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Conceptual combination during novel and existing compound word reading in context: A self-paced reading study

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Abstract
According to the relation-interpretation-competition-evaluation (RICE) hypothesis, compound word processing involves selecting a relational meaning (e.g., *moonlight* is 'light from moon') from a larger set of competing possible relational meanings. Prior lexical decision experiments with existing compound words have demonstrated that greater *entropy of conceptual relations*, i.e., greater competition between conceptual relations, impedes lexical processing speed. The present study addresses two unresolved issues: First, it is unclear whether the competition effect generalizes to the processing of novel compounds (e.g., *grassladder*), and second, it is not yet known whether competition between possible relational meanings extends to compounds when they are read in a sentence context. A series of self-paced reading tasks examined whether the competition effect operates regardless of (i) compound type (existing vs. novel), and (ii) whether sentence context (semantically supportive vs. semantically non-supportive) moderates the competition effect. The experiments confirmed that reading times of novel and existing compounds read in sentences were impacted by entropy of conceptual relations. Moreover, the effect was equally strong in both sentence context types. Additional analyses indicated that relational meanings are more ambiguous and flexible across different contexts for novel compounds compared to existing compounds.

Keywords Morphology · Compounding · Reading · Conceptual combination · Word recognition

Introduction

Compounding is a word formation process by which existing words are combined to express a new meaning. Psycholinguistic research on compound word processing indicates that people arrive at the meaning of a compound by using a *conceputal relation* to mentally link together its constituent parts(see review in Gagné & Spalding, 2013). For instance, *wristband* is a 'band LOCATED ON the wrist' and *bandstand* is a 'stand FOR bands'. In addition, recent word processing studies provide evidence that people attempt to construct a compound's meaning by generating multiple relational meanings at once (e.g., Gagné & Spalding, 2013; Schmidtke, Kuperman, Gagné, & Spalding, 2016; Schmidtke, Gagné, Kuperman, Spalding, & Tucker, 2018a). Specifically, these studies demonstrate that multiple conceptual relations *compete* with one another during processing and that greater competition between the possible relational meanings inhibits word recognition speed. The present study addresses two outstanding gaps in the literature on the competitive nature of relational processing during compound word recognition.

The first issue is that it is unclear whether the mechanism of competition that is found during the processing of existing compound words, e.g., *tinfoil*, also generalizes to the processing of novel compound words, e.g., *beefolk*. Although the results of previous research imply that relational processing is competitive for novel compounds, in the interest of parsimony, we wish to establish whether relational competition of existing *and* novel compounds can be captured with a single measure of competition: namely, 'entropy of conceptual relations'.

The second issue is that most prior studies of conceptual combination have adopted lexical decision techniques, which measure word processing effort of compounds that are presented in isolation. It therefore remains unclear whether the competitive aspect of conceptual combination plays a role in the processing of contextually embedded compounds. Since compounds are typically encountered

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within sentences, it is crucial to establish whether relational competition is shaped by contextual factors. We address both outstanding issues in a series of self-paced reading experiments. In the following sections, we briefly review the theoretical and empirical work on relational processing during compound word recognition, and then outline the research gaps and methodological approach of the study.

Relational structure

Early work on the linguistic expression of combined concepts contended that relational information is integral to the semantic representations of complex nominal phrases (Downing, 1977; Gleitman & Gleitman, 1970; Kay & Zimmer, 1976; Lees, 1962; Levi, 1978). Relational structure provides information about how the concepts denoted by each constituent of a compound combine with one another to construct the meaning of the whole word. The compound *meatball* might be understood as a 'ball made of meat', where 'made of' is a conceptual relation that posits a connection between the head *ball* and the modifier *meat*. Critically, conceptual relations are flexible in that the same conceptual relation does not always apply to the same modifier or head. For instance, the 'made of' conceptual relation does not apply to the compound *mothball*, which might be better paraphrased as 'a ball for moths'. Understanding how humans might rely on relational structures during word recognition is important to establish because relational processing is not always considered in mainstream models of compound word recognition. More generally, the processing of conceptual relations also provides a window into the nature of *conceptual combination*, the cognitive process by which existing concepts are synthesized to generate new meanings (e.g., Estes, 2003, Lucas, Hubbard, & Federmeier, 2017, Parrish & Pylkkänen, 2021; Wisniewski, 1996)

Importantly, relational structure is separate from morphological structure. Relevant to the present study, endocentric compounds are composed of a head noun which denotes the general class to which the compound word belongs, and a modifier, which serves to attribute a more restricted meaning to the head (Lieber, 2005; Bauer, 2009). For example, the English compound *sandpaper* consists of the modifier *sand* and head *paper*, whereby the meaning of 'sandpaper' is a hyponym of 'paper'. In English, almost all endocentric compounds are right-headed, meaning that the head of the compound appears as the right constituent position of the compound. Thus, while morphological information such as headedness is encoded in the surface form of a compound word in English, relational structures are 'invisible' in that they are not attested in a word's orthographic (or acoustic) form.

Relational competition

A large body of experimental research on compound words presented in spaced (e.g., *school yard*) and unspaced (e.g., *schoolyard*) spelling formats demonstrates that conceptual relations are registered by readers during compound word processing (e.g., Gagné & Shoben, 1997; Gagné & Spalding, 2004a; 2009; Gagné, Spalding, Figueredo, & Mullaly, 2009; Spalding & Gagné, 2011). More recent word recognition research indicates that relational processing is competitive (Spalding et al., 2010; Schmidtke et al., 2016; 2018a). That is, when a compound word is encountered, multiple possible relational interpretations are generated and then compete with one another for selection as the most likely relational meaning (Gagné & Spalding, 2013). Findings from these studies show that compounds that generate many equally plausible and highly competing relational meanings take longer to process than compounds that have a more dominant and readily available relational meaning. The process of relational competition forms the basis of the relational-interpretation-competitive-evaluation hypothesis (RICE; Spalding, Gagné, Mullaly, & Ji, 2010).

Extant research on the RICE hypothesis quantified competition among conceptual relations using data from the 'possible relations task' (Spalding & Gagné, 2014; Schmidtke, Gagné, Kuperman, & Spalding, 2018b). In this task, participants are presented with a list of compound words, and are asked to choose the most plausible conceptual relation out of a set of relations for each compound (see Table 1 for a list of 16 canonical conceptual relations). Entropy of conceptual relations for a compound is defined as Shannon entropy (Shannon, 1948) computed over the resulting probability distribution of relational choices. A lower entropy of conceptual relations score indicates that there are fewer stronger competitor relational meanings for a compound, i.e., most participants tended to converge upon one conceptual relation for a compound in the possible relations task. A higher entropy score indicates that there are more equally plausible conceptual relations for a compound, i.e., participants tended to be less systematic in choosing a conceptual relation that fits the compound. Across multiple visual and auditory lexical decision (unprimed) mega-studies, Schmidtke et al. (2016; 2018a) found that entropy of conceptual relations had a clear and consistent inhibitory effect on the processing speed of existing compounds. In all studies, higher entropy of conceptual relations – stronger competition among relational meanings – was associated with longer lexical decision response times. This pattern of results supports the proposal of the RICE hypothesis, demonstrating that competition among conceptual relations plays an influential role in compound word processing.

Table 1 Semantic relations adapted from Gagné and Shoben (1997). h: head; m: modifier

Conceptual relation	Compound example
h ABOUT m	*newsflash*
h BY m	*handclap*
h CAUSES m	*joyride*
h CAUSED BY m	*sunbeam*
h DERIVED FROM m	*seafood*
h DURING m	*nightlife*
h FOR m	*mealtime*
h HAS m	*bookshop*
m HAS h	*doorframe*
h LOCATION IS m	*farmyard*
m LOCATION IS h	*neckline*
h MADE OF m	*snowman*
h MAKES m	*honeybee*
h IS m	*girlfriend*
h USES m	*steamboat*
h USED BY m	*witchcraft*

Research gap 1: Novel compound words and relational competition

The first contribution of the present study is to address the nature of conceptual combination in novel compound word processing. The role of relational information on the processing of novel compounds has been examined in prior research (e.g., Coolen, Van Jaarsveld, & Schreuder, 1991; 1993; Gagné, 2002; Gagné & Spalding, 2004b; Gagné, Spalding, & Gorrie, 2005; Štekauer, 2005). Pertinent to the present research, Gagné et al. (2005) investigated the role of competition among conceptual relations for novel compounds in two experiments. In an initial experiment, participants were presented with a list of spaced novel compounds, and for each compound were required to select one out of two plausible meanings as their preferred meaning. For example, for the compound *bark cream*, participants were required to choose 'cream for bark' or 'cream made from bark' as their preferred interpretation. In a follow-up experiment, a separate group of participants were asked to judge the plausibility of the same set of novel compounds which were embedded in a sentence context. Participants took longer to judge the plausibility of the compounds for which the two possible meanings were judged in the first experiment as equally likely relative to those for which there was a clear bias toward a preferred meaning. This study points to a competition effect, indicating that novel compounds are processed more slowly when one meaning does not clearly dominate over another.

While Gagné et al.'s (2005) study was important in that it pointed to a competition effect for novel compound word recognition, competition was examined as the relative dominance (measured as a probability) of one relational interpretation out of only two competing conceptual relations. If the RICE hypothesis claims that relational competition is a general property of compound word processing, then it ought to be possible to demonstrate that novel compound processing is also sensitive to competition between *all* 16 possible relations (see Table 1), as measured by entropy of conceptual relations (Schmidtke et al., 2016; 2018a).

Research gap 2: Context and conceptual combination

The second contribution of the present research concerns the role of sentence context on the processing of conceptual relations. Several studies have confronted the question of whether the context in which a compound is encountered during reading influences the way in which conceptual relations are accessed during reading. Gagné and Spalding (2004b) showed that relation-based interpretations for novel compounds could be verified more quickly if they read the compound placed in a supportive context versus when they were placed in a neutral context. Further, they found that novel compounds were read faster when they were associated with more frequently chosen conceptual relations compared to novel compounds that were associated with less frequent conceptual relations. Crucially, context type did not moderate the effect of the overall frequency of the modifier relation, suggesting that relational information is evaluated for a compound regardless of whether the context is supportive of a particular relational interpretation or not.

Gagné et al.'s (2005) study also manipulated discourse context. Participants were asked to provide acceptability judgments for compounds embedded within sentences that supported either a dominant or sub-dominant relational meaning. The result indicated that relational meanings were attuned to context even for established compounds. They found that contexts that supported the plausibility of sub-dominant meanings of compounds elicited shorter response times to acceptability judgments about their relational meanings. Based on these results, the processing of relational meanings appears to be a facet of novel and existing compound word processing irrespective of whether they are encountered in contexts that are both supportive and non-supportive of a particular relational meaning.

Eye-tracking during reading has also been used to investigate the issue of relational competition during sentence comprehension. In one experiment, Brusnighan and Folk (2012) found that, overall, novel compounds were read more slowly compared to existing compounds. However, novel compounds that were presented in meaning-supportive contexts elicited shorter re-reading times compared to neutral contexts. Interestingly, Brusnighan and Folk also reported that readers spent longer reading sentences containing novel compound words that they accurately remembered in a subsequent vocabulary test. The authors reasoned that increased time spent reading novel words led to a stronger semantic representation of these words in memory, resulting in better memory retention in the vocabulary test. This latter result may be explained by the Noticing Hypothesis (Schmidt, 1990), which claims that the learning of novel linguistic features requires the input to be consciously attended to and registered.

In a corpus of eye movement studies in which existing English compound words were read silently in sentence contexts, Schmidtke, Van Dyke, and Kuperman (2021) presented evidence that relational competition may not even be a feature of compound word processing during sentence reading. They reported one significant main effect of entropy of conceptual relations in gaze durations (the sum of all fixations on the word in the first pass of reading), the one significant effect of this measure out of seven sub-studies. Moreover, the entropy effect was not reliably present in an analysis of the entire corpus, showing that insufficient power may have been the reason for the failure to detect the entropy effect in the eye-movement record.

While there may have been insufficient power to find a significant effect of entropy of conceptual relations in Schmidtke et al.'s (2021), there are two additional reasons why the effect may not have been found. The first is that competition between possible relational candidates is not a feature of compound word processing during sentence reading. That is, contextual cues provide sufficient information to disambiguate the many relational interpretations of the upcoming compound word, nullifying the potential for competition between conceptual relations. The second reason for an absence of an effect null effect on eye movement during reading is that the ratings that were used to compute the measure of entropy of conceptual relations were obtained from compounds presented in isolation. These ratings were therefore not attuned to the sentences that the compounds were embedded in during the eye-movement study. Thus, in Schmidtke et al. (2021) the entropy of conceptual relations measure was an imprecise measure of competition for compounds presented in sentences and did not predict reading behavior.

Hypotheses

The present study addresses two hypotheses based on the research gaps identified in the literature. The first hypothesis tests whether relational competition effects in existing and novel compound processing can be captured by a single information-theoretic metric: entropy of conceptual relations. The RICE hypothesis predicts that competition effects during conceptual combination should arise irrespective of whether the compound is novel or exists in the language, i.e., is familiar to the language user. If the mechanism of competition generalizes across novel and existing compounds, then the same measure of entropy computed over all 16 possible relations (Schmidtke et al., 2016; 2018a) should predict the processing times of both novel and existing compounds.

The second hypothesis tests Gagné and Spalding's (2004b; 2013) claim that although contextual cues might be used to help reach a relational interpretation of a compound, relational processing is competitive irrespective of whether compounds are encountered in context or in isolation. We test this hypothesis by examining the predictive role of entropy of conceptual relations on processing speed when compounds are read in contexts that provide support for a more restricted meaning versus those that do not. To address the issue of Schmidtke et al.'s (2021) failure to detect a competition effect for compounds read in sentence contexts, sentence-specific measures of entropy were obtained for compounds, and their ability to predict reading times were compared against that of an entropy measure obtained for compounds that were presented isolation. On the one hand, if sentence-specific entropy measures predict reading times of compounds in sentences, in both supportive and non-supportive contexts, then this would show an extension of the entropy of conceptual relations to sentence reading tasks, confirming that possible relations for novel and existing compounds are not "insulated from the sentential context" (Gagné et al., 2005, p. 215). On the other hand, if neither measure of entropy of conceptual relations reliably predicts the processing of compounds read in sentences, then this would lend support to the hypothesis that context cancels-out the potential for competition between conceptual relations.

The present study

To address the research goals, data was collected from two separate possible relations tasks wherein compound words were presented in isolation; one task included existing compounds as critical stimuli and the other task included novel compounds. In addition, data was collected from two self-paced reading studies in which compounds were read in sentences. One self-paced reading study included existing compounds as stimuli and the other included novel compounds. In both self-paced reading studies, the same compounds were presented in one of two discourse contexts. In the non-supportive context condition, compounds were embedded in sentences that did not provide any semantic information that might guide the possible relational interpretation of the compound word, e.g., *There is no airforce anywhere around here*. In the supportive context condition, compounds were embedded in sentences that were designed to provide a narrower semantic interpretation leading up to the compound word, e.g., *Pilots in the airforce need a lot of experience flying*. After the presentation of each sentence, participants were asked to select a relational interpretation that best fit the meaning of the compound.

We present our results as two separate analyses. In Analysis 1, we assess distributional and qualitative differences in the relational meanings generated by participants for existing and novel compounds across all three presentation types: isolation, supportive context and non-supportive context. The motivation for this analysis is to provide an initial step in understanding the ways in which the meaning generation of novel and existing compounds might be differentially affected by contextual information and its absence. In Analysis 2, we turn to word processing during self-paced reading, examining the role of competition between conceptual relations on processing of novel compounds, and whether the effects of entropy for existing and novel compounds are moderated by context type.

Method

Materials

A list of 100 existing compounds and a list of 100 novel compounds were created. The novel compounds and existing compounds always belonged to separate experimental lists and were shown to separate groups of participants. For the existing compounds, 100 compounds were randomly sampled from the possible relations data set made publicly available in Schmidtke et al. (2018a) while ensuring that the entropy values were normally distributed. The list of novel compounds was created using the LADEC database (Gagné, Spalding, and Schmidtke, 2019). Novel compounds were created by crossing all the left and right constituents from existing compounds in the database. The final list of 100 novel compounds were cross-checked for frequency of occurrence across all sections of the Corpus of Contemporary American English (COCA; Davies, 2008) and the Wikipedia corpus (Davies, 2015) to ensure that none were already lexicalized.

Sentences

Both lists of compounds were embedded in sentences for the self-paced reading task. Two sentence frames were created for each compound, one with a supportive context, and one with a non-supportive context. Supportive contexts were provided for novel compounds based on the compounds' constituents. For example, in the sentence *They always forget to lock the lifegate after they close it*, *lock* is semantically related to the right constituent *gate* in *lifegate*. We ensured that the critical compound never occupied the first or last position in the sentence. After constructing the stimuli, we used a corpus-derived computational measure of semantic similarity to verify that there was a stronger semantic relation between the constituents of the compounds (including the whole words themselves for existing compounds) and all content words in the preceding sentence frame. The results verified that the semantic association between words in the preceding sentence frame and the constituents of the critical compounds (and also the whole compound words) was stronger in the supportive vs. non-supportive context conditions (see online Supplementary Materials S1 for details).

After creating the sentence frames, there were 200 sentences containing existing compounds and 200 sentences with novel compounds. Each of the 200 sentences were divided into two counterbalanced lists of 100 sentences (List A and List B) ensuring that novel and existing compounds were never inter-mixed. Each list contained one sentence for each compound, 50 of which provided supportive contexts and 50 of which provided non-supportive contexts. The materials are provided in Tables 9 and 10 in the Appendix. An example sentence frame for each experimental condition is provided in Table 2.

Procedure

There were two experimental tasks: a possible relations task where compounds were presented in isolation and a possible relations task combined with self-paced reading. Each task is described in turn below.

Possible relations task in isolation

Data for the possible relations task for existing compounds was obtained from Schmidtke et al. (2018a). The method for the possible relations task for novel compound words was identical to the method reported by Schmidtke et al. (2018a). In the possible relations task, participants were asked to pretend that they were learners of English who knew the meanings of the individual components of each compound and had to figure out the meaning of the whole word. For each trial, participants were shown a compound word in isolation. Afterwards, they were presented with 16 possible meanings for the novel compound based on the possible relations. For example, for the novel compound *dogsong*, participants would be asked to choose between 'song CAUSES dog', 'song CAUSED BY dog', 'song HAS dog', 'song BY dog', 'song MAKES dog', 'song FROM dog', 'song MADE OF dog', 'song IS dog', 'song USED BY dog', 'song USES dog', 'song LOCATED dog', 'dog

Table 2 Examples of a sentence in each of the experimental conditions in the self-paced reading tasks

Experiment	Context type	Example sentence
Novel compounds	Supportive context	They always forget to lock the *lifegate* after they close it.
	Non-supportive context	They lost the *lifegate* so they have to buy a new one.
Existing compounds	Supportive context	The baker took the *fruitcake* out of the oven.
	Non-supportive context	He threw away the *fruitcake* because he didn't like it.

The compounds are italicized for presentation purposes

LOCATED song', 'song FOR dog', 'song ABOUT dog', 'song DURING dog', and 'song BY dog' (Gagné & Shoben, 1997). Each participant selected a relational interpretation for each compound. At the beginning of the experiment, participants were given examples of relations and were given four practice trials. Both experiments (existing and novel compounds) were administered on the Amazon Mechanical Turk (MTurk) data collection platform. The experiments took approximately 25 min each to complete.

Possible relations task with self-paced reading

We combined a self-paced reading task with the possible relations task. This task was performed for four different lists by different groups of participants: the two counterbalanced lists of existing compounds embedded in sentences, and the two counterbalanced lists of novel compounds embedded in sentences. Each trial began with a fixation cross appearing for 1 s. A sentence then appeared one word at a time, with each word appearing in the center of a screen in Arial font with a letter height of 50 pixels. Participants progressed to the next word in the sentence by pressing the space key, and the latency of each button press was recorded. After reading each sentence, participants performed the same possible relations task for the embedded compound as was used in the possible relations task in isolation. Participants read a total of 4 practice sentences and 100 critical trials. Each participant completed one list (either List A or List B) of existing or novel compounds. Each experiment took approximately 40 min to complete. The self-paced reading task was programmed and administered using PsychoPy and was hosted online by Pavlovia. The online repository for the experiment, which includes the PsychoPy experiment code, is available at the following GitLab link: https://gitlab.pavlovia.org/danschmidtke/spr_compounds.

Participants

For the possible relations task with novel compounds presented in isolation, 30 consenting participants (ten female, 20 male) from the USA were recruited from Amazon Mechanical Turk. The median age of participants was 30 (IQR = 26.5). Participants were paid USD $1.50 to complete the experiment. The same task was hosted on the Amazon Mechanical Turk platform and was released to participants from the USA for the task involving existing compounds presented in isolation (refer to Schmidtke et al., 2018a for more details). The median participant age for this sample was 33 years (IQR = 17.5).

For the self-paced reading tasks, a desired minimum sample size of 40 participants per task was determined by consulting reference tables reported in Brysbaert and Stevens (2018). Based on the reference tables, the desired sample size was set at a minimum of 40 participants for each experiment. This ensured the self-paced reading experiments were sufficiently powered to detect an effect size of d = 0.4 for the interaction between Context type and Entropy of conceptual relations. Participants from the USA and Canada were recruited from the Prolific online platform. For the novel compound task 47 consenting participants were recruited (23 female, 22 male, 1 gender fluid, 1 undisclosed) with a median age of 34.5 years (IQR = 18). For the existing compound task 55 consenting participants were recruited (27 female, 26 male, 2 undisclosed) with a median age of 30 years (IQR = 18). Participants were paid USD $2.50 to complete the experiment. All participants were native English speakers. Participants across experiments were matched on gender, age and education level (see online Supplementary Materials S2). All studies were approved by the McMaster University Research Ethics Board (protocol 2020-4923).

Dependent variables

In Analysis 1, entropy of conceptual relations was the dependent measure. We computed entropy of conceptual relations based on this dataset. Entropy of conceptual relations is defined as $H = -\Sigma p_i \log_2 p_i$, where p_i is the probability of a relation within the respective distribution of chosen possible relations for a given compound. For example, let us assume the compound *toolbox* had the following distribution of possible relations judgments; 'box HAS tool' (selected 10 times), 'box FOR tool' (7), 'tool LOCATED box' (5), and 'box USED BY tool' (3). The probability distribution for these relations would be .4, .28,

.2, .12, which would result in an entropy value of 1.87 bits. To reduce noise and prevent relations that may have been chosen accidentally from affecting the results, only relations that were chosen more than once for a compound were included in the probability distributions. Figure 4 in the Appendix visualizes the language-wide distribution of conceptual relations, i.e., the probability distribution of conceptual relations collapsed across all compounds.

In Analysis 2, we analyzed log-transformed reading times, defined as the latency of the button press for the critical novel compound word in milliseconds (ms). Descriptive statistics for the raw and log-transformed reading latencies are provided in Table 3, along with descriptive statistics for all entropy values.

Independent variables

In Analysis 1, the presentation type of the compound (three levels: isolation, non-supportive context and supportive context) and the type of compound (two levels: existing and novel) served as the critical categorical predictor variables.

In Analysis 2, the self-paced reading data for existing and novel compounds was analyzed using two separate statistical models because the set of available lexical control variables differ for each compound type. There were two critical independent variables common to both analyses. The first is entropy of conceptual relations computed from data from compounds presented in context during the self-paced reading task, which we henceforth label as Entropy-*c*. The second is Context type (2 levels: supportive context vs. non-supportive context). We also fitted separate models including entropy values derived from the possible relations task in isolation, which we refer to as Entropy-*i*).

Lexical predictors

Frequency per million counts were obtained for the left constituent and right constituent as standalone (monomorphemic) words from the 1.9-billion-word Wikipedia corpus (Davies, 2015). We also included word length (in characters) in models for both analyses. Only the analysis of existing compounds included the frequency per million count of the compound word, also obtained from the Wikipedia corpus (Davies, 2015). For existing compound words, we also considered two semantic transparency measures from the compound word corpus made available by Schmidtke et al. (2021): left-whole semantic transparency and right-whole semantic transparency. Both semantic transparency measures capture the amount of meaning similarity between the whole compound word and the left constituent (left-whole transparency, e.g., *air* and *airforce*) and the right constituent (right-whole transparency, e.g., *force* and *air-*

Table 3 Descriptive statistics for the dependent and independent variables used in the self-paced reading studies

Variable	Original			Transformed		
A. *Existing compounds*	range	mean	sd	range	mean	sd
Reading time, ms	133:2752	459	350	4.89:7.92	5.93	0.59
Entropy-*c*	0:2.88	1.36	0.73	−1.88:2.1	0	1.01
entropy-*i*	0.66:3.21	2.01	0.59	−2.29:2.02	0	1
Compound length	6:13	8.71	1.29	−2.1:3.32	0	1
Left constituent frequency (per million)	0.28:1126.97	150.89	234.19	−3.75:2.01	0	1
Right constituent frequency (per million)	1.13:560.03	127.22	150.2	−2.68:1.58	0	1
Compound frequency (per million)	0:203.45	4.84	23.13	−9.56:1.09	0	1.01
Left-whole transparency	2.17:6.77	4.78	0.94	−2.78:2.12	0	1
Right-whole transparency	2.6:6.79	4.67	0.94	−2.19:2.25	0	1
B. *Novel compounds*	Original			Transformed		
Reading time, ms	133:4031	773	595	4.89:8.3	6.37	0.75
Entropy-*c*	0:2.75	1.51	0.64	−2.38:1.95	0	1
entropy-*i*	1.77:3.3	2.54	0.32	−2.45:2.38	0	1
Compound length	6:12	8.63	1.37	−1.92:2.46	0	1
Left constituent frequency (per million)	0.57:691.8	72.69	122.3	−2.56:2.18	0	1
Right constituent frequency (per million)	0.42:513.39	68.52	117.4	−2.64:2.05	0	1

Reported are the range, mean and standard deviations of the original and transformed variables. For reading times, we report the distribution after outlier removal *force*). The semantic transparency estimates were provided by human raters on a scale from 1 to 7 (1 = not related, 7 = highly related). Table 3 provides distributional characteristics of all original and transformed lexical variables and reading times for existing and novel compound self-paced reading studies.

Separate correlation matrices of independent variables used in the self-paced reading task for existing and novel compounds are provided in Tables 4 and 5. The condition number was computed to assess the level of harmful collinearity that might be present between all lexical measures. The condition numbers for both existing (κ = 2.27) and novel compounds (κ = 1.26) indicate that there was no harmful collinearity present in the data (condition number > 30 indicates strong collinearity).

Statistical considerations

Linear mixed-effects regression models were used in Analysis 1 and Analysis 2. Mixed-effects regression takes into account group-level effects of multiple predictors on the dependent variable (fixed effects) in addition to individual variation between different participants and different items (random effects) (Baayen, Davidson, and Bates, 2008). In Analysis 1, Entropy of conceptual relations values served as the dependent variable. Context type (3 levels: isolation, non-supportive context and supportive context) and Compound type (2 levels: existing and novel) served as critical independent variables. Control variables included the frequencies of the left and right constituents. Random intercepts were included for items (compound).

In Analysis 2, we fitted linear mixed-effects regression models to log-transformed reading times. Separate models were fitted to log-transformed reading times for existing and novel compounds data. Random intercepts were included for participants and items for both models. Dummy coding was used for Context type in Analysis 2 (2 levels: non-supportive context and supportive context) with 'non-supportive context' set as the reference level. In addition to the lexical variables listed in Table 3, control variables included the position of the compound in the sentence, list type (2 levels: A and B), and the randomized trial number of the sentence. All frequency-based measures were log-transformed prior to inclusion in models.

All analyses were conducted in R, the open-source software for statistical computing (R version 4.0.5; R Core Team) using RStudio (RStudio Team, 2021). The `lme4` package (Bates, Mächler, Bolker, & Walker, 2015) was used to compute the mixed-effects regression models with restricted maximum likelihood (REML) estimations. *P*-values for models were obtained using the `lmerTest` package (Kuznetsova, Brockhoff, & Christensen, 2017), which uses Satterthwaite's degrees of freedom method. All continuous measures were *z*-transformed prior to model inclusion. We refitted linear mixed-effects regression models after removing outlying residuals exceeding ±2.5 standard deviations from the mean (Baayen & Milin, 2010). Effect size estimates for mixed-effects models were extracted from models in R using the `effects` package (Fox et al., 2019).

For Analysis 1 and 2, additional parameters were included to a model if the more complex model showed a statistically significant improvement in model fit. Improvement in model fit was assessed by conducting a Chi-square test on deviance statistics of models (Akaike information criteria). Omnibus effects were calculated for all analyses, with Type III model comparisons, using the `car` package in R (Fox & Weisberg, 2011). An alpha level of .05 was used for all statistical tests across all analyses. *Post hoc* contrasts in Analysis 1 were computed using the `emmeans` package in R (Lenth, Singmann, Love, Buerkner, & Herve, 2018). The Bonferroni *p* value correction adjustment was

Table 4 Correlation matrix of lexical variables for existing compounds

	1.	2.	3.	4.	5.	6.	7.
1. Entropy-*c*							
2. entropy-*i*	.59***						
3. Compound length	−.04	−.09					
4. Left constituent frequency (log)	.00	.07	.13				
5. Right constituent frequency (log)	.17*	.25***	.01	.09			
6. Compound frequency (log)	.13	.32***	.05	.23***	.17*		
7. Left-whole transparency	.08	−.05	.25***	−.05	−.07	−.06	
8. Right-whole transparency	.00	−.21**	.30***	.01	−.27***	−.14*	.25***

Lower triangle provides Pearson correlation coefficients

*Correlation is significant at the .05 level

**Correlation is significant at the .01 level

***Correlation is significant at the .001 level

Table 5 Correlation matrix of lexical variables for novel compounds

	1.	2.	3.	4.
1. Entropy-*c*				
2. entropy-*i*	−.06			
3. Compound length	−.06	.07		
4. Left constituent frequency (log)	−.03	.06	.04	
5. Right constituent frequency (log)	.06	−.15*	−.01	−.14*

Lower triangle provides Pearson correlation coefficients
*Correlation is significant at the .05 level

computed for the statistical tests applied to the *post hoc* contrasts. All plots were generated using the `ggplot2` package (Wickham, 2011).

Results and discussion

For the possible relations task for novel compounds in isolation, 28 participants contributed a total of 3000 responses. We applied the same clean-up procedure as reported in Schmidtke et al. (2018a) for the possible relations data for existing compounds. To ensure that we did not consider responses that were made randomly, we removed all data points from any participants who selected the same relation for more than 50% of all trials. This resulted in the complete removal of data from five participants. In addition, 22 trials across all participants were removed due to no response being logged. The resulting data set consisted of 2279 judgments from 23 participants (17 male, 6 female).

The original data set for the self-paced reading task with novel compounds comprised 4700 trials (100 sentences, 47 participants). We eliminated all data from three participants who selected the same relation for more than 50% of trials. We also removed all trials from one participant who responded below 33 ms for critical compound trials for more than 50% of trials. In addition, the responses from three trials were not logged due to software error. The final data set contained 4297 trials from 43 participants (List A: 22 participants, List B: 21 participants).

For the self-paced reading task with existing compounds, the original data set included 5500 trials (100 sentences, 55 participants). We removed all trials from two participants who selected the same relation for more than 50% of trials. The responses for 47 trials were not logged due to software error. The final data set contained 5253 trials from 53 participants (List A: 28 participants, List B: 25 participants). For the analysis of reading times we excluded responses in the bottom 1% (below 133 ms for both tasks) and top 1% (above 4032 ms for the novel compound task and above 2758 ms for the existing compound task) of the reading time distribution.

Analysis 1

The goal of Analysis 1 is to determine the extent to which contextual information influences the ways in which relational meanings are generated for novel and existing compounds in different contexts. We analyzed two aspects of conceptual combination across compound types and contexts: semantic ambiguity and semantic flexibility.

Semantic ambiguity

We expect to see differences in the uncertainty, or ambiguity, of relational meanings for compounds across contexts. The possible relations task for compounds that are presented in isolation demands an interpretation for a compound in the absence of any contextual semantic cues that may help provide a more circumscribed meaning for the compound. We therefore predict that participants will be most uncertain about meanings of the compounds in the isolated condition, as reflected by highest entropy values. Since Shannon Entropy captures uncertainty in a system, greater entropy would indicate that participants tend to converge less on the set of possible relations for a compound word, signaling that the meaning for that compound is more ambiguous. Furthermore, we expect that entropy of conceptual relations will be lower for compounds embedded in any sentence context. We predict that after reading compounds in a sentence, participants will converge more on the same relations, reflecting a narrow hypothesis space of possible relational meanings of compounds. We expect that compounds presented in supportive contexts will have the lowest entropy values. This is because contexts with supportive semantic information will reduce the ambiguity of the meaning of a compound, leading to greater convergence in selecting a particular relational interpretation.

We also predict that, overall, participants providing relational interpretations for novel compounds will converge less on the same relational interpretations in comparison to participants providing responses to existing compounds. This prediction is based on the reasoning that when participants select relational interpretations to existing compounds, they will be able to draw on stored semantic knowledge about the compound based on prior exposures to the word. For novel compounds, a meaning has not been established, leading to a greater range of possible interpretations.

We tested these predictions in a mixed-effects regression model that examined the effects of compound type (existing and novel) and presentation type (isolation, supportive context and non-supportive context) on entropy of conceptual relations. We also explored the interaction between both variables to examine the possibility that novel and existing compounds are differentially affected by presentation type. Descriptive statistics of entropy of conceptual relations are provided in Table 6. The omnibus effects of the results of the mixed-effects model for entropy of conceptual relations is provided in Table 7. The results of the full mixed-effects regression model is reported separately in Appendix Table 11. The results are plotted in Fig. 1.

The main effect of compound type was significant: as expected, entropy of conceptual relations was significantly greater on average for novel compounds [M = 1.85 bits, SE = 0.04 bits] compared to existing compounds [M = 1.58 bits, SE = 0.04 bits, t = 6.28, $p < .001$]. This result indicates that, on average, participants tended to converge more on the same relational interpretations for existing compounds versus novel compounds.

The main effect of presentation type was also significant and indicated that entropy of conceptual relations differed significantly across presentation types. As expected, entropy was significantly lower when the compounds were presented in supportive contexts [M = 1.38 bits, SE = 0.05 bits] compared to when they were presented in isolation [M = 2.28 bits, SE = 0.04 bits, t = -20.4, $p < .001$]. Entropy for compounds that were presented in non-supportive contexts was also lower [M = 1.49 bits, SE = 0.05 bits] compared to when they were presented in isolation [t = -17.44, $p < .001$]. These main effects suggest that participants were more variable when picking relational interpretations for compounds presented in isolation compared to compounds presented in a sentence frame.

There was a significant interaction of presentation type and compound type. Contrasts showed that this interaction was driven by differential entropy patterns in non-supportive vs. supportive conditions across compound type (see bottom two panels in Fig. 1). Entropy was greater for novel compounds compared to existing compounds in non-supportive contexts [t = -3.59, all ps $<$ .001] (this contrast was also significant for the isolation condition), but there was no statistically reliable difference between compound types in supportive contexts [t = -0.84, p = .4]. In addition, entropy was greater for novel compounds in non-supportive contexts than when in supportive contexts [t = 3.89, $p < .001$], but this contrast was non-significant for existing compounds [t = 0.11, p = .99]. In summary, these results indicate that when embedded in semantically supportive contexts, participants tended to be equally systematic for both novel and existing compounds when choosing conceptual relations. Furthermore, when providing judgments to compounds that are embedded in sentence contexts, participants tend to be especially variable in choosing a relational meaning when exposed to a novel compound in a context that is non-supportive.

Semantic flexibility

The prior analysis showed that the meaning uncertainty of relational meanings of compounds behaved differently depending on presentation type and compound type. However, an analysis of entropy values is not ideal for examining the qualitative differences in meanings between novel and existing compounds across presentation conditions. We refer to the degree to which the same compounds may elicit different meanings across contexts as *semantic flexibility*. In this analysis, we used an index of overlap (Arita, 2017; Koch, 1957) to estimate semantic flexibility across the three presentation conditions (isolated, supportive context, and non-supportive context). The index of overlap for a compound is defined as $\frac{(\frac{T-S}{n-1})}{S}$, where n is the number of conditions in which that compound is presented, T is the grand sum of the total unique possible relations for each individual condition, and S is

Table 6 Descriptive statistics for entropy of conceptual relations

	Entropy of conceptual relations	
	Existing compounds	Novel compounds
Isolation	2.01 (0.06)	2.54 (0.03)
Non-supportive context	1.38 (0.07)	1.61 (0.07)
Supportive context	1.34 (0.07)	1.41 (0.06)

Standard errors are provided in parentheses

Table 7 Omnibus effects in the analysis of entropy of conceptual relations

Effect	$F(df, df_{res})$	p
Intercept	1131.66 (1,401.33)	< .001
Presentation type	75.36 (2,389.9)	< .001
Compound type	39.48 (1,401.33)	< .001
Left constituent frequency (log)	0.01 (1,195.87)	.92
Right constituent frequency (log)	3.08 (1,196.31)	.055
Presentation type × Compound type	14.06 (2,390.53)	< .001

the total number of unique possible relations collapsed across all conditions. In keeping with the entropy measure, we restricted the dataset to include all relations that were selected more than once for a compound.

The semantic flexibility metric ranges from 0 to 1, where values closer to 0 mean that there is less meaning overlap for a compound across conditions, i.e., more semantic flexibility. Values closer to 1 indicate that there is more meaning overlap or less semantic flexibility: the same possible relational interpretations tend to be selected for a compound in each of the three presentation conditions. To provide an example of greater semantic flexibility, consider the novel compound *grassladder*. When embedded in a sentence with a supportive context – *The girl is climbing up the grassladder in the yard* – participants selected the following three relational interpretations: 'ladder BY grass' (selection probability = .12), 'ladder LOCATION IS grass' (.12), and 'ladder MADE OF grass' (.76). None of these relational interpretations overlapped with those selected for the same novel compound embedded in a non-supportive context – *I'll bring the grassladder into the house later.* – which were 'ladder FOR grass' (.89), and 'ladder USES grass' (.11). Thus, this novel compound elicited a different set of relational interpretations in each context, yielding a value of .17 using the metric outlined above.

Existing compounds had significantly higher relational meaning overlap across conditions (M = .44, SD = .16) compared to novel compounds (M = .24, SD = .09), $t(157.92) = 10.77$, $p < .001$ (Fig. 2). This finding indicates that relational meanings tended to be more flexible for novel compounds compared to existing compounds in each presentation condition. In sum, not only were participants less certain about the relational meanings for novel compounds compared to existing compounds, especially when presented in isolation, participants also tended to choose qualitatively different sets of relational meanings for novel compounds compared to existing compounds.

Analysis 2

The RICE account proposes that conceptual relations compete for selection during compound word processing (Spalding et al., 2010). The goal of Analysis 2 is to examine whether this aspect of the RICE account holds when existing and novel compounds are processed during sentence reading. An effect of entropy of conceptual relations (either entropy-c or entropy-i) on the processing speed of both existing and novel compounds during sentence reading would confirm that relational competition is a general property of compound word processing during sentence reading. Based on Schmidtke et al. (2016; 2018a), we expect the effect of either entropy measure, if found, to be inhibitory for both compound types: greater entropy is expected to be associated with longer reading times.

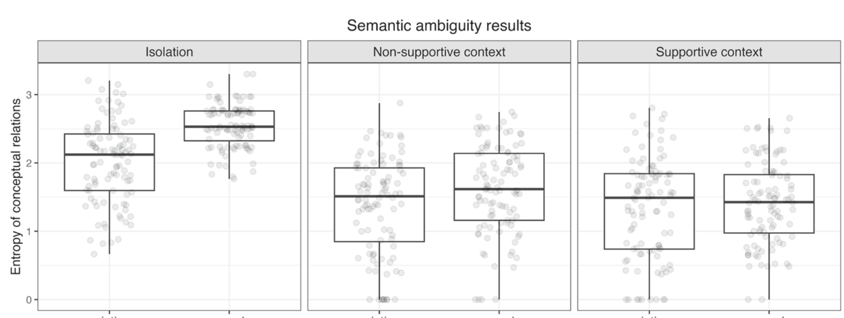

Fig. 1 Box plots of entropy of conceptual relations broken down by compound type and presentation type. Each point represents a compound. Jitter added for readability

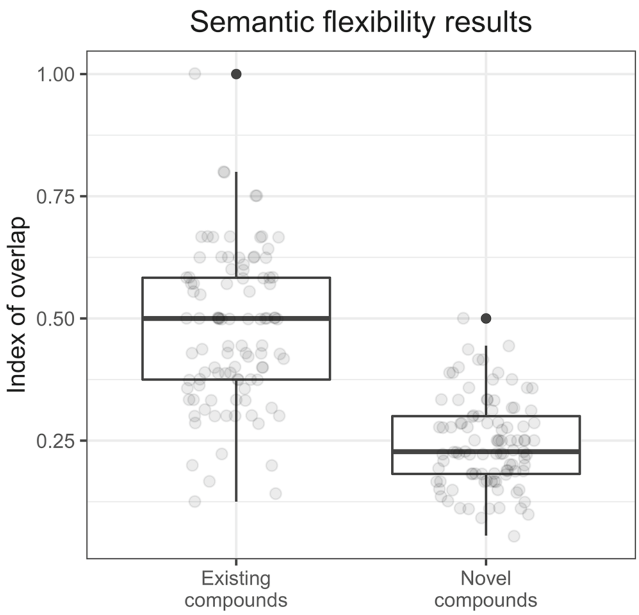

Fig. 2 Box plots of meaning flexibility by compound type. Each point represents a compound. Jitter added for readability

Furthermore, we expect that the entropy values derived from the possible relations tasks that were implanted in the self-paced reading task (entropy-*c*) to elicit a stronger effect than the entropy values derived from the experiment in which compounds were presented in isolation (entropy-*i*). We base this expectation on the reasoning that (i) the probability distribution of possible relations for compounds presented in the self-paced reading would give rise to an entropy value that is attuned to the context that the word appeared in, while this would not be possible for compounds presented in isolation, and (ii) the entropy-*c* measure is calculated from the same participants that read the compounds.

In addition, we tested whether the context in which a compound is presented influences the extent to which conceptual relations are engaged. Based on Gagné and Spalding (2004b), though meaning supportive contexts are expected to facilitate word processing, the presence of context itself is not expected to eliminate the engagement of conceptual relations. We examined this hypothesis for novel and existing compound processing by testing the interaction between each measure of entropy of conceptual relations (entropy-*c* and entropy-*i*) and context type. A significant entropy of conceptual relations (entropy-*c* or entropy-*i*) × context type interaction would indicate that the level of competition between conceptual relations during reading is moderated by context, but the absence of a significant interaction effect would suggest, in support of Gagné and Spalding (2004b), that the strength of the competition effect is not different across supportive and non-supportive contexts. The omnibus effects of the results of the mixed-effects models for existing and novel compounds are provided in Table 8. The full results of the respective models are reported separately in Appendix Tables 12 and 13.

There was a significant main effect of entropy-*c* on novel compound reading times [$\hat{\beta}$ = 0.018; *SE* = 0.008; *p* = .036], and on existing compound reading times [$\hat{\beta}$ = 0.015; *SE* = 0.005; *p* = .004]: in both studies greater entropy led to longer reading times. The effect size, defined as the amount of change in reading times estimated for the contrast between the minimum and the maximum value of entropy-*c*, was 44 ms for novel compounds and 22 ms for existing compounds.

There was a significant main effect of context on novel compound reading times [$\hat{\beta}$ = 0.03; *SE* = 0.014; *p* = .035] and existing compound reading times [$\hat{\beta}$ = -0.021; *SE* = 0.01; *p* = .036]. Novel compounds that were embedded in supportive contexts were read 17 ms slower than novel compounds embedded in non-supportive contexts. However, the opposite trend was true for existing compounds: existing compounds were read 8 ms faster in supportive contexts than when in non-supportive contexts. The partial main effects of entropy-*c* and context type on existing and novel compound reading are visualized in Fig. 3 (to aid interpretability, plots depict back-transformed values of reading times, in milliseconds).

The main effect of entropy-*i* did not reach statistical significance in reading times for novel compounds [$\hat{\beta}$ = -0.008; *SE* = 0.01; *p* = .428] and existing compounds [$\hat{\beta}$ = 0.01; *SE* = 0.007; *p* = .124]. A chi-square goodness of fit on deviance statistics of existing and novel compounds showed that the addition of entropy-*i* did not improve model fit [existing compounds: $\chi^2(1) = 2.27$, *p* = .13; novel compounds: $\chi^2(1) = 0.63$, *p* = .43]. The interactions of context type with entropy-*c* or entropy-*i* did not reach statistical significance for existing and novel compound reading times. The inclusion of interactions between either entropy measure and context did not improve model fit [existing compounds: $\chi^2(2) = 0.41$, *p* = .52; novel compounds: $\chi^2(2) = 1.72$, *p* = .19], so we did not include these interactions in our final model.

The results of Analysis 2 demonstrate that there is a processing cost to novel compound word reading when no single possible relational interpretation dominates over all other relational meanings. This finding indicates that novel compound word processing involves constructing multiple relational meanings and that these meanings compete with one another. Further, the same effect of entropy-*c* was present in existing compound word recognition and was also not moderated by context, suggesting that for both existing and novel compounds, the competition effect is reliable and operates independently of context. We discuss these results in the General discussion.

Table 8 Omnibus effects in the analysis of reading times (log) in the self-paced reading tasks for existing and novel compounds

Effect	Existing compounds		Novel compounds	
	$F(df, df_{res})$	p	$F(df, df_{res})$	p
Intercept	4931.01 (1,51.41)	< .001	2729.88 (1,41.54)	< .001
Entropy-*c*	8.54 (1,123.93)	< .001	4.38 (1,338.52)	.04
Context type	4.39 (1,3798.59)	.04	4.46 (1,3858.42)	.03
Compound length	27.35 (1,91.19)	< .001	35.06 (1,95.08)	< .001
Left constituent frequency (log)	1.08 (1,92.34)	.3	2.9 (1,95.66)	.09
Right constituent frequency (log)	0.02 (1,92.03)	.89	1.33 (1,94.62)	.25
Sentence position	174.27 (1,286.54)	< .001	221.24 (1,617.78)	< .001
Trial number	1307.18 (1,4965.68)	< .001	734.01 (1,4062.49)	< .001
List	0.27 (1,51)	.61	2.33 (1,41)	.13
Compound frequency (log)	5.1 (1,95.65)	.03		
Left-whole semantic transparency	5.7 (1,91.92)	.02		
Right-whole semantic transparency	0.17 (1,90.15)	.69		

Finally, we report the effects of predictors of compound word processing that are not relevant to the current study. There was an effect compound length on both novel [$\hat{\beta}$ = 0.057; *SE* = 0.01; p < .001] and existing compound types [$\hat{\beta}$ = 0.029; *SE* = 0.005; p < .001]: as expected longer compounds were read more slowly. For existing compounds, the effect of compound frequency was significant [$\hat{\beta}$ = -0.012; *SE* = 0.005; p = .026] and was in the expected direction: more frequent compounds tended to be read faster than infrequent compounds. We also found a significant effect of left-whole semantic transparency [$\hat{\beta}$ = 0.013; *SE* = 0.005; p = .019]. Higher semantic similarity between the meaning of the left constituent and whole form led to longer processing times. The direction of the effect is surprising given the amount of evidence showing that high semantic similarity is associated with faster reading times (Schmidtke et al., 2021; Gagné et al., 2019; Kim, Yap, & Goh, 2019). One possibility for this result is that greater semantic similarity imposes a discrimination cost on processing whereby the closely related meanings of the left and whole word make it difficult for the cognitive system to reduce the uncertainty between the outcomes associated with each word under comparison (see also Schmidtke, Van Dyke, & Kuperman, 2018). Since this result is not the focus of the present study, we do not discuss it further.

General discussion

A series of experiments reported herein were designed to test two hypotheses about the roles of relational competition and context on the processing of existing and novel compounds. The first hypothesis is that both novel and existing compound word reading times should be sensitive

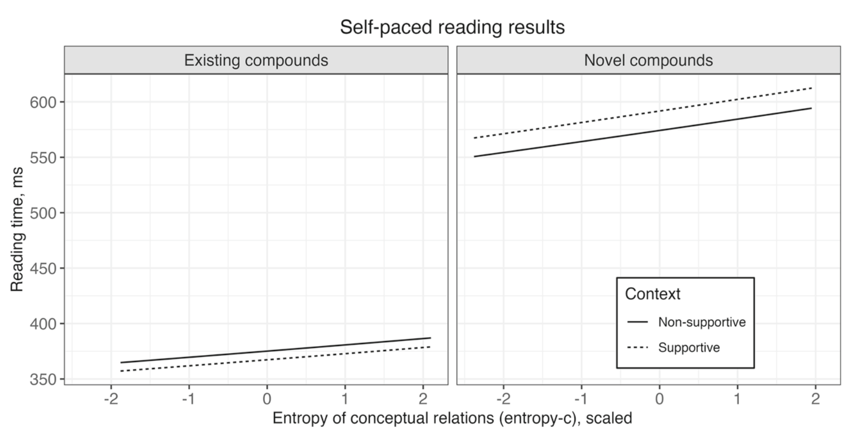

Fig. 3 The partial main effects of entropy-*c* (scaled) and context on reading times of novel compounds during self-paced reading

to a common metric of competition between conceptual relations. This hypothesis was confirmed by the self-paced reading time data: entropy of conceptual relations was a significant predictor reading times to novel and existing compounds, such that greater competition between a compound word's possible conceptual relations leads to longer reading times. The second hypothesis is that relational processing is competitive irrespective of whether compounds are encountered in context or in isolation. The self-paced reading data supports this hypothesis. We report that entropy of conceptual relations predicted reading times to compounds embedded in sentences, and that this effect was equally strong in sentences that supported a particular compound word meaning versus those that did not.

Our results were presented across two analyses. In Analysis 1, we first examined differences in the kinds of relational interpretations generated by participants across three presentation conditions (isolation, supportive sentence contexts and non-supportive contexts). This analysis provided a preliminary quantitative overview of differences in the ambiguity and flexibility of relational information between existing and novel compounds. In Analysis 2, we turned to the effect of conceptual relations on processing times during sentence reading. In what follows, we discuss the results of each analysis in turn.

Differences in semantic ambiguity and flexibility across novel and existing compounds

Semantic ambiguity

Context serves to reduce meaning ambiguity of compound words. Analysis 1 showed that entropy of conceptual relations was lower for both novel and existing compounds after they were read in sentences compared to when presented in isolation. This result indicates that participants tend to choose a more restricted set of relational interpretations for compounds when they are encountered in a sentence context. This aligns with the conclusion drawn by Gagné et al. (2005) that the space of possible semantic interpretations of a compound is affected by sentence context.

Analysis 1 also showed that whenever there was a reliable difference in entropy of conceptual relations between compound types, entropy was always greater for novel compounds. This result confirms that, as expected, relational meanings for novel compounds are more diffuse in comparison to existing compounds. A straightforward explanation for this pattern is that participants draw upon stored semantic knowledge when selecting plausible conceptual relations for existing compounds in the possible relations task (for an extensive discussion on how individual print experience and compound frequency affect flexibility and precision of relational knowledge see Schmidtke et al., 2018a). Perhaps the purest support for this hypothesis is in the comparison between the entropy of novel and existing compounds in the isolated condition: entropy of conceptual relations was significantly lower for existing compounds even when there was no contextual information to narrow the space of possible meanings. In sum, even in the absence of supporting contextual information, participants tend to rely upon existing semantic knowledge more readily when deciding upon the relational interpretations of existing compounds compared to novel compounds.

Interestingly, the results of Analysis 1 indicated that possible relations judgments of existing and novel compounds were differentially affected by context type. That is, supportive vs. non-supportive contexts yielded differences in entropy values for novel compounds but not for existing compounds. When selecting meanings for existing compounds, participants were equally systematic when the same compound was encountered in a context that aided a narrow interpretation of the compound vs. a context that did not provide specific semantic support for a plausible meaning.

This was not the case for novel compounds. Participants were less variable in selecting a plausible conceptual relation for novel compounds after they were read in supportive contexts compared to when encountered in non-supportive contexts. Only when novel compounds were presented in meaning supportive contexts was the degree of convergence upon relational meanings equivalent to that of existing compounds. Since the meanings of novel combinations are not established in memory, readers may rely more heavily on available contextual information to help choose a plausible meaning. Altogether, these results suggest that relational meanings of novel compounds are more sensitive to contextual information than existing compounds.

Semantic flexibility

Were there qualitative differences in the relational meanings for novel and existing compounds across presentation types? The results of the semantic flexibility metric in Analysis 1 suggest so. Participants tended to choose overlapping sets of relational interpretations when existing compounds were presented in isolation or in either context type, but were more likely to choose different sets of relational meanings for novel compounds in each of the presentation formats. These results further support the idea that the types of relational meanings ascribed to novel compounds tend to be more flexible and sensitive to the contexts in which they are embedded.

In sum, Analysis 1 showed that relational meanings of novel compound words are more ambiguous in comparison to lexicalized compounds. Furthermore, compared to existing compounds, participants tended to select different sets of meanings for novel compounds across contexts. We argue that the relational meanings of existing compounds are tied to the meanings of their stored lexical representations in memory, but that conceptual combination of novel compounds relies instead on sources of available semantic information from the surrounding context. These findings are consistent with the extensive literature on the critical role of contextual information during novel word learning (Adelman, Brown, & Quesada, 2006; Chaffin, Morris, & Seely, 2001; Johns, Dye, & Jones, 2016; Pagán & Nation, 2019; Snefjella, Lana, & Kuperman, 2020).

Competition between conceptual relations affects novel and existing compound word processing in context

In support of the RICE hypothesis, the results of Analysis 2 provide evidence for relational competition during the processing of both novel and existing compounds: greater entropy among possible conceptual relations inhibited reading times for both novel noun-noun combinations and lexicalized compounds during sentence reading. These results represent two new contributions to the field of compound processing. First, as far as the authors are aware, the effect of entropy of conceptual relations (Schmidtke et al., 2016; 2018a) has not been previously shown to affect novel compound word processing. This study therefore demonstrates, via a common measure, that relational competition is a general property of novel and existing compound word reading. Second, this is the first occasion that competition between conceptual relations has been shown to affect compound processing during sentence reading rather than in isolated word processing.

Linking the results of Analysis 1 and 2 together, it is possible to conclude that relational competition occurs even when the same compounds did not always elicit a fully overlapping set of competing relational interpretations across different contexts. Recall that in Analysis 1 we found that the sets of relational meanings that participants selected tended to overlap across different presentation formats for existing compounds, but did not overlap as much for novel compounds. We therefore argue in favour of the account posited by Gagné et al. (2005) that relational competition is an automatic process, even when the types of activated possible interpretations are particular to the context in which a compound appears. In sum, despite each sentence frame giving rise to different sets of possible meanings for the same compound, ambiguity in the resulting sets of meanings were equally predictive of lexical processing in each condition.

Contradicting the results of the present study, as stated at the outset of this study, the entropy effect was not reliably found in eye movements during sentence reading (Schmidtke et al., 2021). There are two possibilities for these conflicting results. The first possibility concerns differences in task demands. Although both studies involved sentence reading, the eye-tracking study reported by Schmidtke et al. (2021) was a naturalistic reading task that recorded a very different behavioral measure of processing. That is, instead of serial presentation of words and a key-press response time, participants silently read sentences that were presented fully on a screen while eye movements were tracked. Participants were also given an additional task in the current study. Participants were required to make a possible relations judgement after the sentence, which may have caused participants to pay more attention to conceptual relations.

The second possibility is that detecting an effect of entropy during sentence reading might depend on whether the entropy values for compounds are derived from judgments made only when the compounds are embedded in the same sentences that are used in the reading task itself (entropy-*c*). Only the entropy-*c* measure, and not the entropy-*i* measure, reliably predicted processing speed for novel and existing compounds. Although the entropy-*c* measure was predictive of reading times, as noted above, there was no interaction between context type. This result leads us to speculate that the competition effect is observable when the corresponding measure of meaning uncertainty is attuned to sentence context, and that the size of the effect is not necessarily moderated by the amount of semantic support in the preceding context. Therefore, a pressing question is whether entropy-*c* affects eye movements during the reading of existing and novel compounds embedded in the same sentences used in this study. This would help disentangle the two possibilities for lack of a significant effect of conceptual combination in the eye-movement record.

General processing differences across context type

Novel compounds were processed around 200 ms more slowly than existing compounds overall. However, there was a difference in the direction of the effect of context between compound types. Supportive contexts aided the processing of existing compounds, such that compounds in supportive contexts were processed significantly faster than the same compounds embedded in non-supportive contexts. Conversely, the overall processing of novel compounds was significantly slower in the supportive context condition relative to the non-supportive context condition. We interpret our result as a manifestation of the Noticing Hypothesis (1991). That is, readers spend more time when reading novel compounds since readers devote greater attention to figuring out the possible meaning of unfamiliar words, and devote even more effort inferring the meaning of the novel compound when it is possible to integrate the meaning more readily with the preceding sentence context. We note that this pattern of results for novel compounds did not conform with the results presented by Gagné and Spalding (2004b), which we speculate may be a consequence of task differences. In Gagné and Spalding's study, participants were asked to provide an acceptability judgement after reading the entire sentence. This response type was a measurement of the time taken to process a relational interpretation that was readily provided to the participant and not the processing time on the compound word as it is encountered in the sentence itself. Therefore, in Gagné and Spalding's study, the faster response time in the supportive context condition relative to the neutral context may have reflected post hoc evaluation of the consistency of the meaning of the relational phrase with the preceding sentence without capturing the online processing associated with integrating a plausible novel compound meaning with the preceding sentence, as outlined in the Noticing Hypothesis.

Conclusions

In conclusion, this study provides confirmation of the RICE hypothesis (Spalding et al., 2010), demonstrating, via a common measure, that possible conceptual relations compete for selection during the processing of existing and novel compound words during sentence reading. The amount of semantic support that is present in the preceding sentence context differentially constrains the flexibility and ambiguity of the sets of possible relational meanings for novel and existing compounds. Despite these constraining factors, competition between relational meanings remains a stable and consistent predictor of reading times of novel and existing compounds during sentence reading.

Appendix

Table 9 List of stimuli used in the existing compound self-paced reading task

Context type	Sentence
non-supportive	There is no **airforce** anywhere around here.
supportive	Pilots in the **airforce** need a lot of experience flying.
non-supportive	Kyle didn't know what to do when his **airway** was causing problems for him.
supportive	A piece of food got stuck in his **airway** and he started to choke.
non-supportive	The shop was out of **applesauce** when he went today.
supportive	He was hungry so he got some **applesauce** out of the fridge.
non-supportive	The old and broken **armchair** needs to be replaced.
supportive	The woman sat in the **armchair** to read a book.
non-supportive	Jake went to the **ballgame** on Saturday afternoon.
supportive	The sports fans watched the **ballgame** that was played last week.
non-supportive	The man finished using the **baseball** after he almost lost it.
supportive	The pitcher threw the **baseball** directly into the crowd.
non-supportive	You should get some **bearskin** the next time you go to the store.
supportive	That rug made of **bearskin** is on the floor.
non-supportive	Ken took the **birdcage** and put it on the table.
supportive	The parrot flew out of the **birdcage** when it was left open.
non-supportive	She couldn't remember his **birthday** even if her life depended on it.
supportive	Jen's friends celebrated her **birthday** by throwing a party.
supportive	The baby with the low **birthweight** needed to stay at the hospital.
non-supportive	There is a new **bordertown** where the old one used to be.
supportive	The family moved to the **bordertown** last year.
non-supportive	I met her **boyfriend** when I went for a walk.
supportive	You enjoyed the date that your **boyfriend** planned for you.
non-supportive	Tom is out of **brainpower** so he'll have to try again later.
supportive	Solving that problem used a lot of **brainpower** that afternoon.

Table 9 (continued)

Context type	Sentence
non-supportive	Shawn hated the **brickwork** at his cousin's house.
supportive	The builder will lay the **brickwork** down for the new patio.
non-supportive	Tim is reading about a **bullfight** in his book.
supportive	The matador was injured in the **bullfight** he was in today.
non-supportive	He met the **businesswoman** when he went to the mall.
supportive	The meeting led by the **businesswoman** was very thorough.
non-supportive	Rachel didn't really like the **campground** so she'll find another one.
supportive	We pitched a tent at the **campground** before it got too dark.
non-supportive	He had a **catnap** yesterday morning, but not last week.
supportive	After a tiring morning he took a **catnap** before getting back to work.
non-supportive	We will buy some **cheesecake** as soon as we can.
supportive	You ate a slice of **cheesecake** for dessert last night.
non-supportive	Sam used to work for the **coastguard** when she was younger.
supportive	The sailors were rescued by the **coastguard** after being stuck in a storm.
non-supportive	I don't like this new **cookbook** as much as the old one.
supportive	He followed a recipe from the **cookbook** when he made dinner.
non-supportive	The new **courtroom** was made too close to the previous one.
supportive	The judge worked in the **courtroom** every single day last year.
non-supportive	They hired the **covergirl** from the last shoot.
supportive	He gazed at the magazine with the beautiful the **covergirl** on the front.
non-supportive	Jamie put the **crossbow** on the lowest shelf.
supportive	Arrows shot using a **crossbow** can travel very far.
non-supportive	I want to replace the old **crowbar** with a newer one.
supportive	The robber used a **crowbar** to break into the house.
non-supportive	Sara broke the **dollhouse** because she was angry.
supportive	The children played with the **dollhouse** before they went to bed.
non-supportive	Since it was sunny, the **dressmaker** went for a walk outside.
supportive	The clothes made by this **dressmaker** are fancy and expensive.
non-supportive	Ben received his favourite **drumstick** as a gift from a friend.
supportive	The percussionist couldn't play in the song because her **drumstick** was broken in half.
non-supportive	I don't think there is a **duckpond** near my house.
supportive	The woman threw breadcrumbs into the **duckpond** to feed the birds.
non-supportive	She returned the **eggcup** to the store and got a new one.
supportive	After breakfast, Bob cleaned the **eggcup** and put it away.
non-supportive	He decided to have his **eyeball** examined since it was bothering him.
supportive	The vision loss because of the **eyeball** injury will be permanent.
non-supportive	The teacher packed his **facemask** in his bag before going to work.
supportive	You need to wear a **facemask** if you want to go into the store.
non-supportive	Greg got the **factsheet** I sent to him.
supportive	Jack read the information on the **factsheet** to make sure he knows it all.
non-supportive	I don't know if there is much **farmland** in this area.
supportive	There are many cows and horses in the **farmland** just outside of town.
non-supportive	The photographer saw the **fireball** and took a picture of it.
supportive	The burning building created a **fireball** that lit up the whole sky.

Table 9 (continued)

Context type	Sentence
non-supportive	Chris did not want a **fireplace** but he got one anyway.
supportive	He lit some wood in the **fireplace** in order to warm up the house.
non-supportive	The students met the **flightcrew** after school on Thursday.
supportive	When they are on the plane, the **flightcrew** works very hard.
non-supportive	There used to be a **floodgate** nearby, but it was destroyed recently.
supportive	A lot of water poured out when the **floodgate** was opened after the storm.
non-supportive	You don't like the same **folksong** as I do.
supportive	The singers performed the **folksong** on stage in front of a large audience.
non-supportive	He threw away the **fruitcake** because he didn't like it.
supportive	The baker took the **fruitcake** out of the oven.
non-supportive	The kid read about the **hailstorm** online for a project.
supportive	The damage from the **hailstorm** destroyed multiple homes.
non-supportive	Nora hasn't had a **haircut** for a while.
supportive	She went to the barber to get a **haircut** before the party.
non-supportive	David had forgotten about the **handclap** by the end of the day.
supportive	The sound of the **handclap** woke him up.
non-supportive	The child drew a **handprint** on the piece of paper.
supportive	Since the paint was wet, a **handprint** was left on the wall.
non-supportive	The journalist wrote an article about the causes of **heatstroke** for the news.
supportive	Because of the temperature, many people suffering from **heatstroke** were treated in the hospital.
non-supportive	There are pictures of their **homeland** in their album.
supportive	After living abroad for several years, he returned to his **homeland** to live with family.
non-supportive	He found the **houseplant** that was inside the drawer.
supportive	Mary watered the **houseplant** and put it back on the shelf.
non-supportive	The most recent **jailbreak** in this city was a decade ago.
supportive	The prisoners who escaped in the **jailbreak** were found by the police.
non-supportive	The lawyer talked about her **kneecap** with her colleagues.
supportive	He fell on his leg, which caused a **kneecap** injury that required surgery.
non-supportive	Last week, Carl saw his **landlord** when he went to the park.
supportive	The apartment was in bad shape because the **landlord** was neglecting it.
non-supportive	She used to be a **lifeguard** when she was younger.
supportive	The pool is safe to swim in because the **lifeguard** works very hard.
non-supportive	I will check what kind of **lightbulb** I need to get.
supportive	She unscrewed the old **lightbulb** so she could replace it.
non-supportive	After eating breakfast, the **mailman** cleaned his dirty dishes.
supportive	The package was left by the **mailman** on the front porch.
non-supportive	Lauren bought a **meatball** when she was shopping this morning.
supportive	The chef rolled the **meatball** for the new recipe that he designed.
non-supportive	They made sure to replace the **mincemeat** that was used up.
supportive	The chef prepared the **mincemeat** needed for his recipe.
non-supportive	It made a **molehill** in the corner of the room.
supportive	The gardener in the yard found a **molehill** and she stepped around it.
non-supportive	Yesterday he met a **moneylender** when he went to the beach.
supportive	She took a loan from the **moneylender** at the bank.
non-supportive	Jeff and Sam went to the **mountaintop** on a rainy day.

Table 9 (continued)

Context type	Sentence
supportive	We climbed to the **mountaintop** and enjoyed the beautiful view.
non-supportive	He threw the broken **paperclip** away and got a new one.
supportive	The pages were held together with a **paperclip** so none would get lost.
non-supportive	She couldn't find her **passport** anywhere in her house.
supportive	The traveller grabbed her **passport** and suitcase before going to the airport.
non-supportive	He lost the **photobook** that he had received as a gift.
supportive	The mother showed her favourite picture in the **photobook** to the rest of the family.
non-supportive	Nate drove by the **racetrack** on his way to work.
supportive	The spectators at the **racetrack** usually make bets.
non-supportive	They are building a **railway** about a kilometre from the other one.
supportive	The trains on the **railway** make a lot of noise.
non-supportive	Mark knows that there is a **restroom** somewhere near here.
supportive	John washed his hands in the **restroom** before eating dinner.
non-supportive	Jen got a new **ringtone** because she didn't like her old one.
supportive	She didn't answer the phone because the **ringtone** was too quiet to hear.
non-supportive	They can't see the **riverbed** from over here.
supportive	The rocks they collected from the **riverbed** were covered with mud.
non-supportive	They were going to go to the **roadhouse** but they changed their minds.
supportive	They went to eat at the **roadhouse** in the evening with friends.
non-supportive	John couldn't reach the **sandpaper** that was on the shelf.
supportive	She smoothed the table she was building with **sandpaper** before painting it.
non-supportive	Alex threw the **sawdust** away because she didn't need it.
supportive	Since construction is happening, there is **sawdust** in the air around here.
non-supportive	They will go out for dinner with a **schoolfriend** later tonight.
supportive	After class, Alice met with a **schoolfriend** to work on homework.
non-supportive	We met the **schoolgirl** who lives across the street.
supportive	Once her classes were over the **schoolgirl** went home and did her homework.
non-supportive	I gave a gift to my **schoolmate** for his graduation.
supportive	She needs to work on a project with a **schoolmate** so she met him at the library.
non-supportive	We are far away from the **schoolyard** right now.
supportive	The students played in the **schoolyard** after their classes ended.
non-supportive	The store I went to does not sell **seafood** on Saturdays.
supportive	The chef is cooking **seafood** in the fancy restaurant.
non-supportive	She got a new **shotglass** as a gift for her friend.
supportive	Kate poured alcohol into the **shotglass** at the party.
non-supportive	He left hime at the **sideline** after the soccer game.
supportive	The soccer player waited at the **sideline** for instruction.
non-supportive	There used to be a **sinkhole** here, but it is gone now.
supportive	The road collapsed because of the **sinkhole** that appeared this morning.
non-supportive	Jeff is going to the **skatepark** after work today.
supportive	The girl was performing tricks at the **skatepark** with her friends.
non-supportive	A few days ago there was a **smokescreen** at the foot of the mountain.
supportive	They couldn't see because of the **smokescreen** that had been used.
non-supportive	Kate did not take a photo of the **snowfall** because she forgot to.
supportive	The roads were covered by the **snowfall** from last night's storm.
non-supportive	He sent the broken **snowshoe** to be repaired so he could use it again.

Table 9 (continued)

Context type	Sentence
supportive	Since it was winter in Canada she decided to **snowshoe** instead of walking.
non-supportive	Yesterday, the girl saw a **songbird** when she was walking home.
supportive	In the morning, the sound from the **songbird** woke the whole family up.
non-supportive	He painted the **spacecraft** with a bright yellow colour.
supportive	The astronauts in the **spacecraft** have been there for several days.
non-supportive	The children saw a **spaceship** when they were playing outside.
supportive	The astronaut landed the **spaceship** on the moon safely.
non-supportive	They collected some **stardust** at the fairytale castle.
supportive	The astronauts were studying **stardust** that was found in space.
non-supportive	Jack didn't see the **sunbeam** that was here this morning.
supportive	The bright light from the **sunbeam** lit up the whole room.
non-supportive	The last time a **swordfight** happened was several years ago.
supportive	The knight was injured in the **swordfight** and needed medical treatment.
non-supportive	I have not seen a **taxicab** anywhere around here.
supportive	The driver parked the **taxicab** outside the theatre.
non-supportive	The most recent **thunderstorm** happened several months ago.
supportive	The rain from the **thunderstorm** caused serious flooding.
non-supportive	He forgot to put the **tinfoil** away after using it.
supportive	They wrapped the leftovers with **tinfoil** after eating dinner.
non-supportive	Larry forgot to buy **toothpaste** when he went to the grocery store.
supportive	Sally put her toothbrush and **toothpaste** away in the bathroom.
non-supportive	They couldn't find the **topsoil** so they eventually gave up.
supportive	Hannah dug through the **topsoil** in the garden.
non-supportive	The man bought a **tracksuit** when he went shopping.
supportive	The athlete put on her **tracksuit** before going for a run.
non-supportive	Jacob found a **trapdoor** somewhere around here.
supportive	They closed the **trapdoor** so nobody would fall in.
non-supportive	Alex went to the **vineyard** after she finished her work.
supportive	The grapes from this **vineyard** will be made into wine.
non-supportive	She needed to go back because the **waistband** was left at home.
supportive	He needed to wear a belt because the **waistband** on his pants was too loose.
non-supportive	There is a huge **waterfall** next to the building.
supportive	The rushing sound of the **waterfall** can be heard from a distance.
non-supportive	He put the **wheelchair** back at the end of the day.
supportive	She pushed the **wheelchair** up the long ramp.
non-supportive	I replaced the **windshield** that doesn't work anymore.
supportive	I can't see out the car because the **windshield** is covered in dirt.
non-supportive	I couldn't find the **wingspan** anywhere in the book.
supportive	This bird can't fly because its **wingspan** is too short.

Table 10 List of stimuli used in the novel compound self-paced reading task

non-supportive	I saw an **airmedic** when I went to the mall.
supportive	The girl wants to work as an **airmedic** when she grows up.
non-supportive	There's an **alebank** across the street from there.
supportive	Todd got a drink from the **alebank** last night.
non-supportive	Jacob got a new **bagweb** as a gift on his birthday.
supportive	She will hang up her purse on the **bagweb** once she's done with it.
non-supportive	She bought a new **barbox** to replace the one she lost.
supportive	John opened up the **barbox** so he could put something away.
non-supportive	He decorated the **bedscreen** with ribbons and glitter.
supportive	She hung up the **bedscreen** before taking a nap.
non-supportive	There are no **beefolk** in this country.
supportive	The hive owned by the **beefolk** was quite large.
non-supportive	The house's **beltmast** was destroyed recently.
supportive	The boat was missing its **beltmast** so it could not sail.
non-supportive	They put the **bogeylist** in the fridge after returning from the store.
supportive	He wrote down the **bogeylist** in his notebook.
non-supportive	Paul wanted to get a **bookbasin** but couldn't find one.
supportive	The librarian filled up the **bookbasin** and put it on the table.
non-supportive	They put a **brainbed** in their new kitchen.
supportive	It helps to rest in a **brainbed** after a long day.
non-supportive	She forgot to buy a **breadnut** when she went to the mall.
supportive	The baker used some **breadnut** in his new recipe.
non-supportive	Ella put away the **bridefeather** at the end of the day.
supportive	The groom gave her a **bridefeather** before the wedding.
non-supportive	There was a **butterlamp** on the table.
supportive	He turned on the **butterlamp** to light up the room.
non-supportive	He returned the **cakebaby** to the store.
supportive	The baker decorated the **cakebaby** and added it to the display.
non-supportive	The house was built with a **cakenest** in the hallway.
supportive	The baker put the desert in the **cakenest** after he took it out of the oven.
non-supportive	He ordered a new **catpen** last week.
supportive	There was a kitten meowing from the **catpen** in the next room.
non-supportive	Bella drove the **cavehouse** away from the town.
supportive	The family moved into the **cavehouse** last month.
non-supportive	The lawyer put the **chalkbaby** away after she was done with it.
supportive	The teacher wrote on the board using a **chalkbaby** from his desk.
non-supportive	There is a sale on **cheekwater** at the grocery store.
supportive	He poured the **cheekwater** into the sink.
non-supportive	Did you see the **coaljet** at the park yesterday?
supportive	The pilot landed the **coaljet** at the airport.
non-supportive	I wasn't sure what **deedword** I should put there.
supportive	He didn't hear what **deedword** Sara said over the phone.
non-supportive	Joe helped his daughter with her **deskscarf** earlier today.
supportive	Mark tied his **deskscarf** before he left his house for work.
non-supportive	There will be a **dinnersale** next weekend.
supportive	We paid for our meal at the **dinnersale** this afternoon.
non-supportive	The bird carried the piece of **dogrope** away.
supportive	She tied the piece of **dogrope** in a knot.
non-supportive	The kids didn't have enough money for the **dogsong** they wanted.
supportive	Yesterday I heard a **dogsong** on the radio.
non-supportive	You shouldn't call the **dyestore** so early in the morning.

Table 10 (continued)

supportive	The artist went to the **dyestore** to buy supplies.
non-supportive	When I was walking I saw a **fairycoat** on the ground.
supportive	Joe took off the **fairycoat** and hung it in the closet.
non-supportive	She needed to get the **figbike** fixed because it broke.
supportive	The boy rode his **figbike** to school this morning.
non-supportive	We bought a **flowerbeard** at the supermarket.
supportive	He planted a **flowerbeard** in the garden.
non-supportive	She needed a **gemtruck** but she didn't have one.
supportive	We drove in the **gemtruck** for a long time.
non-supportive	She was happy to see the **ghostlip** when she went to the park.
supportive	The kids in the haunted house were scared of the **ghostlip** so they ran away.
non-supportive	Can you find where the **grainhouse** is located?
supportive	They built a new **grainhouse** to store wheat.
non-supportive	He saw that there was no **grassgap** anywhere.
supportive	In the garden, the dog ran through the **grassgap** very quickly.
non-supportive	I'll bring the **grassladder** into the house later.
supportive	The girl is climbing up the **grassladder** in the yard.
non-supportive	I wanted to buy a **gumsheet** so I went to the store.
supportive	You should spread the **gumsheet** on the ground before you start.
non-supportive	He doesn't want to get any **gymguilt** from them.
supportive	They've been feeling a lot of unpleasant **gymguilt** lately.
non-supportive	They didn't enjoy the **hamstyle** they got at the movies.
supportive	The chef had to learn about **hamstyle** in order to prepare the dish.
non-supportive	There isn't a **helltower** anywhere around here.
supportive	The tall **helltower** was built a long time ago.
non-supportive	He looked on the **horsebench** and found a backpack there.
supportive	The rider is going to sit on the **horsebench** and wait for a while.
non-supportive	He removed the **jazzbox** from the shelf.
supportive	We're going to listen to the **jazzbox** this afternoon.
non-supportive	He has a **junkroom** even though he doesn't think he needs one.
supportive	Sam put the extra things in the **junkroom** when he was done with them.
non-supportive	Rob cleaned the **lakebasket** before he put it away.
supportive	Did she pack them in the **lakebasket** or not?
non-supportive	I couldn't find a new **lifebasket** anywhere I looked.
supportive	Peter packed the **lifebasket** up and brought it with him.
non-supportive	They lost the **lifegate** so they have to buy a new one.
supportive	They always forget to lock the **lifegate** after they close it.
non-supportive	She didn't like the **lionrug** I bought on sale.
supportive	He unrolled the **lionrug** and spread it on the floor.
non-supportive	She could not find a **lunchcup** in the closet.
supportive	At noon, Alex took a **lunchcup** out of his bag.
non-supportive	Where can I find a **monkeyhat** for sale?
supportive	Fred is going to knit a new **monkeyhat** for her.
non-supportive	It was impossible to find the **moondisc** anywhere.
supportive	At night, we could see the **moondisc** when we were outside.
non-supportive	Janet threw the **mouthscreen** away because she didn't want it.
supportive	He didn't want to wear the **mouthscreen** over his face.
non-supportive	They threw away the **mucklust** because they didn't like it.
supportive	The pig in the mud had **mucklust**, so it made a huge mess.

Table 10 (continued)

non-supportive	Charlie didn't like the **neckbird** that he saw.
supportive	The kids were excited to see the **neckbird** at the zoo.
non-supportive	Noah put the **oceanpen** away in the drawer.
supportive	That artist used an **oceanpen** in his newest piece.
non-supportive	The woman passed the **papertruck** on her way to work.
supportive	The driver parked the **papertruck** outside the store.
non-supportive	The author wrote about the **peaceproof** in her new book.
supportive	The war ended when the **peaceproof** was presented.
non-supportive	You won't be able to find **policyfolk** in that building.
supportive	The law written by the **policyfolk** seems unfair.
non-supportive	Could you bring another **poolbrick** for him?
supportive	The builder brought another **poolbrick** outside to use.
non-supportive	A new **prayermantel** was built for the room.
supportive	He put the candles on the **prayermantel** after he lit them.
non-supportive	Do you think you'll be able to find the **prisonlap** somewhere around here?
supportive	The guard ran for a distance of one **prisonlap** before she caught up to him.
non-supportive	There is a new **radiostory** for sale at the store.
supportive	Jake listened to the **radiostory** in the car on the way to work.
non-supportive	Kate threw the **ricewig** away because it was ruined.
supportive	She wore a **ricewig** as part of her costume.
non-supportive	They were sitting near the **rifleshelf** in the room.
supportive	She took a gun off the **rifleshelf** on the wall.
non-supportive	She got some **roadcheese** when she was at the mall.
supportive	When Greg got into the car, he ate the **roadcheese** he brought with him.
non-supportive	Dave got another **roofbrick** for Sally.
supportive	The construction worker placed the **roofbrick** on top of the wall.
non-supportive	The students got a **screenday** last month.
supportive	The people at the movie theatre on the **screenday** celebrated it together.
non-supportive	Did she put the **sealeaf** she bought in her bag?
supportive	The boy found a **sealeaf** in the garden and showed it to his mother.
non-supportive	The woman found a new **seatcone** in the box.
supportive	The man sat down on the **seatcone** when he needed to rest.
non-supportive	They forgot to order more **shirtcream** when they ran out.
supportive	She spread some of the **shirtcream** on her sweater.
non-supportive	He sold his **shoecycle** because he didn't need it anymore.
supportive	Jen took her sneakers from the **shoecycle** and put them on.
non-supportive	He doesn't think there should be a **sightcentre** over there.
supportive	They are going to watch it at the **sightcentre** tomorrow afternoon.
non-supportive	Nobody has seen a **soapdevil** before.
supportive	The room must have been cleaned by the **soapdevil** last night.
non-supportive	She was annoyed by **soapeye** for the rest of the day.
supportive	After washing her face, the girl's **soapeye** bothered her for hours.
non-supportive	He made sure to throw the **soupbag** out when he was done with it.
supportive	You should fill up a **soupbag** and bring it with you.
non-supportive	He didn't want the **sportpower** that he had.
supportive	The athlete improved her **sportpower** by practicing often.
non-supportive	He thinks he'll need to replace his **stagejaw** some time soon.
supportive	The actor warmed up his **stagejaw** before the performance.

Table 10 (continued)

non-supportive	They need more **stairpaper** because they ran out.
supportive	I need scissors to cut the **stairpaper** into several pieces.
non-supportive	There was no room to put the **steamjar** anywhere.
supportive	I asked him to open the **steamjar** for me.
non-supportive	They forgot to buy **stovemeat** when they went to the store.
supportive	She sent the undercooked **stovemeat** back to the kitchen.
non-supportive	Do you know if there's a **stovetown** near here?
supportive	They've been living in the **stovetown** for a few years.
non-supportive	The mother got a **styledragon** as a gift for her son.
supportive	The knight defeated the **styledragon** in a dangerous battle.
non-supportive	Are you going to build a new **stylepod** to replace the broken one?
supportive	He took his clothes out of the **stylepod** so he could get dressed.
non-supportive	Sally got a **sugarstraw** for her birthday.
supportive	When he made his tea, he used a **sugarstraw** to stir it.
non-supportive	He drew a picture of a **summerforest** on the canvas.
supportive	We're going for a hike in the **summerforest** this weekend.
non-supportive	The woman didn't know where she could find a **summerpit** nearby.
supportive	They were tired after digging the **summerpit** in the garden.
non-supportive	He put the **sungown** away after using it.
supportive	Rachel got her **sungown** out of the closet before she went outside.
non-supportive	It seems like **swinelouse** isn't an issue anymore.
supportive	The veterinarian treated the case of **swinelouse** the animal had.
non-supportive	She made a **swordmask** out of paper.
supportive	The knight got a new **swordmask** to use in battle.
non-supportive	Jack recorded a video of the **tentboom** on his phone.
supportive	They heard a loud **tentboom** when they went camping.
non-supportive	The kids put their toys away in the **textbed** when they tidied up.
supportive	He put the book in the **textbed** when he was done reading it.
non-supportive	Aaron didn't want to go shopping at the **theaterbarn** but he had to.
supportive	The actors can't perform at the **theaterbarn** today.
non-supportive	They got rid of the **tideroad** because they didn't need it anymore.
supportive	Be careful driving on the **tideroad** after it rains.
non-supportive	He put the **toolmat** on the table.
supportive	She placed the hammer on the **toolmat** when she was finished with it.
non-supportive	Every time he makes a **treeshirt** he sells it to someone.
supportive	I'm going to put a **treeshirt** on the maple in my garden.
non-supportive	Her husband replaced the **videojar** because it was too old.
supportive	Did you remember to fill the **videojar** up this morning?
non-supportive	She was sent a **voicerod** last weekend.
supportive	He spoke using a **voicerod** to help him.
non-supportive	The invention of the **wandjet** happened quite recently.
supportive	The passengers got on the **wandjet** at the airport.
non-supportive	The new **warbed** was built last week.
supportive	The soldier rested in the **warbed** at the camp.
non-supportive	The doctor found some more **webcloth** in the cupboard.
supportive	The tailor needs to get more **webcloth** to finish his work.
non-supportive	The scientist built an impressive **winebrain** in the lab.
supportive	Most of the people at the party experienced **winebrain** when they got home.

Table 10 (continued)

non-supportive	They forgot to bring the **woolgear** with them.
supportive	She wore her **woolgear** when she went out in the cold.
non-supportive	The new **yardnest** is much smaller than the old one.
supportive	The birds in the **yardnest** are making a lot of noise.

Table 11 Results of the linear mixed-effects regression model fitted to entropy values (Analysis 1)

Fixed effect	$\hat{\beta}$	*SE*	*t*
Intercept	2.011	0.06	33.64***
Presentation type: Non-supportive context	−0.648	0.061	−10.566***
Presentation type: Supportive context	−0.654	0.061	−10.673***
Compound type: Novel	0.531	0.085	6.283***
Left constituent frequency (log)	0.003	0.034	0.094
Right constituent frequency (log)	0.06	0.034	1.755
Pres type: Non-supportive context × Comp type: Novel	−0.225	0.087	−2.579**
Pres type: Supportive context × Comp type: Novel	−0.46	0.087	−5.304***
Random effect	*SD*		
Compound	0.41		
Conditional R^2	.68		
SD of the residual	0.37		
N trials	600		
N trials after trimming	593		

Context type is dummy coded with the isolated condition as the reference level. Continuous variables were *z*-transformed before they were added to the model

*p < .05. **p < .01. ***p < .001

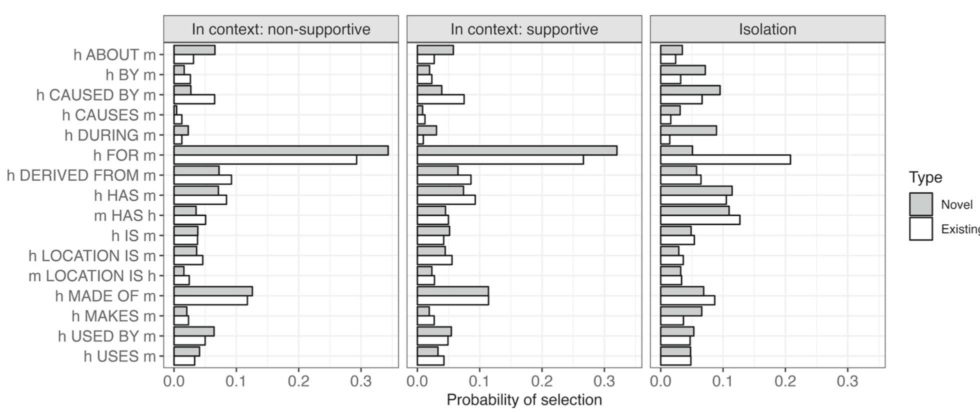

Fig. 4 Barplot of the probability distribution of conceptual relation choices broken down by presentation type

Table 12 Results of the linear mixed-effects regression model fitted to reading times (logged) of existing compounds (Analysis 2)

Fixed effect	$\hat{\beta}$	*SE*	*t*
Intercept	5.898	0.084	70.221***
Entropy-*c*	0.015	0.005	2.93**
Context type: supportive	−0.021	0.01	−2.097*
Compound length	0.029	0.005	5.23***
Left constituent frequency (log)	0.005	0.005	1.041
Right constituent frequency (log)	−0.001	0.005	−0.141
Sentence position	0.069	0.005	13.273***
Trial number	−0.169	0.005	−36.167***
List: B	0.063	0.122	0.518
Compound frequency (log)	−0.012	0.005	−2.259*
Left-whole semantic transparency	0.013	0.005	2.388*
Right-whole semantic transparency	−0.002	0.006	−0.406
Random effect	*SD*		
Participant	0.44		
Compound	0.02		
Conditional R^2	.68		
SD of the residual	0.33		
N trials	5163		
N trials after trimming	5031		

Context type is dummy coded with non-supportive as the reference level. List is dummy coded with List A as the reference level

Continuous variables were *z*-transformed before they were added to the model

$*p < .05$. $**p < .01$. $***p < .001$

Table 13 Results of the linear mixed-effects regression model fitted to reading times (logged) of novel compounds (Analysis 2)

Fixed effect	$\hat{\beta}$	*SE*	*t*
Intercept	6.485	0.124	52.248***
Entropy-*c*	0.018	0.008	2.104*
Context type: supportive	0.03	0.014	2.113*
Compound length	0.057	0.01	5.921***
Left constituent frequency (log)	−0.017	0.01	−1.704
Right constituent frequency (log)	−0.011	0.01	−1.154
Sentence position	0.124	0.008	14.949***
Trial number	−0.179	0.007	−27.1***
List: B	−0.27	0.177	−1.526
Random effect	*SD*		
Participant	0.58		
Compound	0.07		
Conditional R^2	.70		
SD of the residual	0.41		
N trials	4214		
N trials after trimming	4134		

Context type is dummy coded with non-supportive as the reference level. List is dummy coded with List A as the reference level

Continuous variables were *z*-transformed before they were added to the model

$*p < .05$. $**p < .01$. $***p < .001$

Supplementary Information The online version contains supplementary material available at https://doi.org/10.3758/s13421-022-01378-z.

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Data Availability Anonymized behavioral data and associated lexical data can be downloaded from the Open Science Framework (OSF) (https://osf.io/5r93v). Stimuli lists are also available in the Appendix.

Code Availability R scripts for analysis can be downloaded from OSF (https://osf.io/5r93v/).

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