronger association reflecting the interactional influence of both constituents. Investigating this hypothesis, we examined the extent to which people are aware of how a modifier's bias is affected by the nature of the head noun. We conducted a speeded sensibility task with two conditions involving combinations with a low modifier relation frequency. In one of these conditions, the basic ontology of the head ruled out the high modifier frequency relation (Low Constrained or LC condition, e.g. *mountain height*) while in the other, it did not (the Low Unconstrained or LU condition, e.g. *mountain magazine*). In addition, we included a further condition where the same modifier was used with a high frequency relation (High or H condition, e.g. *mountain goat*). Thus, the L and H refer to the modifier relation frequency while the C and U labels describe whether the incorrect high frequency modifier relation was ruled out by the head or not.

The CARIN theory asserts that the modifier's relation frequency is directly correlated with ease of interpretation while that of the head noun has no effect. Regarding our experiment, this theory predicts that the H combinations should be the easiest to interpret and that there should be no difference between the LC and LU conditions since both involve equally low frequency modifier relations. In contrast, we propose that it is the interaction of both constituents which is of relevance. Accordingly, we predict that the LU combinations will be more difficult to interpret than the LC combinations, since the misleading bias of the modifier in the LC condition is effectively mitigated by the properties of the head. In addition, we do not predict a difference between the H and LC combinations: only the unconstrained LU combinations should be associated with an increase in difficulty.

Method

Participants Twenty-four first year undergraduate students from University College Dublin participated in the experiment for partial course credit. All were native English speakers.

Materials We generated a set of twenty combinations for each of the three conditions LC, LU and H. The twenty modifiers in each condition were repeated in order to facilitate a repeated measures design (e.g. *leather smell*, *leather needle*, *leather saddle*). In order to determine high and low frequency relations, Gagné and Shoben (1997) paired a set of 91 modifiers with 91 heads and classified the relations for the sensible combinations that emerged. The high frequency relations for any given modifier denoted those relations with the highest relative frequencies for that modifier. This group was determined by first identifying the highest frequency relation. If that relation accounted for 60% or more of the sensible combinations for that modifier, then that one relation was the only high frequency relation. If not, the relation with the next highest frequency relation was added to the high frequency group, until the selected relations accounted for 60% or more of the sensible combinations for that modifier. All other relations were considered low frequency. Forcibly pairing an arbitrary set of modifiers and heads is unlikely to result in a representative sample (cf. Storms & Wisniewski, 2005). Furthermore, the use of a precise 60% dichotomization threshold is unreliable as, theoretically, an infinitesimal variation in the frequency of a relation can make the difference between that relation being categorized as high or low frequency (cf. Maguire, Devereux, Costello & Cater, 2007). Using Gagné and Shoben's paradigm, any relation with a frequency up to 40% can potentially be classified as low frequency while relations with frequencies as low as 3% can be classified as high frequency. In order for the distinction to be meaningful, high frequency relations should be as frequent as possible and low frequency relations should be as rare as possible.

To avoid these problems and obtain a reliable sample of high and low modifier frequency combinations, we made use of the technique used by Maguire and Cater (2005). In order to ensure appropriately biased modifiers, we selected 20 modifier nouns which met the criterion that a 100-combination sample of the British National Corpus (BNC) contained at least 60 combinations involving a single most common relation for that head. Our high modifier frequency combinations involved the dominant relation for that modifier while the low frequency combinations used another relation. In this way, we ensured that the H combinations had modifiers that were suggestive of a particular relation and that the LC and LU combinations used relations that contradicted this bias, having a substantially lower modifier relation frequency.

All three conditions were controlled for a range of factors with the potential to influence ease of interpretation, namely word length, frequency, plausibility and familiarity. The length of the head nouns did not differ reliably between conditions using a repeated measures ANOVA, $F(2, 38) = .26$, $p = .77$; nor did the syllable length, $F(2, 38) = .39$, $p = .68$. As a measurement of head frequency, we used the log of the total number of occurrences of a noun within the BNC. This variable did not differ significantly between conditions, $F(2, 38) = 1.08$, $p = .35$. As in previous experiments, we controlled for the factors of plausibility and familiarity by obtaining the log of the Google frequency for each of our combinations. This measure did not differ reliably between conditions, $F(2, 38) = .09$, $p = .91$.

Design A within-participants design was used for the experimental manipulation of condition. Each participant saw the same set of 120 stimuli, comprising the three conditions of 20 items each and 60 nonsensical filler items.

Procedure The procedure for this experiment was similar to that used by Gagné and Shoben (1997). Participants sat in front of a computer screen and placed the index finger of their left hand on the F key of the computer keyboard and the index finger of their right hand on the J key. They were informed that a series of noun-noun compounds would be displayed on the screen for which they would have to make sensibility judgments, pressing J for sense and F for nonsense. Emphasis was placed on the fact that participants should only press F if the combination was truly incomprehensible. Each trial was separated by a blank screen lasting for one second. The combination then appeared in the middle of the screen and participants had to make a decision by pressing the appropriate key.

Participants were initially given a short practice session where feedback was given regarding their judgments. The aim of this practice session was to familiarize them with the process of making quick sensibility judgments and also to set a reliable threshold for sensibility. Without such a measure, participants would have been liable to disregard unusual but potentially sensible combinations as nonsense. After completing the practice session, participants were instructed that they were now beginning the experiment. The stimuli were then presented in a random order.

Results and Discussion

A total of 4.8% of the data were omitted from the analysis in calculating mean response times. Those responses deemed unreasonably fast (< 400ms, 0.3%) or unreasonably slow (> 4000, 3.5%) were excluded. Furthermore, any remaining response times which were more than three standard deviations outside each participant's mean for that condition were also excluded. This eliminated a further 1.0% of trials.

The mean response times were 1423, 1485 and 1379 ms for the H, LU and LC conditions respectively while the mean accuracy rates were .83, .66 and .93. We conducted a series of repeated measure ANOVAs in order to examine the differences between conditions using both participants and items as random factors. We found a significant difference in response time by participants but not by items, $F_1(2, 46) = 4.83$, p = .01, $MS_e = 17005.88$; $F_2(2, 38) = 1.62$, p = .21, $MS_e = 37253.07$. Subsequently, we conducted pairwise comparisons between conditions by participants using Bonferroni adjustments. As predicted, there was a significant difference between the LC and LU conditions by-participant, although not by-item, $F_1(1, 23) = 13.44$, $p < .01$, $MS_e = 12169.48$; $F_2(1, 19) = 3.57$, $p = .07$, $MS_e = 33686.54$. There was no significant difference between the H and LC conditions, $F_1(1, 23) = 1.58$, $p = .22$, $MS_e = 20265.13$; $F_2(1, 19) = .66$, $p = .43$, $MS_e = 34913.22$ or between the H and LU conditions, $F_1(1, 23) = 2.74$, $p = .11$, $MS_e = 18583.05$; $F_2(1, 19) = .88$, $p = .36$, $MS_e = 43159.45$.

The accuracy ratings proved to be particularly revealing. Here, there was a significant effect both by participant and by items, $F_1(2, 46) = 60.00$, $p < .001$, $MS_e = 3.14$; F2(2, 38) = 12.19, $p < .001$, $MS_e = 18.55$. Again, we conducted pairwise comparisons between the various conditions. As predicted, there was a significant difference between the LC and LU conditions, $F_1(1, 23) = 94.64$, $p < .001$, $MS_e = 3.93$; $F_2(1, 19) = 20.85$, $p < .001$, $MS_e = 21.53$. We also found a significant difference between the H and LU conditions, $F_1(1, 23) = 35.08$, $p < .001$, $MS_e = 3.52$; $F_2(1, 19) = 6.21$, $p = .02$, MSe = 23.86. Finally, there was a significant difference between the H and LC conditions, but in the opposite direction to that predicted by the CARIN theory, with the low modifier frequency combinations being judged most accurately, $F_1(1, 23) = 34.74$, $p < .001$, $MS_e = 1.95$; $F_2(1, 19) = 7.90$, $p = .01$, $MS_e = 10.28$.

In sum, the LC combinations were verified more quickly and more accurately than the LU combinations. Because Gagné and Shoben's (1997) CARIN theory assumes that the influence of a modifier is constant, it is unable to account for this finding. In addition, the LC combinations proved no more challenging for participants than the H combinations and were actually interpreted more accurately. This contradicts the CARIN theory's premise that low modifier relation frequency combinations should always be more difficult to interpret. Clearly, a modifier's typical association with a particular relation is only of relevance when that bias is not contradicted by the head. For example, although *chocolate* as a modifier usually suggests the <made of> relation, this bias is redundant in the case of *chocolate taste* since combinations of the type [substance – attribute] are more generally associated with the <has> relation. As a result, *chocolate taste* (LC) was interpreted more quickly than *chocolate factory* (LU) and indeed more quickly than *chocolate rabbit* (H). These findings support the idea that people respond to the interaction of noun properties in generating an interpretation. The results are also compatible with the statistical patterns in relation diagnosticity observed by Maguire, Wisniewski and Storms (2007). In other words, the information that people bring to bear in the interpretation process accurately reflects the probability of a relation.

Only two participants (8%) correctly judged *leather needle* as a genuine combination, whereas twenty (83%) were able to judge that *leather smell* was sensible. Presumably, in the former case most participants were interpreting the combination as a needle made out of leather and dismissing the phrase as nonsensical. This can be explained by the fact that *leather* is strongly biased towards the <made of> relation. However, an additional fact (which the CARIN theory fails to accommodate) is that leather is only diagnostic of this relation when the head is an artifact. Those combinations involving leather and the <made of> relation are generally of the form [leather – artifact], as only artifacts are associated with a constitution. Our results demonstrate that people are sensitive to this additional information and are not simply guided by an aggregate measure of how a noun has been used in all previous combinations. Most participants in our experiment interpreted *leather needle* as a needle made of leather and judged it as nonsense because needles are artifacts and artifacts can be made out of a material. However, they did not interpret *leather smell* as a smell made out of leather because they were aware that a smell is not solid. The fact that the modifier *leather* is biased towards the <made of> relation is not relevant for the interpretation of the combination *leather smell*.

General Discussion

Various probabilistic models of human language comprehension have been proposed in the past, based on the idea that probabilistic information about words, phrases and other linguistic structure is represented in the minds of language users and plays a role in language comprehension. Event-related brain potential recordings have shown that readers can use the words in a sentence to estimate relative likelihood for upcoming words (cf. DeLong, Urbach & Kutas, 2005). This suggests that prior experience, as well as something akin to frequency distributions, might be a factor in human language processing. Indeed, our results have vindicated certain aspects of the CARIN theory in that combinations using low modifier frequency relations were more difficult to interpret in cases where the head did not overrule the modifier's misleading bias.

Although Gagné and Shoben's (1997) approach has some merit, we believe that their theory in its current state is overly simplistic. We propose a more realistic model with several key differences. Firstly, Gagné and Shoben claimed that people store separate modifier relation frequency distributions for every single modifier. This seems unnecessary, as the influence of a modifier is often closely related to its properties (e.g. one can infer that *mountain* prefers the <located> relation based on the fact that it refers to a place). The BNC corpus study by Maguire, Wisniewski and Storms (2007) revealed that nouns of the same type tend to combine in very similar ways. It therefore appears unlikely that people would fail to exploit such predictable patterns. For example, the knowledge that time periods tend to combine using the <*during*> relation is not information that needs to be learned and stored separately with every time period modifier.

We suggest that people's knowledge about how combinations should be interpreted is mostly centered on noun properties. Specific information relating to one noun in particular is only likely to be maintained when that noun is extremely frequent or its use deviates considerably from the norm (e.g. *mammoth* is often used as a modifier to indicate large size, as in *mammoth sandwich*; this use is not shared by similar nouns like *whale* and thus a large sandwich is unlikely to be described as a *whale sandwich*). Importantly, any knowledge regarding noun use in combination is likely to reflect how a noun interacts with other nouns, as opposed to being represented by a crude aggregate measure.

Modifier Primacy

Although the modifier may represent a more predictive measure of the appropriate relation, the key finding of our experiment is that both constituents must be taken into account rather than being considered individually. The reason that Gagné and Shoben (1997) failed to detect a significant influence exerted by the head may have been because their study did not examine the influence of each constituent separately but instead varied both factors at the same time. Consequently, the head's influence may have been swamped by that of the modifier. When other factors were properly controlled for, Maguire and Cater (2005) demonstrated a significant influence of the head noun's relation bias. It may be the case that Gagné and Shoben's materials were better suited to detecting a modifier influence than a head influence. For example, Maguire, Wisniewski and Storms (2007) found that substance, time and location modifiers are all extremely biased towards one particular relation. This bias is unaffected when the head is an artifact, making combinations of this type more difficult to interpret when the biased relation is inappropriate (e.g. *paper equipment*, *wood money*, *chocolate plant*). As it happens, 11 of Gagné and Shoben's 19 LH combinations were of this form. In contrast, head nouns rarely exhibit a bias towards one particular relation that is maintained for a wide range of different modifiers. For example, Maguire and Cater (2005) found that *soup* as a head noun is biased towards the <made of> relation, but only when the modifier is a food substance. Similarly, *pain* is biased towards the <located> relation, but only when the modifier is a body part. In contrast to the majority of their modifiers, few of Gagné and Shoben's (1997) head nouns exhibit a consistent bias[1]. For example, although Gagné and Shoben determined that the head noun *bird* tends to be used with the <located> relation, it is unlikely to suggest this relation in the context of *chocolate bird* since animals are not usually located in substances. Similarly, although *toy* might be frequently associated with the <made of> relation overall[2], it is certainly not suggestive of this relation in the context of *cooking toy*, since objects cannot be made of activities. In light of this, we suggest that the reason Gagné and Shoben observed a modifier primacy effect was because the modifiers used in their study were less susceptible to the interactional influence of the opposite constituent. The current study clearly indicates that the head noun exerts an influence, and that the nature of this influence depends on the modifier.

Although we have concentrated on the influence exerted by a combination's constituent nouns, the surrounding context is also likely to play an important role in relation selection. For example, if one were to use the combination *plastic box* while holding aloft a cardboard box full of pieces of plastic, this would no doubt enhance the availability of the <contains> relation, while at the same time strongly mitigating the likelihood of the <made of> relation. In order to examine the potential influence of sentential context on relation selection, we conducted a brief

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[1] The only exceptions are *book* and *magazine* for which a large variety of modifier types can act as a subject matter

[2] Wisniewski and Storms (2005) and Maguire, Devereux, Costello and Cater (2007) identified several potential sources of inaccuracy associated with the technique used by Gagné and Shoben (1997) to obtain these statistics

experiment. In total, 40 participants were recruited. Half were presented with the phrase "…*a mountain x*" while the other half were presented with the extract "*John was going on a hike. He went down to his local hardware store to buy some mountain x*". Both groups were told that the extract had been lifted from a written source and that the final word had been replaced with the *x* symbol. They were allowed three guesses as to what that word might be. Each of the participants' responses was ascribed to one of Gagné and Shoben's relations, allowing a relation frequency to be determined for the modifier *mountain* in each of the two scenarios.

For the combinations generated in the context-free condition, the relation with the highest frequency was <located> with 45%, followed by the <for> relation with 19%. In contrast, every single combination generated in the context condition involved the <for> relation. This finding indicates that people are sensitive to the way in which sentential context affects relation likelihood, again contradicting Gagné and Shoben's assumption that the influence of relation frequency can be modeled independently of any other factors. In light of this, we propose that relation availability is likely to reflect a complex interaction of statistical inferences based on the modifier, the head and the associated context. Although Gagné and Spalding (2004) demonstrated that the association between modifier relation frequency and ease of interpretation persists in context, this does not preclude nor account for the interactional influence of context, just in the same way that Gagné and Shoben's (1997) observation of a modifier influence does not preclude nor account for the interactional influence of the head noun.

Conclusion

We believe that the CARIN theory is too simplistic in its current form to represent a realistic model of conceptual combination. For one, there is little evidence to suggest that storing one basic statistical distribution per modifier is the best way to encapsulate experiential knowledge. We have demonstrated that the head noun exerts an influence on interpretation and that this influence is dependent on the nature of the modifier. Furthermore, we have provided evidence that sentential context can have an interactional influence. These findings suggest that the knowledge that people bring to bear in interpreting a combination is far more complex than the CARIN model allows.

The ability of the CARIN model to account for differences in the ease of interpretation of combinations is quite poor (Gagné & Shoben report a correlation of 0.44 between the model output and response time). This may be due to the fact that the model includes only a single factor, namely an aggregated statistical relation frequency pertaining to the modifier. Our study has demonstrated that other factors affect interpretation and that these factors are interactional and context-specific. A more comprehensive model that takes into account these alternative influences may prove more successful in modeling the interpretation of noun-noun combinations.

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