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ORIGINAL ARTICLE

Activating Basic Category Exemplars in Sentence Contexts: A Dynamical Account

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Abstract This paper examines the influence of context on the processing of category names embedded in sentences. The investigation focuses on the nature of information available immediately after such a word is heard as well as on the dynamics of adaptation to context. An on-line method (Cross Modal Lexical Priming) was used to trace how this process unfolds in time. We found that the information available immediately after a category word is presented is not altered by the sentence context in which the word is immersed. Rather, the structure of availability of particular exemplars of the category resembles the typicality structure of a conceptual representation. The adaptation to context occurs later (between 300 and 450 ms after the category word) and takes the form of a rapid reorganization of the structure rather than a gradual activation of a contextually relevant exemplar. We claim that such data is best accounted for in a dynamical framework, where a coherent global structure emerges through locally guided self-organization.

Keywords On-line semantic adaptation · Category structure · Typicality

Introduction

If you heard the sentence "During Thanksgiving dinner, we ate the whole bird," the probability is rather low that you would think about a sparrow or a robin as the bird being eaten. You

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wouldn't think about a penguin, either. Only a few of the members of the category "bird" would likely come to mind, proudly led by the turkey. In other words, the set of possible instantiations of a category may narrow considerably when encountered in context.

The main focus of the present study is to understand how and when sentence context influences category interpretation. In so doing, we straddle two areas of research in cognitive psychology that are seldom considered together. One concerns how sentence context might constrain lexical access during sentence understanding; the other concerns the structure of category representations activated during natural language processing (in particular, typicality structure). We begin with a brief review of research from both areas. Next, we describe three experiments aimed at elucidating the processes that take place when a category name is encountered in sentential context. The first two experiments evaluate whether initial access to categorical representation is context-independent or context-dependent and whether the typicality structure influences the initial processing of a category name in a sentence. The third experiment examines the temporal characteristics of the contextual adaptation of categories. In all experiments, we use Cross Modal Lexical Priming (CMLP; see, for example, Nicol et al. 2006; Shapiro et al. 1998; Swinney 1979; Whitney et al. 1985) as a task that appears to be sensitive to fast-acting and relatively automatic processes that underlie on-line sentence understanding. Finally, in the discussion of present results we try to reconcile the form-driven and interactive approaches to contextual adaptation of lexical items by interpreting them in a dynamical framework. Such an approach has become increasingly popular over the last decade, including explanation of specific phenomena [see e.g., Kawamoto (1993) model of ambiguity resolution, or Cree et al. (1999) model of semantic priming] as well as general models of sentence comprehension (such as e.g., Tabor's view of sentence processing as a locally guided self-organization during which a coherent global structure emerges [see e.g. Tabor et al. 2003)]. We believe that the present study may add to such a general model, pointing to the "multipotentiality" of lexical representation, which allows for contextual flexibility as well as detailing the time-course of the processes of contextual adaptation. A dynamic view of lexical representation helps also to account for some meta-analysis of studies on contextual adaptation of polysemous words, Simpson (1984).

Contextual Constraints on Lexical Access

An important area of study in psycholinguistics concerns how sentence context influences the interpretation of linguistic stimuli. Several studies have focused mainly on clearly polysemous words (such as homographs and homophones) but as some linguists and philosophers have noted (for example, Barwise and Perry 1983; Łozowski 2000), almost all expressions of natural language are ambiguous and receive their final, specific interpretation only in the context of the whole sentence, utterance, and/or situation. The dominance of context is such that we rarely even notice the potential ambiguities. The fact that context influences interpretation is not at issue. The questions of interest are when and how the effect occurs. These questions are often posed to distinguish between a modularist position and an interactionist position. Within a modularist framework (see, for example, Fodor 1983; Forster 1979), the initial retrieval of information about a word is claimed to be "form-driven" (i.e., driven by the phonological or orthographic form of a word) and "informationally-encapsulated" [i.e., independent of the context provided by sentence or situation (e.g., Swinney 1979; Forster 1985; Borsky et al. 1998)]. Within the interactionist view, context (especially a strongly constraining one) can 'select' the appropriate meaning at the time of access or at least constrain the access

(Rumelhart et al. 1986; Marslen-Wilson and Tyler 1987; Tabossi 1988; MacDonald et al. 1994).

To illustrate the different predictions of these two general accounts, consider:

(1) John opened the trunk of his car and took out the case stuffed with papers.

The word “case” in this example is polysemous; it allows at least two different meanings (“court case” and “briefcase”). Note, however, that sentence context is biased toward the second sense of the word. A strong form-driven position would predict that all senses of “case” would be activated immediately upon hearing the word (because the module does not ‘know’ the context that preceded the word “case”). Only later during the unfolding of comprehension, according to this view, would context influence processing. Though all meanings of “case” would be accessed initially, only the sense appropriate for the sentence context would remain active downstream from the lexical ambiguity. In an interactionist model, contextual information occurring prior to the polysemous word would limit the word’s possible interpretations. Thus, the meaning “court case” will not be activated at all, or only to a much smaller degree, than the meaning “briefcase.” In both approaches frequency of occurrence of a word is seen as a modifying factor of lexical activation, however the interactionist approach seems to allow for a greater penetration of such extra-lexical factors in general.

Despite some suggestions in the literature that initial lexical access is constrained by context (Marslen-Wilson and Tyler 1980; Simpson 1981; Tabossi 1988), there is reasonably strong support for the position that initial lexical access during normal comprehension is context-independent. All meanings of an ambiguous word are activated immediately after hearing the word, but only the contextually-relevant meaning remains activated about one-half to one second later during processing. Thus, context effects may take place following lexical access, not prior to lexical access (see, for example, Onifer and Swinney 1981; Seidenberg et al. 1982; Swinney 1979). It is this observation that we exploit here, but instead of examining polysemous words we investigate category names because the typicality structure of a category may provide an additional and perhaps a more sensitive test of whether context influences initial lexical access. We expand this idea in the next section.

The Structure of Representations of Categories

The cognitive representation of categories has been intensively explored for over 30 years (Bruner 1973; Rosch 1975; Mervis and Rosch 1981; Rips et al. 1978; Medin and Wattenmaker 1987; Barsalou 1982; Hampton 1998, etc.). In the 1970s, research showed that the classical definitions of categories, inspired by logic, were inadequate as models of human categorization. As has been pointed out first by philosophers, many conceptual categories cannot be described by a set of features that are jointly sufficient and each of them necessary (e.g., Wittgenstein 1953). Moreover, subject’s performance in various tasks (e.g., speed of categorization, Rosch 1975; sentence verification, Collins and Quillian 1969; sentence acceptability ratings, Mervis and Rosch 1981, as well as electrophysiology studies, such as those using priming by Fujihara et al. 1998) indicated that the representation of categories should allow for some ‘typicality structure’, i.e., for the fact that some members are more typical examples of categories than others.

Several theories of categorization have incorporated these findings. Arguably, the most well-known is prototype theory, proposed by Rosch (e.g., Rosch 1975, 1976). According to this account, categories are both internally coherent and distinct from each other. This coherence and distinctiveness is achieved by considering categories in terms of their ‘clear’ cases, i.e., prototypes. A prototype is an object (abstract or real) that has the greatest number of features in common with other members of a category and the smallest number of features in common with non-members of a category. The "distance" from a prototype (in terms of the number of common features) determines the typicality of a given exemplar.

It is important to notice that the features on which objects are described are not independent. The presence of one feature may imply or correlate with the presence of another. Prototypes are those exemplars whose descriptions are more coherent and more congruent with this correlated feature structure. Research showed that much more information can be distorted in prototypical exemplars than in non-prototypical exemplars without serious categorization problems, and that typical exemplars are recalled and recognized more easily than atypical ones (e.g., Posner and Keele 1968; Rosch 1976). Recently several investigations have pointed out that typicality might be indicated not only by a number of individual features shared by an exemplar and a prototype but also by the similarity of the feature intercorrelations (e.g., McRae et al. 1997; Cree et al. 1999). Categories must also be flexible if they are to be functional. Flexibility includes both the creation of new categories and the modification of membership and typicality structure of existing categories. Even 'basic' established categories have been shown to be flexible in their typicality structure, depending on the individual's experience or the context. For example, "ostrich" can be a more typical bird than "robin" from an African point of view (Barsalou 1982). A category's representation is also said to reflect recent experience so that the last classified instance facilitates categorization of a new, similar instance (Barsalou 1987; literature on order effects on categorization: e.g. Rączaszek et al. 1999).

Category Names in Sentential Context

Sentential context also seems to influence category structure, although few studies have explored this question directly. For example, Roth and Shoben (1983), using the method of anaphoric reference, established that context not only determined which exemplar will be considered the best member of a category but also changed the dimensions on which similarity to the prototype was judged. This finding is important because it draws attention to the relation between typicality structure in biasing and in neutral contexts. It confirms earlier results concerning flexibility of categories and shows that this flexibility may involve a serious reconfiguration of category representations. It is here where we find a parallel with the earlier described work on the contextual influence on semantic interpretation. As in that work, there is little argument that context can influence a category's typicality structure. The question is *when* during the temporal unfolding of sentential context does the effect occur. Are categories created or adjusted on-line, and immediately context appropriate (as would be suggested by research of Anderson et al. 1976; or studies on ad-hoc category formation by Barsalou 1983)? Or is there something invariant across sentence contexts that we can call a 'conceptual representation' activated every time a category name is encountered? Roth and Shoben's method involved presentation of a target stimulus in a second sentence, at least 1 s after introducing the category term. Thus the study did not investigate what is activated immediately after the word was presented. With their method the suggestion that there is no meaning representation independent of context cannot be sufficiently substantiated.

Other work on conceptual categorization in a sentential context was carried out by Whitney and colleagues (Whitney 1986; Whitney and Kellas 1984; Whitney et al. 1985). In their 1984 study using the Stroop effect, Whitney and Kellas showed that when category names are encountered in a sentence they do *not* seem to be encoded as particular (contextually congruent) exemplars. Instead, typical exemplars seem to be activated even when sentential context is biased toward atypical ones. This finding contradicts ‘constructivist’ theories that claim that categories do not possess a relatively fixed internal structure and that the meaning of a category can change dramatically, depending on the context in which the name of the category is immersed (Anderson et al. 1976; Anderson and Shiffrin 1980).

For the present question of when context influences category structure, Whitney et al. 1985 work is most relevant because it entailed an on-line investigation of processing using Cross Modal Lexical Priming (CMLP). CMLP, which has also been used in some of the studies of lexical access mentioned previously, is based on the semantic priming effect: Words closely associated with previously perceived words will be recognized faster than unrelated words (see, e.g., Neely 1977). For example, after hearing the word “doctor” (the ‘prime’) people recognize the word “nurse” shown on the screen (the ‘probe’) faster than, for example, the word “board”. Whitney et al. (1985) used this technique to study the evolution of activation of features of noun concepts (from a set of features assumed to comprise a conceptual representation). High or low dominant features describing the category were presented visually as lexical decision probes at various time points (0, 300, 600 ms) relative to an audio prime (in this case the category name). High dominant features are those that belong to the contextually invariant core of a category; low dominant features belong to the periphery (cf. Barsalou 1983, 1987).

Probing with such features, Whitney et al. (1985) found that both high and low dominant properties were activated immediately after the noun concept, independently of context, but only in the context appropriate for low-dominant properties were these still activated at 300 ms. In the context inappropriate for low dominant properties only the high dominant properties stayed active. Whitney interpreted his results as supporting Barsalou’s (1982) division of the descriptive features of a concept into context-independent core (high dominant) and context-dependent periphery, but with a correction congruent with Swinney’s (1979) work on lexical access: initially all information is accessed independent of context; the contextual adaptation of concepts occurs a few hundred milliseconds after the category name appears. One problem with this study, however, is that it presupposed a certain (feature-based) description on the category structure that may severely limit the generality of the conclusions. In the present work, we probe with members of categories (elements of extension of each category) rather than with semantic features, thereby making no assumptions about the elements of an inferred intension of categories.

More generally, the issue of when and how contextual adaptation happens is important both for theories of sentence processing and for theories of conceptual flexibility. The on-line CMLP task (e.g., Swinney 1979; Shapiro et al. 1998; Whitney et al. 1985) provides us with a tool for investigating processes occurring over time, that is, immediately after the category word has been heard (before any conscious decision about sentence or word interpretation has taken place), as well as later in sentence processing.

Here we consider evidence concerning lexical access and categorization within the same framework in order to ask new questions. Are several members of a category activated regardless of context? If so, does their typicality influence activation? Does the relative degree of their activation change in time? If, on the other hand, a context-independent representation is not observed immediately after a category word is presented, then we have to account for the process of construction of a contextually-relevant representation and reconcile this process with research that indicates exhaustive initial lexical access.

In Experiment 1, designed to answer the question of initial context sensitivity of category structure, we embedded general category names in sentences that were either neutral (unbiased) or that suggested a particular category member (biased). A CMLP task was used to investigate the type and the time course of context effects. Lexical decision probes (visually presented) included typical members of a category and atypical members of a category congruent with the biased context. Response times were measured to probes presented at the offset of the category name in the sentence, 450 ms past category word offset, and 750 ms past category word offset. Experiment 2 used the same methods to determine if the information facilitated upon encountering a category name in a sentence really pertains to the category representation and not only to most typical and/or contextually relevant exemplars. Therefore response times to atypical members of a category at the offset of the category word were compared to response times to non-members that fit the sentential context. In Experiment 3, we examined the activation of atypical category members in finer temporal detail.

Experiment 1

Methods

Participants

Thirty-six Florida Atlantic University undergraduates (all native speakers of American English) participated in the experiment. Thirty-three were female and 13 male. The students were between 18 and 30 years old. All had normal auditory acuity and normal (or corrected-to-normal) visual acuity by their own report. Participants received credit in their Introductory Psychology class for participation.

Materials

Ten general category names were each embedded in two types of sentence context (neutral or biased toward an atypical member of the category), yielding 20 test sentences. Context was considered biased if the part of the sentence before the category word clearly pointed to a small subset of category members possessing a specific salient feature. Neutral contexts did not point to any feature of the category members. Contexts were read and judged by two graduate students from the psycholinguistics lab; only those sentences which were considered biased or neutral by both were included in the stimulus set. There were 25 filler sentences, 15 with non-words and 10 with words as a probe. The non-words were produced by replacing one letter of words with similar length and frequency characteristics as the test words, with the final result conforming to the orthographic rules of English.

The probes were placed either at 0, 450, or 750 ms after the category name. For example, in the following sentences the probe ROBIN is a typical member, and EAGLE an atypical member, of the category BIRD.

> Neutral context: The food was eaten by the *bird* even though it was not fresh.
>
> Probe position: 1—or——2—or—3
> |–450 ms—|
> |————750 ms—|
>
> Biased context: The mouse was eaten by the *bird* even though it tried to hide.
> Probe position: 1—or——2—or—3
> |—450 ms—|
> |————750 ms—|

The later two probe positions were chosen based on previous work showing later-occurring context effects (Swinney 1979; Tannenhaus and Lucas 1987; Whitney et al. 1985; Kawamoto 1993). The position of category words in sentences was varied to lessen expectations on the part of the listener. A complete list of test sentences and probes is included in Appendix A.

Typicality of the category members was assessed using category norms created by McEvoy and Nelson (1982). The typical and atypical category members were matched for word length and frequency of occurrence, two variables that affect the speed of recognition. Mean word length for typical exemplars was 5.9 letters; for atypical exemplars, 5.4 letters. Frequency matches were based on Francis and Kuçera (1982) frequency norms. In order to ensure that baseline response times were equivalent for typical and atypical exemplars, we performed a simple lexical decision study in which subjects ($N = 20$) had to decide whether probes presented on a screen (with no priming) formed a word or a non-word. Response times (RTs) to the words denoting typical and atypical exemplars did not differ (RT = 611 ms, SD = 53 ms and RT = 624 ms, SD = 45 ms for typical and atypical members, respectively, $t\ (19) = 0.81$, $p < 0.43$).

Apparatus

Sentences were digitized and recorded on a single channel, with a sampling frequency of 22 kHz. On the second channel a 1,000 Hz tone was recorded in positions in which probes were to be presented. All sentences, together with the tones were then recorded onto a stereo tape recorder that was also used to present the sentences to the subjects. The tone, which was inaudible to the subject cued the computer to present the visual probe (in uppercase large type) centered on the monitor. RTLab software (© Swinney 1998) controlled the hardware, presentation of the stimuli, and recording of responses.

Design

CONTEXT (neutral vs. biased toward an atypical exemplar) and TYPICALITY (typical vs. atypical category members used as probes) were within-subject factors; PROBE POSITION (0, 450, and 750 ms from category word offset) was a between-subjects factor. The dependent variable was the response time to the test probes that were correctly identified as words.

Participants took part in two sessions 1 week apart, with context and typicality balanced across sessions, so that no sentence or probe word was repeated within a session. For example, if in Session 1 a participant heard a neutral context sentence with an atypical member of the category as the visual probe and a biased context sentence with a typical member as the probe, then in Session 2 this combination was reversed. That is, in the second session this participant received a neutral context sentence with a typical exemplar as probe and a biased context sentence probed by an atypical exemplar.

Procedure

Participants were seated in front of a computer monitor and listened to the sentences presented binaurally over headphones. During the temporal unfolding of the sentence, a string of letters appeared on the screen for 500 ms at one of the predetermined probe positions. Participants had to decide as quickly as possible if the letters formed a word or a non-word by pressing the keys labeled “WORD” and “NON-WORD” on the response box placed in front of them. The time from onset of the visual probe to the button press response was recorded by computer. Time was recorded for additional 3,000 ms. Note that neither the visual probe nor the response interrupted the audio sentence presentation. Since processing the meaning of the sentences was not necessary to perform the word recognition task correctly, subjects were told explicitly to listen to the sentences for their meaning and were informed that their understanding of the sentences would be checked by asking them, from time to time, to paraphrase the sentence they just had heard. This was done on random sentences on approximately half of the trials. For sentences that were not paraphrased the inter-sentence interval was 4 s. Ten practice sentences were presented at the beginning of each session.

Results and Discussion

All sentences were accurately paraphrased (as judged by the experimenter), indicating that subjects were paying attention to their meaning. Only response times to correctly recognized probes were included in the analyses. The errors (words identified as non-words) comprised 1.7% of the data and were distributed as 0.8% in the 0 ms group, 1.3% in the 450 ms group and 3% in the 750 ms group. Eighty percent of all errors were made in response to atypical probes.

If response time is sensitive to the typicality structure of a category, then in a neutral context typical members of the category should be responded to faster than atypical members of the category at the offset of the category word (0 ms delay). If context does not influence the structure of the category representation immediately then the same relation between response times to typical and atypical instances of a category should be observed at the category word (at 0 ms delay) regardless of context (biased or neutral). Although contextual facilitation of atypical members in biased context might be seen downstream, 450 or 750 ms after the category word, this result would indicate that the information *initially* evoked by a category name possesses a structure that is context-independent. In contrast, if a biased

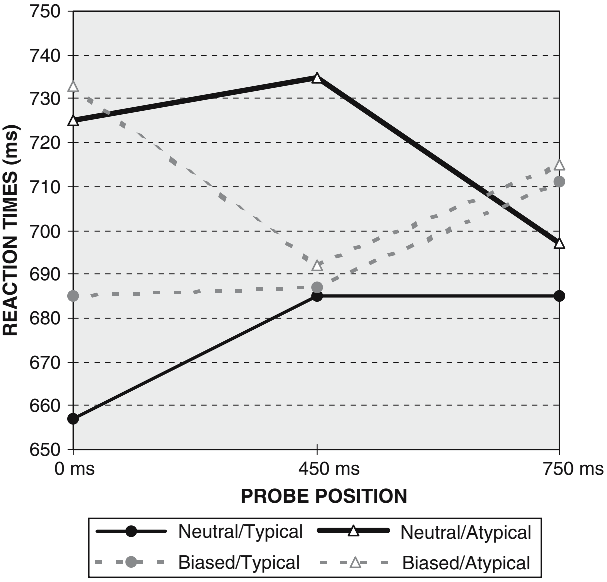

Fig. 1 Response times to typical and atypical probes in neutral and biased context at three probe positions

Table 1 Mean response times (ms) and standard deviations (in parenthesis) to typical and atypical probes presented in neutral or biased context at each probe position

Context	Probe	Probe position (ms)		
		0	450	750
Neutral	Typical	657 (138)	685 (120)	685 (145)
	Atypical	725 (111)	735 (132)	697 (109)
Biased	Typical	685 (138)	687 (105)	711 (139)
	Atypical	733 (161)	692 (111)	715 (142)

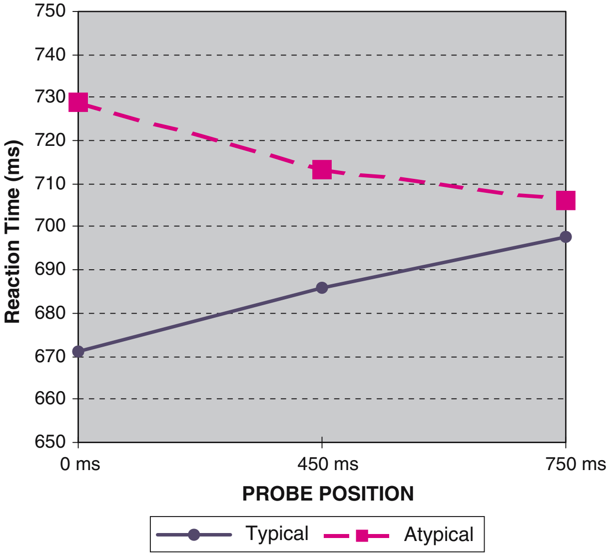

Fig. 2 Response times to typical and atypical probes at each probe position

sentence context facilitates responses to atypical exemplars *at the category word* (recall that all biased sentences were biased towards atypical members of the category) then context can influence the structure of the category representation immediately. The pattern of response times observed is shown in Fig. 1, for neutral and biased sentence contexts and for both kinds of probes. Mean response times and standard deviations are given in Table 1.

A mixed-design, three way analysis of variance (ANOVA) with PROBE POSITION as the between-subjects variable and TYPICALITY and CONTEXT as the within-subjects variables was performed. There was a significant main effect of TYPICALITY, with typical exemplars (685 ms) being responded to faster than atypical ones (716 ms), F (1,33) = 12.81, $p < 0.002$.[1] Note that typical and atypical probes were matched for frequency and thus the relative strength of priming effects can only be ascribed to the similarity to the category prototype. The TYPICALITY effect decreased slightly with time, although the TYPICALITY × PROBE POSITION interaction did not reach significance at 0.05 level ($p < 0.08$), see Fig. 2.

There was a significant interaction between CONTEXT and PROBE POSITION, F (2, 33) = 4.075, $p < 0.03$.[2] This interaction stems from the reversal of the relative response

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[1] Partial eta-squared value for the TYPICALITY effect: 0.32.

[2] Partial eta-squared value for the CONTEXT * PROBE POSITION effect: 0.23.

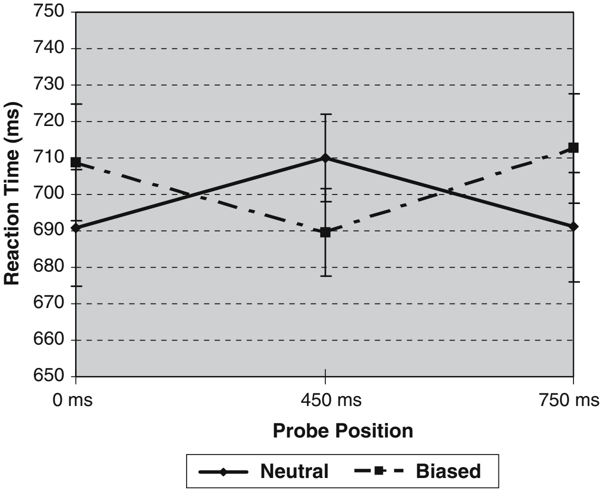

Fig. 3 Response times in neutral and biased context at each probe position

times in Biased and Neutral context at 450 ms. At 0 and 750 ms, response times in Biased context are slower than in Neutral, while at 450 ms they are faster than in Neutral context (Fig. 3). This drop in response time for Biased context at 450 ms is likely due to the decrease in response time to atypical probes at this point.

The three way interaction (PROBE POSITION × CONTEXT × TYPICALITY) was not significant, although the pattern of response times is suggestive of the effects observed in earlier studies. There is a marked drop in response times to atypical exemplars in the biased context between 0 and 450 ms (from 733 to 692 ms), see Fig. 1. Also, we can see from this figure as well as from Fig. 2, that the TYPICALITY effect is most pronounced at 0 ms probe position, and then decreases. At 750 ms both the typicality effect as well as the facilitation of responses to the atypical exemplar seem to decrease. Thus the time course of the responses to the category members seems to be as follows: at 0 ms typical exemplars are recognized faster than the atypical ones, which is indicative of context-independent access; at 450 ms typical exemplars are recognized faster only in the Neutral context, in Biased context the RTs to atypical and typical exemplars are almost equal and the RTs to the atypical exemplars are over 40 ms faster in Biased context than in Neutral (735 vs. 692 ms). At 750 ms probe position all the effects seem to disappear.

Our theoretical predictions concerning typicality effects at 0 ms probe positions were checked by planned comparisons, which revealed the significant difference between response times to typical and atypical probes both in Neutral (t (11) = 4.13, $p < 0.01$) and in Biased (t (11) = 2.93, $p < 0.01$) context. The planned comparison confirmed also our prediction regarding the facilitation of atypical exemplar in the Biased context at a later probe position (450 ms) compared to 0 ms probe position (t (11) = 2.48, $p < 0.05$).

An item analysis showed that 7 out of 10 pairs of sentences yielded the predicted pattern of results, i.e., typicality effect at 0 ms, which decreased at 450 ms in biased condition due to the activation of atypical exemplar. Out of the remaining three sentences, in 2 (number 6 and 9, see Appendix A) the initial typicality effect was observed but there was no decrease in RT to the atypical probe in biased condition. In one sentence, however (number 4, see Appendix A) the pattern of results did not resemble any of the above. The reason was probably the atypical probe used (the word "axe" which occurred to be troublesome for the subjects).

Before we further discuss the results of Experiment 1, one limitation of this experiment needs to be addressed. It is possible, given the design, that only the typical exemplar was initially activated and the atypical one was as inactive as any other word from outside the category. Subsequent activation of the atypical member in the biased context might indicate easier access to an individual word in a context rather than conceptual activation per se. The complicated design of Experiment 1 made it difficult to check for this effect without presenting the subjects with the same sentence many times. Thus in Experiment 2 we compare response times obtained for the atypical exemplars to response times for control words that do not denote category terms but *which do fit the context*. A significant difference between the two (that is, faster response times to the atypical exemplars of the category relative to response times to the control probe, which is not a member of the category but is contextually appropriate) would indicate activation of the category representation.

Experiment 2

Methods

Participants

Nine undergraduate students, six female and three male, native English speakers, age 19–26, participated in the experiment and received credit for participation. All had normal auditory acuity and normal (or corrected-to-normal) visual acuity by their own report.

Materials

We used the same test sentences as in Experiment 1 (Appendix A). Probes were either atypical members of the category or words matched for frequency that were not members but fit the context semantically. Mean word length for atypical exemplars was 5.4 letters and for contextually relevant non-members 5.9 letters. Frequency matches were based on Francis and Kuçera (1982) frequency norms. In order to ensure that baseline response times were equivalent for typical and atypical exemplars, a simple lexical decision study was performed on 26 subjects. Response times (RTs) to the words denoting atypical exemplars and non-members did not differ significantly (RT = 595 ms and RT = 602 ms, respectively; t (25) = 0.48, $p < 0.636$).

Each probe was presented both in a neutral and in a biased context but at only one probe position—the offset of the category word. The test sentences and control probes are included in Appendix B. For example, in the following sentences the probe EAGLE is an atypical member of the category BIRD, and PYTHON is a control probe:

neutral context: The food was eaten by the bird even though it was not fresh
biased context: The mouse was eaten by the bird even though it tried to hide.

If a conceptual structure is activated after a listener encounters a category name in context, even an atypical member of the category should be recognized faster than a control word.

Procedure

The procedures were the same as in Experiment 1. PROBE TYPE (atypical vs. control) was crossed with CONTEXT (neutral vs. biased) and sentences were presented over two

Fig. 4 Response times to atypical exemplars and control words

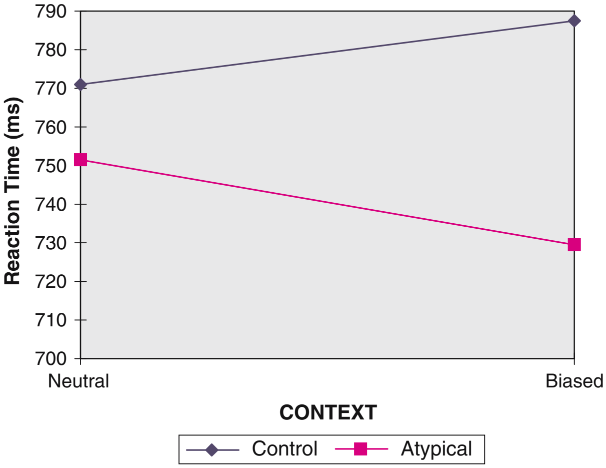

Table 2 Mean reaction times (ms) and standard deviations (in parentheses) for responses to control (non-members of a category) and atypical (non-prototype members of category) probes in two kinds of contexts: neutral and biased toward the probe

Probe type	Context	Response time (SD)
Control	Neutral	772 (76)
	Biased	787 (86)
Atypical	Neutral	751 (74)
	Biased	729 (78)

sessions which prevented the same sentence or the same probe occurring twice during the same session.

Results

The data from one participant were not included in the analysis because of inordinately long response times (mean RT > 2 standard deviations above the group mean). Participants correctly paraphrased the sentences which indicated that they were paying attention to the sentences' meaning. Errors comprised 2.7% of the data, with 60% of the errors occurring with control probes, 40% with atypical category member probes. Errors were evenly distributed across contexts. The pattern of results is shown in Fig. 4. Table 2 shows the RTs and standard deviations obtained.

A two way analysis of variance, with PROBE TYPE and CONTEXT as main effects, showed no significant interaction. There was, however, a significant effect of probe type: response times to atypical probes (741 ms) were significantly faster than response times to control probes (779 ms), $F\ (1, 7) = 5.75$, $p < 0.05$.[3] Thus, atypical members of a category were primed relative to control nouns that were not members of the category mentioned in the sentence.

Discussion

Experiments 1 and 2, taken together provide us with several conclusions regarding the processing of category names in context. At the offset of the category word in a neutral context,

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[3] Partial eta-squared value for the PROBE TYPE effect: 0.38.

response times to typical members of the category are faster than response times to atypical members. The RT difference between responding to typical and atypical category members at the offset of the category word does not change when context biases interpretation to the atypical category member. And, the atypical member is responded to significantly faster than an unrelated control, suggesting that both the atypical and typical members are indeed activated when a category is encountered in a sentence. Lack of a priming effect for control probes in biased condition in Experiment 2 (even though, as we remember, they were contextually appropriate) may point to stronger local effects (priming for category members) than global effects (maintaining the semantic coherence of a sentence) in sentence processing. A further experiment is needed to assure if the probes were equally strongly primed by the context in order to disentangle contextual and category-activation effects. Perhaps, as one of the reviewers pointed out if would be useful to probe with the atypical members also before the category name in order to assess the time-course of activation due to contextual and to lexical processes.

Recent studies tend to explain semantic priming in terms of feature overlap between prime and target (Cree et al. 1999), and under the assumption that typical members are more similar to category word representation than less typical members (McRae et al. 1997) and less typical members are more similar than non-members, this pattern of results seems quite clear. Since context does not change this pattern, we can conclude (with Whitney and Kellas 1984) that initial access to category representations is context independent but sensitive to the typicality structure of the category. Downstream, 450 ms after the category word offset, typical exemplars are still recognized faster than atypical ones in a neutral context. In contrast, in the biased context RT to contextually relevant atypical exemplars shortens so that response times to atypical and typical exemplars are almost equal. This pattern suggests that categories do eventually adapt to context over the temporal unfolding of the sentence. Contextually appropriate members become more accessible within 450 ms of the category word, a result that is congruent with earlier studies of ambiguity resolution (e.g., Swinney 1979; Kawamoto 1993). The typicality effect appears to be “washed out” because of the activation of the atypical but contextually relevant member.

How do categories adapt to context? Any putative mechanism of adaptation is strongly dependent on the assumptions regarding conceptual representation per se. Over last 30 years theories of categorization have markedly departed from classical, feature-based and logic-inspired approaches to models that stress the internal *coherence* of conceptual descriptions (Rosch 1976; Hampton 1998). Such models seem to capture better the typicality structure of representations of categories, as well as their flexibility.

A good example of such coherence-based models of conceptual structure is provided by network models, using distributed representations of categories. One example might be Knapp and Anderson’s (1984) neural network model, in which a concept is represented by a pattern of activation over a large number of units. During the learning phase a number of patterns corresponding to exemplars are presented and the network forms a prototype. Prototypes are viewed as coherent patterns (i.e., congruent with the previously encountered structure of co-occurrence among features) that in a neural network have lower energy—i.e., are more stable (a network more easily settles in such patterns)—than patterns that violate certain constraints (e.g., Hopfield 1982). The accuracy of categorization of exemplars is determined by the similarity to the prototype. When compared with the performance of human participants on the same set of stimuli, the network demonstrated almost identical similarity ratings (distances from a prototype) and analogous properties of prototype extraction.

Assuming that the typicality effect observed immediately after the category name is an indication of stable, coherent conceptual structures, the contextual adaptation that occurs within the next 450 ms may be viewed either as a simple facilitation of the contextually appropriate exemplars or as a *reorganization of the conceptual structure itself.* Previous studies of human conceptual representation, converging with the results of neural network modeling, indicate rather a reorganization of the representation as a function of context (Barsalou 1983, 1987; Roth and Shoben 1983). The new, contextually appropriate structure differs from the "neutral" one not only with respect to the degree of activation of its members but also with respect to the dimensions that define typicality.

So far however, only the final effects of such reorganization have been observed, usually several seconds after encountering a category name in context (see, e.g., the above mentioned research by Roth and Shoben 1983 in which they demonstrated the change of relevant dimensions on which similarity to the prototype was judged in different contexts). The on-line method used in our research provides us with the opportunity to confirm if such a reorganization takes place and to determine its time-course.

How can we decide which of the two alternative processes better accounts for contextual adaptation: reorganization of categorical representation vs. linear change in activation of contextually congruent member of category? In order to find appropriate measurable variables that could characterize such changes in categorical representations on line we can resort to the area of psychology devoted to analysis of nonlinear changes in behavior and perception. The domain encompasses a wide scope of behavioral and perceptual phenomena (Schöner and Kelso 1988; Kelso 1990, 1995; Turvey 1990), also pertaining to language (Tuller and Kelso 1990; Tuller et al. 1994). (For a detailed explanation of the theoretical assumptions see, for example, Haken 1983, 1990; Jeka and Kelso 1989). The main idea—not unlike the one proposed in neural network models in psychology, which are a subset of a broader category of dynamical models—is that a coherent behavior or perception of an organism is a stable state in a state space of possible behaviors or perceptions. The novel element brought by the theorists and researchers in the area of dynamical systems is the method of studying such behaviors or perceptions by looking at the points of transition between them—i.e., at the moments in which one coherent behavior or percept gives way to another—and using tools devised by physics to describe such nonlinear dynamical changes. After the analysis of numerous phenomena—ranging from coordinated finger movement (Kelso et al. 1986) to perception-action coupling, to perception of visual patterns (Hock et al. 1993) and perception of speech (Tuller et al. 1994)—it was concluded that indeed changes between behaviors and percepts can be viewed as resulting from the changes of the underlying dynamics. Stable states lose their stability and new stable states emerge, into which a system settles. Such conclusions were based on several characteristic features displayed by such systems at the point of transition. One of them is a rapid and complete reorganization from one—qualitatively different—pattern to another, without any linear "mixtures" of the two stable states. Another one is an increase of variability in performance as the "old" pattern is losing stability (this phenomenon is termed "enhanced fluctuations"), followed by the decrease of variability in performance after reaching a "new", stable state. Other properties of transitions include hysteresis—i.e., the coexistence of two or more stable states at the same time, while the system remains in only one of them as long as it has at least some stability.

As stated previously, such characteristics have also been identified in the domain of language processing, in cases of perception of single words (Tuller et al. 1994), as well as whole sentences (Rączaszek et al. 1999).

In the present research, context can be viewed as a force driving the change from one coherent representation of a category to another. On the other hand, the process may be "simpler", i.e., it can consist, as suggested by models of contextual adaptation of senses of the polysemous words (e.g., Kawamoto 1993), of a linear activation of the appropriate sense—in our case contextually relevant member of a category. The first possibility has some support from off-line research by Barsalou (1987) and Roth and Shoben (1983). Building on research on nonlinear dynamics in speech perception we can, however, make more detailed predictions regarding the on-line patterns of response times while contextual adaptation occurs (i.e., somewhere between the offset of the category name and 450 ms after). If the contextually neutral structure destabilizes before reaching a new organization, the decrease in the response times to the contextually appropriate atypical probes should be sudden rather than gradual and should be preceded by the increase of variability of the within-subject response times. The variability should then drop after a new stable categorical structure has been reached. Experiment 3 was designed to decide between these alternatives.

Experiment 3

Methods

Participants

Fifty psychology undergraduates (age 18–30 years old), 32 females and 18 males from Florida Atlantic University participated in the experiment and received credit for participation in their Introductory Psychology class. All had normal auditory acuity and normal (or corrected-to-normal) visual acuity by their own report.

Material and Design

Test sentences included 15 with context biased toward atypical members of the category (including the 10 biased sentences from Experiment 1), with atypical exemplars of the categories used as probes. There were also 19 filler sentences, 13 of which had probes which were non-words. Test sentences and probes are presented in Appendix C.

In order to ‘zoom in’ on the processes that occur between 0 and 450 ms we probed at five different time positions (0, 150, 300, 450, 750 ms after presentation of the category word). However, a true assessment of the time course of conceptual adaptation requires data from different time points for the *same* subject. The semantic nature of information involved makes it problematic to use a design that exposes the subject to the same sentence over and over again while different time points are probed. Therefore we used a nested design in which each participant was presented with the five blocks of three test sentences, in the same order with the filler sentences randomly interspersed. Each block of sentences used one of the five probe positions so that, across participants, every sentence was tested with every probe position, and every participant was tested on all five probe positions, although on different sentences. Participants were randomly assigned to one of the five orderings of probe positions.

We also constructed a short questionnaire in which participants rated the typicality of the members of categories used in Experiments 1, 2 and 3. This was to confirm that the typicality ratings obtained from McEvoy and Nelson (1982) were preserved in the population we investigated. The details and results of the questionnaire are presented in Appendix D.

Procedure

We again used the CMLP task and thus the experimental procedures were the same as in Experiments 1 and 2. Ten practice sentences were presented at the beginning of the session, followed by the 34 sentences (15 test and 19 filler). At the end of the experiment subjects filled in the questionnaire. The entire procedure took about 40 min in a single session.

Results

As in Experiments 1 and 2, participants correctly paraphrased the sentences. Only response times to test probes correctly identified as words were included in subsequent analyses. Erroneous responses constituted 3.7% of data and were approximately evenly distributed across conditions and probe positions. Forty-five subjects were included in the analysis; the data from five subjects were discarded because of very long average response times (>2 standard deviations above the group mean). Those participants seemed to ignore the instruction that they should respond as quickly as possible.

Response times were first averaged across items within a participant and then across participants. Variability of response times was measured by computing the within-subject within-probe position standard deviation. A mean standard deviation for a given probe position was then computed across subjects.

The response times and mean within subject standard deviations are shown in Table 3 and Fig. 5.

A one way ANOVA performed on response times revealed a significant effect of PROBE POSITION, $F\ (4, 40) = 6.75$, $p < 0.0001$). Further analysis revealed that response times at first three probe positions (0, 150, 300 ms) were significantly slower than response times to the probe at 450 ms, $F\ (1,44) = 6.61$, $p < 0.02$; $F = 4.59$, $p < 0.04$; $F = 5.34$, $p < 0.03$, respectively. Even more pronounced were the differences between response times at the first three probe positions and the last one, at 750 ms, $F\ (1,40) = 15.11$, $p < 0.001$, $F\ (1,40) = 10.16$, $p < 0.003$; $F\ (1,40) = 15.71$, $p < 0.001$, respectively. Also, the response times at 450 ms were significantly slower than response times at 750 ms, $F\ (1, 40) = 6.51$, $p < 0.02$.

A one way ANOVA performed on standard deviations also showed an effect of PROBE POSITION, $F\ (4,40) = 2.75$, $p < .035$). Further analysis revealed that standard deviations of response times to the 300 ms probe was significantly larger than that observed for the probe at 150 ms, $F\ (1,40) = 4.74$, $p < 0.04$, and at 450 ms, $F\ (1,40) = 6.4$, $p < 0.02$. The contrast between standard deviation at 300 and 750 ms approached significance, $F\ (1, 40) = 4.07, p = .055$, but other contrasts did not. Basically, then, response times decreased significantly at 450 ms, yet at 300 ms the response times did not change but variability significantly increased.

Table 3 Mean response times (ms) and mean within-subjects standard deviations (stability measure) to atypical probes at each of the five probe positions

Probe position (ms)	Mean response times	Mean within-subjects SDs
0	724.9	106.8
150	724.7	92.5
300	723.3	121.0
450	692.3	89.9
750	653.2	100.7

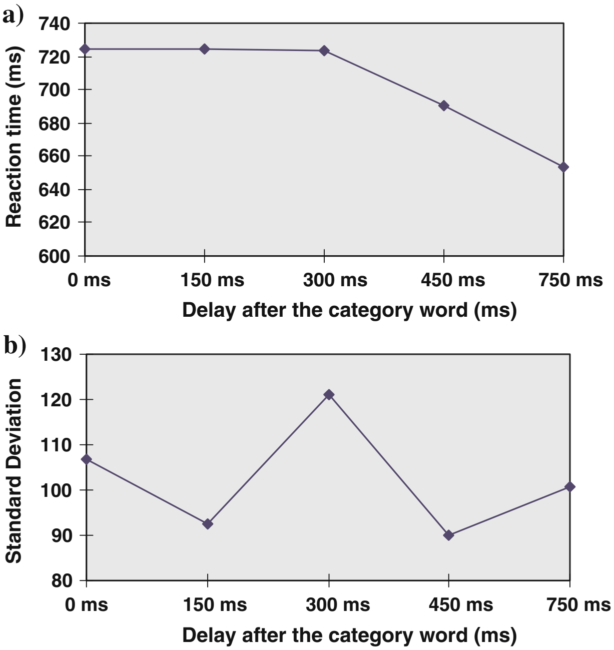

Fig. 5 Changes in (**a**) response times to atypical exemplars in a biased context; (**b**) variability of the response times to atypical exemplars in a biased context

It is important to note that only the within-probe position variability computed first within subjects patterned this way. Differences were not detected when the between-subject variability was taken into account. The Leven's test of the homogeneity of variances at each delay point showed that they should not be considered different F (4, 220) = 0.826; $p > 0.51$.

Discussion

The results from Experiment 3 found that response times to an atypical category member remain relatively stable until 450 ms after the category name; at that temporal point they decreased significantly. This pattern suggests that contextual adaptation occurs within a 300–450 ms temporal window, therefore corroborating the results of Experiment 1. However, an examination of the variability of response times revealed a significant increase at 300 ms past the category name, even though the change in the response times was not observed until 450 ms past the category name. At that point variability appeared to return to levels more like those found at the 0 and 150 ms probe positions. The relation between response time and its variability allows inferences concerning the nature of context adaptation. Recall that a progressive activation of the contextually relevant exemplar would likely entail a smooth decrease in response time downstream from the category name accompanied by a smooth decrease in their variability. In contrast to this prediction the drop in response times was abrupt and was preceded by an increase in variability.

It is just this increase of variability *before* the decrease of the response times to the contextually relevant probes that suggests that contextual adaptation of category representation takes the form of a transition between two stable states. As in other systems investigated in psychology—from coordinated movement to perception of words or sentences (see, e.g., Kelso et al. 1994; Rączaszek et al. 1999)—the achievement of a new coordinated state is preceded by, or rather results from, the loss of stability of another, “old” state. This loss of stability is always marked by the increase of variability of performance—for example in case of coordinated movement there is a marked increase of standard deviation from the required trajectory of movement. The increase of variability takes place *before* the actual transition to a new ordered state. After the switch occurs to a category structure that is contextually adapted, we observed that the response times decrease and the variability returns to baseline. Such a pattern is also a hallmark of transitions in self-organized dynamical systems. This interpretation is developed further in “General Discussion”.

The unexpected result is that at 750 ms response times in Experiment 3 decreased while in Experiment 1 at the same point a slight increase occurred. This discrepancy is even more surprising when we consider the almost exact replication of the response times at the other probe positions. From the results of Experiment 1 we concluded that neither typicality nor contextual effects were present after 750 ms. The results of Experiment 3 challenge this view. Perhaps such differences are due to the effect of the words which followed a category name. At 750 ms after a category name, subjects could have heard already two or three syllables of the next word. Since sentences in Experiment 1 and 3 were not the same, these words might have affected the reaction times differently. Future work should also resolve whether the design differences (in Experiment 1 the PROBE POSITION variable was between subjects, in Experiment 3 it was nested and analyzed as within subjects) or other factors, such as the material used (both neutral and biased sentences in Experiment 1 but only biased sentences in Experiment 3) contributed to the different patterns observed.

General Discussion

In the present experiments we used on-line “sampling” methods to elucidate the time course and the nature of contextual influences on the information available after hearing a category name in a sentence. Our results showed that initial access to categories evinces a typicality structure similar to that observed in off-line studies of categorical representations (Rosch 1976; Mervis and Rosch 1981). Preceding semantic context does not *initially* influence access to typical and atypical exemplars; contextual influence is observed only after some time has passed. Specifically, we found that the response times to contextually relevant but atypical exemplars do not decrease until 450 ms after the category word. This pattern is much like the one found for the time course of lexical ambiguity resolution during sentence comprehension (e.g., Swinney 1979; Seidenberg et al. 1982; Duffy et al. 1988) and work examining the influence of semantic context on phonemic categorization during sentence comprehension (Borsky et al. 1998). Furthermore, the patterns of central tendency and variability suggest that category structure reorganizes in a fashion reminiscent of dynamical systems, that is, this reorganization is a rapid transition between two states, when the initial state becomes unstable.

Can these results be integrated with previous work on lexical access and conceptual representation into a single, coherent and comprehensive picture of concepts in context? Such a model should capture the details of the process of information reorganization in time as well as the effects of typicality and the initial activation of multiple members of the category.

Even though the results of Experiment 1 support one of the models designed within the information-processing approach, namely the exhaustive access model (Forster 1979), the typicality effects and the process of reorganization of category structure during contextual adaptation would be difficult to encompass in this model.

Another view of conceptual representation, which was supported in Experiment 3, is more congruent with recent, dynamical models of categorization (Case et al. 1995; Cussins 1990; Knapp and Anderson 1984; Rączaszek et al. 1999; Schreiber et al. 1990; Tuller et al. 1994). Extrapolating from this view, we propose that encountering a category word could initially entail more than a single potential category structure. Multistability, the coexistence of potentially stable (or potentially available) patterns, is a prerequisite of contextual flexibility (i.e., the sensitivity of categorization to context). Within 300 ms after the category word is encountered, the contextually congruent information progressively destabilizes the initial pattern until, within the next 150 ms, the system adopts a new stable state which has a category structure organized around contextually relevant dimensions. It is important to notice that such a model has a natural mechanism for the contextual adaptation of the initial representation, provided by the requirements for the semantic coherence of a larger structure—such as a sentence.

The data reported here also fit well with Kawamoto (1993) dynamical model of lexical access. In this model, a lexical entry has a distributed representation that consists of several interconnected fields of units that correspond to spelling, pronunciation, grammatical function, and the meaning of a word. The network is recurrent and fully connected, i.e., each unit has connections with every other unit. The network is trained with a set of words using a simple error correction algorithm (Widrow and Hoff 1960). In the simulations of various tasks like lexical decision (interpreted as full activation of the 'spelling' field), naming (full activation of a 'pronunciation' field) and reading times ('meaning' field), the model shows a dependence of performance on frequency of unambiguous words, as well as on the relative frequency of the senses of ambiguous words.

The effects of context on the time course of disambiguation were modeled by Kawamoto by assuming that context activates a subset of units corresponding to semantic features of a lexical entry. In the simulation, the speed of access (here defined as the maximal activation) of a contextually relevant meaning of an ambiguous word decreased as the strength of the context increased. Our results pertaining to category terms in context perhaps also could be accounted for in a similar model. Indeed, our study could be used to extend the Kawamoto model in the direction of detailing its semantic representation. The spelling or pronunciation of a category term would be associated with a complex multistable pattern in a semantic field. This pattern leads to responses congruent with typicality structure as found in a 'neutral' context, with more typical members of category accessed faster than the atypical ones. On this account we can hypothesize that such a structure perhaps arises as an effect of long term experience and learning interacting with basic properties of information organization in human nervous systems. The initial encountering of a category word would lead to the activation of this structure that *overrides* any context effects that might have been present (in the form of activated parts of semantic field).

Such a view of lexical representation and the processes of contextual adaptation may also add more details to the latest efforts to understand sentence comprehension as a self-organized process, of forming a global, coherent representation, congruent with local constraints coming from the properties of lexical items (Tabor and Hutchins 2004; Tabor et al. 2003). Briefly, in their self-organized parsing system, each word that is encountered activates a set of constrained phrase structure fragments that, in principle, can allow multiple attachment sites. These fragments (with corresponding syntactic, semantic, and contextual constraints) combine with one another and are constantly evaluated as a function of how the parse is supported by the input. The analysis yielded by the closest fit to the constraints that are applied wins out over other possible analyses (see also MacDonald et al. 1994). Though such an account is quite compatible with what we suggest here for on-line category activation and context effects, the present study suggests that lexical items should be viewed as *initially "multipotential"*, i.e., ready to enter many possible contexts (which corresponds to multistability of semantic representation). After entering a sentence structure, only one of the possible stable states would be chosen, and "settling down" of the interpretation in this state makes it easier to explain difficulties in re-interpretation if the first interpretation was incorrect (as in garden path sentences). Our data, especially form the Experiment 3, specify the time-course of the process of contextual adaptation on the basis of behavioral data, which—together with recent findings using, e.g. EEG recording (Swaab et al. 2003)—makes the picture clearer.

Even in the light of the above, the dynamical explanation to sentence processing still needs additional empirical support. Thinking in dynamical terms about psycholinguistic processes urges us to find new measures elucidating those processes. The measure proposed here (within-subject variability measure) seems to be a good candidate for a stability measure, however more work needs to be done in order to see how useful it can be. In future work the variability needs to be assessed over more data points. Other measures of on-line stability are also called for, especially in the face of the fact that most of the psycholinguistic evidence supporting dynamical approach to sentence processing is based on either off-line judgments or self-paced reading times. This is critical because it has been shown that allowing participants to pace themselves slows down processing (Rayner 1998); such slowed processing follows from conscious reflection, which in turn allows any number of constraints to permeate the processing system. Furthermore, there is a reasonable set of evidence using tasks such as cross-modal priming that suggests that lexical constraints do not affect initial syntactic analysis (Swinney and Osterhout 1990; Shapiro et al. 2003).

The concept of an initial multistable pattern of activation in a semantic field allows also for encompassing a meta-research finding by Simpson (1984). Simpson noticed that even though psycholinguistic studies on contextual influence often do not find significant facilitation of contextually appropriate meanings over contextually inappropriate meanings immediately after the ambiguous word, the *majority* of research does show a small advantage for appropriate meanings. Simpson remarked that "the pattern holds across virtually every experiment that allows such a comparison" and that "such consistency should not be ignored" (p. 328). Thus the methods used may not be sensitive enough to detect a small amount of facilitation, but an overall pattern of results indicates that such facilitation may be present. The representation of initially available information as a *multistable* structure allows accounting for such small effects of context. A model in which a difference between facilitated and unfacilitated information is quantitative (degree of activation) rather than qualitative (accessed vs. not accessed) may be better suited for incorporating such effects (see also Rączaszek 1996).

Finally, the interpretation of our data bears consideration more generally. What in symbolic models is termed "exhaustive" access, in dynamical terms means a coexistence of potentially stable, or potentially available, patterns. This brief period of multistability is a prerequisite of contextual flexibility. Contextual adaptation means settling into one of the available conceptual organizations. Thus, a strong interpretation of our data suggests that separate access and selection processes do not have to be proposed as in traditional information processing models.

To conclude, let's go back for a moment to the issue of initial contextual penetrability of lexical access. Advocates of interactionist models often formulate them in dynamical terms while advocates of form-driven, modular models stay within an information-processing view of language processing. Here we have tried to show that a dynamical model may also account for data that seem to be a typical confirmation of the "modularity/exhaustive access/contextual impenetrability" view. Moreover, such a model may be better suited to explain the temporal evolution of moment-by-moment processing, i.e., the process of adaptation of meaning to the context of a sentence. On the other hand, the work cast in terms of interactionist, constraint-based models have often eschewed results that report momentary ignorance of context and probabilistic information. The view we support here is that such evidence should be embraced by interactionist accounts—indeed are a necessary part of any such model.

Finally, it remains to be seen whether our results and the types of analyses we suggest (e.g., an analysis of variability over time) are corroborated and can be extended with further work, whether it can be extended to putatively syntactic operations, and whether or not symbolic, information processing approaches can also give a parsimonious explanation for this process of adaptation.

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Appendix A: Test sentences and probes used in Experiment 1

	Category names in a neutral context	Category names in a biased context	Typical category member	Atypical category member
1.	Kim turned off the engine and got out of the *vehicle* in a hurry	Tom paid the driver and got out of the *vehicle* in a hurry	*truck*	*taxi*
2.	The man was determined to succeed even if it meant committing a *crime* that he would regret	The man decided to bring hashish into the country even though it meant committing a *crime* which could throw him in prison	*murder*	*smuggle*
3.	Joanna wanted to eat something light. She bought some *fruit* in the corner store	Kelly wanted to eat something sour. She bought some *fruit* at the grocery	*apple*	*lemon*
4.	The man stood there with his deadly *weapon* looking very determined	The woodcutter stood there with his deadly *weapon* looking dangerous	*knife*	*axe*
5.	John liked to do everything around the house by himself. Surprisingly he did not have a single *tool* at his house	Frank needed to make a small hole in the metal door. He went to borrow a *tool* from his neighbor	*hammer*	*drill*

Appendix A: Continued

	Category names in a neutral context	Category names in a biased context	Typical category member	Atypical category member
6.	The food was eaten by the *bird* even though it was not fresh	The mouse was eaten by the *bird* even though it tried to hide	*robin*	*eagle*
7.	When Paul went for a walk he saw some *birds* sitting in the tree	When John went hunting by the lake he saw some *birds* flying away	*robin*	*duck*
8.	During the school year John trains a lot. He is good at *sports* and is also an excellent student	In the winter, Carl usually goes to his small house in the mountain. There he enjoys *sports* and good mountain air	*football*	*skiing*
9.	Mary played the *instrument* all day long	Nancy played her brass *instrument* during the parade	*piano*	*trumpet*
10.	Mark left the *building* at around 2 o'clock	After the surgery he left the *building* without delay	*apartment*	*hospital*

Appendix B: Test sentences and probes used in Experiment 2

	Category names in a neutral context	Category names in a biased context	Atypical category member	Non-member matching the context
1.	Kim turned off the engine and got out of the *vehicle* in a hurry	Tom paid the driver and got out of the *vehicle* in a hurry	*taxi*	*tour*
2.	The man was determined to succeed even if it meant committing a *crime* that he would regret	The man decided to bring hashish into the country even though it meant committing a *crime* which could throw him in prison	*smuggle*	*smoking*
3.	Joanna wanted to eat something light. She bought some *fruit* in the corner store	Kelly wanted to eat something sour. She bought some *fruit* at the grocery	*lemon*	*pickle*

Appendix B: Continued

	Category names in a neutral context	Category names in a biased context	Atypical category member	Non-member matching the context
4.	The man stood there with his deadly *weapon* looking very determined	The woodcutter stood there with his deadly *weapon* looking dangerous	*axe*	*tree*
5.	John liked to do everything around the house by himself. Surprisingly he did not have a single *tool* at his house	Frank needed to make a small hole in the metal door. He went to borrow a *tool* from his neighbor	*drill*	*patience*
6.	The food was eaten by the *bird* even though it was not fresh	The mouse was eaten by the *bird* even though it tried to hide	*eagle*	*python*
7.	When Paul went for a walk he saw some *birds* sitting in the tree	When John went hunting by the lake he saw some *birds* flying away	*duck*	*deer*
8.	During the school year John trains a lot. He is good at *sports* and is also an excellent student	In the winter, Carl usually goes to his small house in the mountain. There he enjoys *sports* and good mountain air	*skiing*	*reading*
9.	Mary played the *instrument* all day long	Nancy played her brass *instrument* during the parade	*trumpet*	*talent*
10.	Mark left the *building* at around 2 o'clock	After the surgery he left the *building* without delay	*hospital*	*country*

Appendix C: Test sentences and probes used in Experiment 3

	Category names in biased context	Category members matching the context
1.	Because of their precious fur the *animals* are almost extinct	*mink*
2.	Even though it often gave off a bad odor Harry liked his *pet* very much	*skunk*
3.	Steve did not know the meaning of the word so he looked it up in a *book* in the library	*dictionary*

Appendix C: Continued

	Category names in biased context	Category members matching the context
4.	Kerry's mother told her to wash the leaves of the *vegetable* for the salad	*lettuce*
5.	Cheryl could not reach the top of the cabinet so she brought over a piece of *furniture* to stand on	*stool*
6.	The mouse was eaten by the *bird* even though it tried to hide	*eagle*
7.	Frank needed to make a small hole in a metal door. He went to borrow a *tool* from his neighbor	*drill*
8.	Tom paid the driver and got out of the *vehicle* in a hurry	*taxi*
9.	The man decided to bring hashish into the country even though it meant committing a *crime* which could throw him in prison	*smuggle*
10.	Kelly wanted to eat something sour. She bought some *fruit* at the grocery	*lemon*
11.	The woodcutter stood there with his deadly *weapon* looking dangerous	*ax*
12.	After the surgery he left the *building* without delay	*hospital*
13.	When John went hunting by the lake he saw some *birds* flying away	*duck*
14.	Nancy played her brass *instrument* during the parade	*trumpet*
15.	In the winter Carl usually goes to his small house in the mountain. There he enjoys *sports* and good mountain air	*skiing*

Appendix D: construction and results of the typicality ratings questionnaire

In the questionnaire members of a category were printed under the category name with a 1–5 scale next to each member. Subjects were asked to mark on the scale how typical is a given exemplar to the category mentioned above, 1 meaning very typical, 5 meaning very atypical. The order in which exemplars were printed was reversed in half of the questionnaires.

The results revealed that the mean typicality of exemplars considered typical in category norms was 1.3 and those considered as atypical 2.3 (on a 5 point scale). Only one pair of exemplars had different typicality ranking (i.e., the exemplar that was supposed to be more typical according to the category norms than an atypical exemplar was by our subjects considered less typical). This particular item (category: BOOK; exemplars: DICTIONARY and ROMANCE) was not used in the Experiment 1 or 2 but only in Experiment 3, in which the comparison between typical and atypical exemplar was not made at all. The pattern of responses to this item in Experiment 3 (in which only the supposedly atypical exemplar was used) did not deviate from the rest. The small magnitude of the difference in typicality ranking between typical and atypical exemplars could be due to the time of administration of the questionnaire: it was given to subjects who participated in Experiment 3, and thus had recent experience with atypical stimuli. Barsalou (1987) noted that recent experience with certain exemplars can temporarily alter the typicality structure of a category. This effect would in this case work against the typicality ratings and therefore diminish the difference in these ratings. Nevertheless we did obtain lower typicality ratings for the atypical exemplars.

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