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Contextually Representing Abstract Concepts with Abstract Structures

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Abstract

This paper proposes that abstract concepts are represented as contextually derived structures. According to this *abstract structure theory*, abstract concepts are related to mostly temporal and spatial structures that underlie and can be extracted from concrete situations. Linguistic context elements of abstract concepts, such as verbs and prepositions, express these structures, and can thus aid in the acquisition of such concepts. The paper presents results from a corpus study that supports the hypothesis, and discusses implications.

We propose that abstract concepts, such as *faith* or *notion*, are represented as abstract structures, which represent particular contexts in which they occur. Abstract concepts are not directly perceivable, but are often used in verbal descriptions of situations, or in utterances related to a situation. Such utterances have to unambiguously point out the entity that is referred to by the abstract noun. We argue that the relevant abstract structures can be inferred from their linguistic context, in particular, from verbs and prepositions used with the abstract nouns.

Concept Constraints and Contextual Similarity

Similar concepts occur in similar linguistic contexts. Miller and Charles (1991) report that contexts of similar concepts are more often classified as belonging to the same concept. For example, the sentences *the patient rang for the _____* and *the _____ gave the patient an injection* both suggest that the word *doctor* or *nurse* would complete the sentence well. We found that a neural network could be trained to correctly select one out of seven abstract concepts based on linguistic context information in 72% of test cases (Wiemer-Hastings, 1998). An approach to learning verbs from context was described by Wiemer-Hastings, Graesser, and Wiemer-Hastings (1998; see also Hastings, 1994). This work shows a close link between context of use and concepts.

Acquisition from Contexts

The relationship between concept and context similarity has implications for language acquisition: Unknown words can be learned from context. Berwick (1989) discussed a system that acquired word meaning based on contextual similarity of the word to the contextual representation of

familiar words. Sternberg and Powell (1983) have shown experimentally that human participants could infer unknown word meanings from the context of a short text passage.

So, linguistic context provides useful information for language acquisition. In the acquisition of concrete concepts, this information is a "bonus" added to more directly useful information that the learner has access to, that is, information about perceptual or functional characteristics, as well as uses of the objects in situations. It is not even clear to what extent the linguistic information actually *adds* to this perceptual information. It might instead just reflect the information contained in the perceptual context of use, thus being redundant with it.

Linguistic context (in particular, syntactic context) has been shown to facilitate the acquisition of verbs (e.g., Fisher, 1994). Levin (1993) has provided a classification of semantic verb classes based on syntactic verb frames. Thus, much critical lexical information can be extracted from the linguistic context. This is important when the available information is largely *confined* to linguistic information. This is the case for abstract noun concepts, which refer to complex situations and relationships within these situations. If linguistic context is informative for verbs, it should be helpful all the more to acquire abstract concepts, such as *ignorance* or *strategy*. Indeed, Quine (1960) has argued that abstract concepts must be acquired on the basis of linguistic information alone. In support of this hypothesis, we found that abstract concepts can be distinguished pretty reliably based on semantic and syntactic aspects of their context (Wiemer-Hastings, 1998). If the hypothesis holds, then it should also be possible to identify linguistic context elements that are related to abstract concept meanings, thus that they co-occur with similar frequency with similar abstract concepts, and do not co-occur with dissimilar abstract concepts.

Context Dependence

Clearly, the characteristics of entities systematically constrain contexts in which they can occur. However, this statement implies that entities are something that is given a priori, and contexts are selected based on the entities. This may be true for concrete entities, such as furniture items. Concrete entities exist independent of aspects of particular

contexts. A chair is still a chair if it occurs in a new context. Concrete concepts have characteristics that put concrete constraints on how we interact with them. Their characteristics thus determine, to some extent, their use. In this sense, concrete entities are to some extent independent of contexts.

With respect to abstract concepts, it seems that the relationship between context and concept constraints is reversed: their use is not determined by their characteristics, but their characteristics are inferred from their use. It seems that the context is the a priori given in this case, whereas abstract concepts are used to describe and make sense of complex situations and processes. Abstract concepts do not exist independently. They can only "happen" in particular contexts. An *idea*, for example, is conceived mentally, and can be expressed in words. Its consequences can be observed in context. It has the pragmatic function of overcoming some obstacle. In a slightly different context, one may call the concept a *suggestion* or *recollection*, instead of an *idea*. Similarly, *truth* is a characteristic ascribed to a statement that describes a particular state of affairs correctly (see Barsalou, 1999). If the state of affairs is different from a statement, the concept truth does not apply anymore.

This difference in the relation between abstract and concrete concepts and their contexts also affects language acquisition. We first acquire words for concrete entities. Later, we learn that there are abstract concepts, but we need to infer their characteristics from the contexts in which they are used. That is, the context is processed before the abstract concept can be understood. For abstract concepts, we could accordingly postulate that they are understood to be similar to the extent that they are used in the same linguistic contexts.

Operationally Defined Context

Context is a complex notion. In contrast to verbs, there are no particular syntactic frames associated with abstract concepts. However, if abstract concepts put constraints on admissible contexts of use, then some of their contextual elements should reflect important semantic aspects of the concepts. Are there any indications as to what context elements may play a role?

Explaining Contextual Effects with Scripts

Context effects on concept processing (e.g., on the speed in word recognition) have been shown in many studies. A series of experiments showed that such effects are mostly due to global context rather than local context elements (Hess, Foss, & Carroll, 1995). Sharkey and Mitchell (1986) suggested that context effects on lexical processing are mediated by scripts (Schank & Abelson, 1977). Scripts are schemata of actions, such as seeing a doctor, or eating out in a restaurant. According to Sharkey and Mitchell, associated words activate target words not through associations (i.e., through strong connections in a semantic network), but by activating a script that in turn activates the target word.

This hypothesis has received empirical support. However, it cannot easily be applied to abstract concepts. Consider, for example, the difficulty in selecting a script for *idea*. One would likely assign the concrete concept *menu* to the *restaurant script*, but concepts like *idea* can occur in a wide, almost arbitrary, variety of concrete situations such as represented by scripts. Yet, there are particular aspects of contexts that must be true for an abstract concept to apply. In the case of *idea*, for example, the concept typically occurs in a context where there is a problem or obstacle of some kind; an agent who reflects or discusses possible ways to overcome the obstacle; and a thought or utterance (the *idea*) that leads to the problem-solving action. A temporal sequence with causally related elements emerges from this scenario. We collectively call such sequences and structures for other kinds of abstract concepts *abstract structures*.

Abstract Structures

Abstract structures represent integrated processes, events, or particular relationships in situations. They are *abstract*, in that they apply to situations with different concrete aspects. They are *structures*, in that they organize sets of entities in a situation with respect to the causal, temporal, spatial and other relations that hold between them. The concept is similar to schemata or scripts. However, abstract structures are more abstract than scripts, so we opt to use a different term here, to avoid the association with concrete situations.

Abstract concepts have a temporal and spatial dimension. The temporal dimension is critical, because it represents the ontological class of a concept (i.e., whether the concept is a point-like event, a process, or a state), and the sequencing of events within a structure. The representation of many abstract concepts requires information about their time course, for example, *discussion* or *sequence*. Causal aspects usually depend on temporal information as well. For example, concepts like *effect*, *consequence*, *impact* etc. require some temporally preceding entity or event. In principle, this suggested representation format is compatible with a perceptual approach, which integrates perceptual aspects beyond vision. One such theory has recently been proposed by Barsalou (1999). He proposes a combination of situation percepts with introspective information to represent abstract concepts. Our approach does not challenge this view, but approaches the representation from a linguistic point of view, and focuses on dynamic aspects of the concepts within context.

This paper describes first results of an investigation of this *abstract-structure* hypothesis. If linguistic context serves as a basis for abstract concept acquisition, then it is necessary that it reflects critical relationships in the situation context, and thus directs the learner's attention to the relevant aspects in this situation to identify the referent of the abstract noun. In relation to this reasoning, in particular we test the following prediction: Temporal, spatial and other aspects of the abstract structure related to an abstract concept are expressed in, and can be inferred from, its linguistic context.

Context Elements

According to the abstract structures hypothesis, there should be linguistic context features that express causal, temporal, and other information. With this in mind, we examined the linguistic contexts of abstract concepts selectively with respect to such elements. What context elements are likely to reflect spatial, temporal and other relationships between the agents and entities in a situation?

This paper discusses two elements of context: verbs, and prepositions. Selecting two groups of lexical items clearly does not follow the view that it is global context that is critical with respect to concept representation. However, it appears worthwhile to examine context elements that can be easily identified and test these first, instead of attempting to identify more complex structures in text. The selection of verbs and prepositions follows directly from our hypothesis that abstract concepts are represented as contextual structures. Both verbs and prepositions express the relationships pertinent to abstract concepts, according to our hypothesis.

Verbs describe the way in which agents interact with each other and with entities, and convey aspects relevant to abstract concepts, such as events and causality (Basili, Pazienza, & Velardi, 1996). They express causal (e.g., *cause, evoke, produce, lead to*, etc.), temporal (e.g., *follow, end, begin*, etc.) and spatial information (e.g., *leave, hide, bring, remove*). Verbs also express other important aspects of abstract concepts related to agent - object relations, such as evaluations (e.g., *like, want*, etc.), verbal expression (e.g., *announce, explain, suggest*, etc.), and others. The central role of verbs with respect to the processing and identification of agents and objects has been shown in a lot of research, even if not specifically for abstract concepts. Altmann and Kamide (1999), for example, show that verbs guide our attention to particular aspects of a situation, because they lead us to expect what particular kinds of entities will be made reference to subsequently. Whereas this finding generalizes to entities outside the visual domain is an open question, but it is a possibility.

Prepositions can explicitly be classified with respect to the same dimensions (see Table 1). Considering these two context elements in the linguistic context of abstract concepts, we examined the question if the verbs and prepositions that occur in the contexts of particular abstract concepts express semantic aspects of the abstract concepts. We predicted that if they do, then similar abstract concepts should co-occur with similar kinds of verbs and prepositions with similar frequency.

Corpus Analysis of Abstract Concept Contexts

In order to test what kinds of verbs and prepositions occur with abstract concepts, one has to consider a representative number of context samples. For example, one would expect that very general predicates (such as *think about, talk about*) occur with all kinds of concepts, and to provide little basis for differentiation. In order to get at the systematic relationships between verb and preposition context and

abstract concepts, we must therefore look at a variety of contexts and record two aspects: a) patterns of co-occurrence between abstract concepts and verb / preposition classes, and b) the frequencies of the co-occurrences.

We conducted a corpus analysis to obtain both measures. Corpus analyses have been used frequently since large databases of naturally occurring text have become available electronically. Boguraev and Pustejovsky (1996) express the power of corpus analyses proposing that "Text corpora reflect language as it is used and evolves; by studying regularities of use and patterns of behavior of words, which only emerge from analysis of very large samples of text and / or speech, it is possible to induce (among other things) lexical properties (...)" (p. 5). The power of co-occurrence patterns in text for representing semantic aspects of concepts and texts has been demonstrated by the success of systems such as Latent Semantic Analysis (LSA; Landauer & Dumais, 1997) and HAL (e.g., Burgess & Lund, 1997). However, since LSA uses co-occurrence information among all elements of text, it does not tell us much about *which* elements of context play a role in relation to individual kinds of concepts.

The Corpus

A sample of thirty abstract nouns was selected randomly, but so that different ontological classes (e.g., state, process, event, emotion) were represented. The sample included the words *accident, agreement, approach, aspect, attempt, effect, decision, discovery, discussion, essence, fear, freedom, goal, idea, ignorance, impression, indifference, invention, miracle, notion, plan, pride, principle, recollection, result, silence, strategy, surprise, truth, and wisdom*. We collected our corpus from NexisLexis, an online database that contains full texts from newspapers, magazines and other sources, representing a wide range of topics. For each abstract noun, 250 sentences were collected that contained the particular abstract noun. The sampling was principally random. However, we made sure that no sentences were repeated, and that a variety of topics was represented. Altogether, we collected a corpus of 7500 sentences.

Encoding Co-occurrence

For each noun, we looked at every sentence and recorded the verb and preposition that occurred in direct relation to the abstract noun. Verbs and prepositions were recorded with information about whether they preceded or followed the abstract noun. We additionally counted the frequency with which each verb and preposition occurred¹.

This method yielded a large number of verbs and prepositions (about 1700). The raw data would have yielded long context vectors with very low average frequencies. Analyses based on such vectors would

¹ Verbs and prepositions were not recorded in combination. In many sentences, only one of the two occurred. Further, the combinations may lead to an enormously extensive data space that would be hard to reduce by classification.

presumably be distorted by noise. Therefore, we classified our recorded verbs and prepositions into semantic classes. Verbs were classified into the semantic classes constructed by Levin (1992). Her system contains 37 semantic verb classes that occurred in our corpus. They include verbs of *occurrence* (e.g., *happen*), *possession* (*give*, *obtain*), *communication* (*describe*, *announce*), and *psychological verbs* (*amaze*, *disturb*). We only considered verbs that could clearly be classified consistent with these classes.

Prepositions were classified into spatial, temporal, causal, modal, propositional, referential and possessive information, and further sub-classified within these groups (see Table 1).

Table 1
Classification of prepositions

Preposition class	Subclass	Examples
Spatial location	distance	near, by, far from
	relation to 1 object	on, in, behind
	relation to 2 objects	between, amidst
Spatial motion-direction	related to origin	from, out of
	related to destination	into, towards
	related to path	through, across
Temporal	related to future	until, prior to
	related to past	after, since
	related to presence	during, while, at
Temporal	expressing time-range	after (time-range)
	expressing point-in-time	on, at
Causal	related to factor	due to, because of
	related to effect	in order to
	related to means	through, whereby
Modal / concomitative		with
Propositional Referential		about, on
	inclusive	with regard to
	exclusive / adversatives	
Possessive		except, contrary to
		of, from

Abstract Concept Context Vectors

A noun-context element matrix was constructed that listed abstract nouns against context element classes (Table 2). The context elements contained the verb classes 1 to n after Levin (1992) that had non-zero occurrences in the corpus, followed by preposition classes 1 to n . The cells in the matrix contained the co-occurrence frequency in the corpus. Context elements were represented twice. The first time, the co-occurrence data only count times that the abstract noun *preceded* the particular context element class in context. The second time counted the times the context elements were followed by the abstract noun, respectively.

Table 2
Co-occurrence matrix for context elements

	Verb class 1	...	Preposition class n
Abstract noun 1	5	...	0
...
Abstract noun 30	0	...	58

Evaluation

Thirty context-vectors were constructed based on the co-occurrence matrix, one for each abstract concept. Each vector represents how often a particular abstract noun occurs with different kinds of verbs and prepositions in context. These vectors were used to evaluate the hypothesis that linguistic context, in the form of verbs and prepositions, reflects semantic aspects of abstract concepts. If this hypothesis is correct, then the contexts of similar abstract concepts should be similar, resulting in a significant correlation of the cosines of the context vectors with human similarity judgments of the corresponding abstract concept pairs.

We tested what context information is related to abstract concepts in particular. Six different vectors were constructed to represent various aspects of context. We built vectors to represent only prepositions, only verbs, or both. For each of these, there were two versions: an extended, "ordered" version that contained word order information, and a short, "unordered" version that ignored word order information. For the ordered version, we counted co-occurrence separately for context elements preceding versus following the target noun. For the unordered vectors, co-occurrence counts within the verb and preposition classes were collapsed to disregard word order. This vector version thus represents merely how frequently which kinds of verbs and prepositions can in general co-occur with the abstract noun.

To test whether the verb and preposition context relates to abstract concepts, we compared the similarity of the context vectors to similarity judgments of the corresponding abstract concept pairs, provided by human raters. The 30 abstract concepts resulted in 435 vector / abstract concept pairs. Correlations were computed between two similarity measures: human similarity judgments of the concept pairs, averaged across 33 raters, and vector cosines for the context vector pairs. Both measures range from 0 (maximally dissimilar) to 1 (maximally similar).

Results

Table 3 shows the correlation coefficients. The cosines of the full vectors, containing verb and preposition co-occurrences and word order information, were significantly correlated with the human ratings ($r = 0.22$, $p < 0.01$).

Table 3
Correlation coefficients between the vectors and human similarity judgments

	Ordered Vectors	Unordered Vectors
Verbs and prepositions	0.22	0.17
Verbs only	0.22	0.18
Prepositions only	0.20	0.13

This correlation is modest, but highly significant. It indicates that more similar abstract concepts tend to have

similar co-occurrence patterns with verbs and prepositions. This coefficient is higher than the average human interrater correlation coefficient, computed for a random sample of 100 coefficients (mean $r=0.18$, $SD=0.16$).

To estimate the relative relevance of verbs and prepositions, we computed the vector cosines separate for verbs and prepositions. The cosines for both were significantly correlated with the human ratings ($r_{prep} = 0.20$, $p < 0.01$; $r_{verb} = 0.22$, $p < 0.01$). Thus, the co-occurrence patterns of both context elements, verbs and prepositions, are significantly related to abstract concept similarity.

Further analyses tested the relevance of word order information. The question here is whether the correlation is due to the information which verb and preposition classes can co-occur with an abstract concept in general, or whether the word order is critically important. Word order information may play an important role in abstract concept representation. For example, in the phrases "due to the discussion" versus "the discussion due to (...)" the prepositions express very different information about discussion. In the first example, the discussion causes some effect; in the second example, the discussion itself was caused by something.

We computed the cosines for the vectors that just represent co-occurrence with verb or preposition classes without separating co-occurrence counts according to word order. The cosines were correlated with the human ratings. The resulting correlations were significant ($p < 0.01$), but the correlations were smaller than the ones obtained before. The correlation for the verb-only vectors was $r=0.18$; the preposition-only vectors yielded a correlation of $r=0.13$. The combined verb and preposition vectors led to a correlation of $r=0.17$. Thus, word order does increase the correlation, especially in the case of prepositions.

We compared our results to correlations of the human similarity judgments with cosines from LSA for the same concepts. Since LSA takes into account all words in context, and for a lot more text, it is a good model to compare our vector matches to. In particular, if verbs and prepositions cover the important aspects of context related to abstract concepts, then the correlations of human ratings with LSA cosines should be comparable to the ones obtained in our study. If however the match with LSA cosines is substantially higher than our correlations, then verb and preposition context conveys only part of the relevant context information and other word classes should be included. We found that the correlation between human judgments and LSA cosines was significant ($r_{LSA} = 0.23$, $p < 0.01$), but not much higher than the correlations we obtained for our selective context vectors. This might mean that the correlation obtained from LSA is mostly due to the verbs and prepositions in the underlying text corpus. At least, the verb and preposition co-occurrence patterns can account for as much of the similarity ratings as LSA.

Correlations of Verb and Preposition Context

In addition to these correlations with human ratings, we looked at a few correlations among the vector cosines. We found that the cosines of preposition vectors and verb vectors were significantly correlated ($r=0.13$), but only if the vectors separated co-occurrence counts with respect to word order. In other words, similar abstract concepts tend to be preceded and followed by similar types of verbs and prepositions. This means that contexts with similar patterns of verb occurrence also resemble each other in the patterns of prepositions they contain.

The Role of Ontological Information

It was mentioned before that verbs and prepositions convey ontological information (such as states, processes, events). To what extent can the human similarity judgments and context vectors be explained by two concepts being of the same as opposed to different ontological kinds? To test this, we created a Boolean variable that was "1" when both concepts in a pair were of the same ontological status, and "0" otherwise. We correlated this variable with the human similarity judgments, and with the context vector cosines.

The ontological status was significantly correlated to the human ratings, $r=0.23$, $p < 0.01$. That is, the ontological status of two concepts may play a role in how people judge concept similarity. The ontological status was also related to the context vector cosines, but only to a selective group. First, it was correlated to the combined verb and preposition vectors. Interestingly, the correlation coefficient was exactly the same for the vectors containing information about word order and those not containing this information ($r=0.13$, $p < 0.01$). Furthermore, ontological status was correlated with the preposition-only vector cosines that did *not* contain word order information ($r=0.10$, $p < 0.05$).

This interesting result suggests that word order matters with respect to abstract concepts, but may be irrelevant, or even provide misleading information, with respect to the ontological status of the abstract concepts. The information represented by the preposition-only vectors without word order information simply reflects the frequency with which abstract concepts co-occur with the different kinds of preposition classes (Table 1). It makes sense that *statehood*, *eventhood*, etc. would be reflected in the kinds of verbs and especially prepositions that co-occur with the concepts. For example, event concepts may be surrounded by temporal prepositions such as *before* and *after*, whereas process nouns may be marked by prepositions such as *while* or *during*. Ontological status was also significantly correlated to the LSA cosines ($r=0.12$) to a similar extent.

Discussion & Implications

We have proposed that abstract concepts are represented by abstract structures that contain causal, temporal, spatial and other information pertinent to the abstract concept. Assuming that these contextual aspects are reflected by the verbs and prepositions that co-occur with particular abstract concepts, we have conducted a corpus study that examined

whether similar abstract concepts co-occur with similar patterns of verbs and prepositions. We found that the similarity of context vectors based on these word classes were significantly correlated with the similarity of the abstract concepts occurring in these contexts. That is, similar abstract concepts have similar co-occurrence patterns with verb and preposition classes. We found that the correlations of abstract concept similarity was not much higher with cosines of LSA vectors, indicating that verbs and prepositions may indeed be the most informative context elements with respect to abstract concepts. We did find a pretty substantial correlation between the verb and preposition vectors, however. This correlation suggests an alternative interpretation, namely, that different aspects of context are related to abstract concepts but that they are interrelated, thus that they do not add any further information to distinguish abstract concepts.

In future work we plan to examine to what extent a particular set of verb and prepositions can be used to identify the abstract structure corresponding to an abstract concept, and to kinds of abstract concepts (e.g., *states* versus *events*). Another interesting question is how many verb and preposition classes are most informative in relation to abstract concepts. Perhaps the correlations could be improved by choosing more classes with finer distinctions, or conversely, by reducing the class space even further.

Another interesting question is whether our abstract structure theory can explain context effects as reported by, for example, Schwanenflugel and Shoben (1983). Contexts preceding abstract concepts may instantiate the particular abstract structure underlying their representation and thus mediate priming effects. This could be tested by setting up contexts that differ in the amount of information they provide with respect to the relevant abstract structure.

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