EXPERTISE AND CONSTRAINTS IN INTERACTIVE SENTENCE PROCESSING

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ABSTRACT

We examined individual variation in the integration of conceptual and linguistic knowledge during discourse processing. Skilled and average processors received sentences that were strongly or weakly supported by context. To reduce the contribution of special processing strategies, the syntactic constructions and topics were highly familiar. The interactions of context with linguistic processing were more constrained by sentential connectives for skilled processors, but less constrained by imposed reading units, which varied from words to incomplete sentences to complete sentences. These results suggest that a characteristic of expertise in discourse processing is an almost continual focus on organizing the results of linguistic processing into a conceptual framework. The results are discussed in terms of an interactive model with autonomous processors, but with shared resources for attending to the products of these processors.

INTRODUCTION

Discourse processing produces a mental model that is based on the sentences of a text and the knowledge they elicit. Integrating a sentence into this mental model is easy when it is strongly supported by preceding context, as in the second text below:

(1) Jones found a wreck by the road. She found nothing suspicious inside the car. She examined the damage outside the car. The windshield was shattered. She noticed that one wheel was damaged and a fender was smashed in. Jones took off the tire.

(2) While driving her car, Jones heard a loud bang and a flapping sound. She stopped the car and set the brake. She took the jack, a wrench, and the spare from the trunk. She loosened the bolts on the wheel. She jacked up the car. Jones took off the tire.

Two components in obtaining a model of text are organizing words into propositional units, and revising the model in light of these meaningful units. However, the fact that we can conceive of discourse processing in this way does not mean that the component processes are computationally distinct. Unfortunately, evidence on the issue of information flow frequently appeals to performance on complex syntactic forms in minimal linguistic contexts (e.g., Crain & Fodor, 1985; Clifton & Frazier, 1986; Tyler & Marslen-Wilson, 1977); this leaves open the possibility that it does not adequately represent normal discourse processing.

A model in which there are constraints on the interactions between conceptual and linguistic processes is as follows:

(a) Several rules for comprehension map linguistic representations onto conceptual representations, autonomously and in parallel. For example, the sequence of linguistic categories noun-verb-noun yields a conceptual unit consisting of agent-action-object. The mapping rules apply only to representations in a particular format: propositional rules apply to syntactic representations, pragmatic to propositional, etc. Representations become available to mapping rules when there are complete representational units. For example, rules that organize a pair of sentences into a temporally-organized model apply when linguistic mapping rules have produced a pair of complete propositions.

(b) Discourse production rules map between levels to generate expectations. These representations interact with those that are formed by comprehension mapping rules when the representations from the two sources are in similar formats.

(c) Several factors influence the allocation of attentional resources to the products of mapping rules. Completion of a linguistic unit shifts attention to the more conceptual outcome of the rule. Sentential connectives may shift attention toward either the linguistic or the conceptual level.

We determined whether these constraints on integration are similar at different levels of discourse processing skill. Expertise in discourse processing may depend largely on the application of conceptual knowledge about the world (e.g., Riesbeck & Schank, 1978). However, expertise may be better conceived as a process of integrating superficial and conceptual levels of representation. If so, expertise is another factor that influences the fluctuations of attention between linguistic and conceptual representations, with highly skilled processors presumably focusing more on the conceptual level.

EXPERIMENT 1

The meanings of connectives such as <u>because</u> and <u>although</u> shift the focus of attention (Townsend, 1983). <u>Because</u> states that two propositions are causally related; it is a cue to organize propositions causally as they are formed. <u>Although</u>, however, denies an expected causal relation; it is a cue to search for information about what aspect of the presumed cause is responsible for this denial. In terms of the interactive model, <u>because</u> shifts attention to a conceptual representation, but <u>although</u> shifts it to a linguistic representation. With no linguistic context, listeners show poorer access to the meaning of an initial clause introduced by <u>although</u> (e.g., Townsend, 1983). Experiments 1 and 2 determined whether contextual supports that provide the expected causal relation facilitate processing an <u>although</u> clause, and whether skilled processors show larger effects of context in reading <u>although</u> clauses, as predicted by the view that they focus more on integrating linguistic information into a coherent conceptual framework.

METHOD

To prepare materials for the four experiments, 24 students at Montclair State College listed 10 events that typically occur in common situations like "changing a flat tire," "finding an abandoned car", and so on (see Bower, Black, & Turner, 1979). These responses were used to construct eight "supportive" stories (e.g., (2)) which included a target event that was mentioned by 90% or more of the subjects, as well as several other events that were frequently mentioned by the subjects. Eight "neutral" stories (e.g., (1)) were constructed which contained the frequently-mentioned target event from the supportive story; none of the subjects mentioned this event in their list of events for the neutral scenario. Target events appeared in the third through sixth sentence in the stories, and position was matched within pairs. Independent ratings confirmed that target events were more essential in supportive stories than in neutral stories, F (1,157) = 66.4, $p < .01$.

Subjects read eight stories one clause at a time on a computer screen. In all four experiments, their goal was to write a two-sentence summary of each story. Target sentences (e.g., "Jones took off the punctured tire") were introduced by because or although. Subjects moved through the stories by pressing a key on the keyboard; each key-press removed the previous clause, displayed the next clause, and recorded the time from the last key-press. Half of the stories presented target sentences in supportive contexts, and half in neutral contexts. Connective was crossed with type of context. Since combinations of the materials variables on items were randomly assigned to subjects, statistical tests treating subjects and items as random variables are identical (Clark, 1973).

The subjects were 32 right-handed undergraduates from Montclair State College and Columbia University. In all four experiments, subjects with Verbal Scholastic Aptitude Test scores from 400 to 520 (mean = 440) were designated "average processors;" those with scores from 540 to 700 (mean = 645) were designated "skilled processors."

TABLE 1

MEAN READING TIMES PER WORD (MSEC) IN TARGET SENTENCES

	Skilled		Average	
	Because	Although	Because	Although
Neutral	301	295	392	339
Supportive	310	278	336	321
Facilitation	-9	17	56	18

RESULTS AND DISCUSSION

Table 1 shows that skilled processors read target sentences faster than average processors, F (1,33) = 5.04, $p < .01$, and reading times were faster in supportive contexts than in neutral contexts, F (1,33) = 4.45, $p < .05$. Average processors showed facilitation with both connectives, F (1,33) = 8.06, $p < .01$, but skilled processors showed facilitation only with although, F (1,33) = 6.25, $p < .05$. Skilled and average processors differ in their sensitivity to connectives that map propositions onto a conceptual model of text.

EXPERIMENT 2

Experiment 2 showed that reading time differences for connectives are associated with strategies for focusing on different levels of representation.

METHOD

Thirty-two subjects listened to recordings of the eight critical stories plus 18 filler stories. A brief tone before the last word of the target clause signalled a test 300 msec later; subjects heard a phrase (e.g., REMOVING A FLAT) and indicated whether the phrase was similar in meaning to any part of the story. The correct answer was always 'yes' for the critical stories. After responding, the subjects heard the rest of the story, then wrote a two-sentence summary. Filler stories balanced for correct answer, contextual supportiveness, and connective.

RESULTS AND DISCUSSION

Response times for trials on which errors occurred (10%) were replaced with the corresponding mean for correct trials. Table 2 shows that skilled processors responded faster than average processors, F (1,33) = 12.2, $p < .01$, and that response times were faster in supportive than in neutral contexts, F (1,33) = 6.24, $p < .01$.

TABLE 2

MEAN TIMES TO JUDGE MEANING SIMILARITY (SEC) IN TARGET SENTENCES

	Skilled		Average	
	Because	Although	Because	Although
Neutral	2.31	2.39	2.55	2.48
Supportive	2.30	2.22	2.33	2.30
Facilitation	.01	.17	.22	.18

Average processors showed facilitation for both connectives, but skilled processors showed facilitation only for although, F (1, 33) = 4.48, $p < .05$. Both connectives and context influence skilled processors' accessibility to meaning, but it is mainly context that influences average processors' accessibility to meaning. Expertise in discourse processing is not simply a matter of applying a large store of conceptual knowledge to the interpretation of sentences.

EXPERIMENT 3

The interactive model predicts that supportive contexts have greater effects at the ends of sentences, but that skilled processors may show effects of supportive contexts within sentences as well.

METHOD

Subjects read stories like (1) and (2) one line at a time on a screen. The target line presented either a complete or an incomplete sentence. As in Experiment 1, a key-press removed the previous line, presented the next line, and recorded the viewing time. There were 32 subjects.

RESULTS AND DISCUSSION

Table 3 shows that reading times were faster for skilled processors, F (1, 30) = 10.2, $p < .01$, and faster for complete sentences than for incomplete sentences, F (1, 30) = 6.1, $p < .01$. Facilitation was greater for complete sentences than for incomplete sentences, F (1, 30) = 4.5, $p < .05$.

Skilled processors showed significant facilitation for incomplete sentences, compared to average processors, F (1, 30) = 3.8, $p < .05$. This suggests that skilled processors use context to inform linguistic processing.

TABLE 3

MEAN READING TIMES PER WORD (MSEC) IN TARGET SENTENCES

	Skilled		Average	
	Incomplete	Complete	Incomplete	Complete
Neutral	313	289	488	456
Supportive	299	247	508	323
Facilitation	14	42	-20	133

EXPERIMENT 4

According to the interactive model, context effects depend partly on the form in which contextual information is represented.

Subjects read texts with active vs. passive forms of the target sentences, either one clause at a time or one word at a time. We expected whole-clause presentation to allow readers to form a more conceptual representation of context, producing facilitation especially for more complex passive constructions: the conceptual representation may 'prime' the subject, verb, and object concepts in the target, but in an unordered conceptual representation. Subjects who read word-by-word, however, must assign a structure to each word in sequence as it appears and build up an ordered, linguistic representation; this should induce readers to generate expectations in a more ordered, linguistic format. Since the normal order of a transitive proposition in English is 'agent, patient', word-by-word presentation should produce contextual facilitation of active sentences, which correspond to the canonical order. Passive sentences, however, should be read SLOWER in supportive contexts because of the mismatch between the ordered prediction and the actual form of the sentence.

METHOD

One group of subjects read the critical stories clause-by-clause on a screen and another read them word-by-word. Each key-press recorded the viewing time for a segment, removed it from the screen, and displayed the next one. Target sentences contained an inanimate logical object and a verb that required an animate logical subject, as in (1)-(2). They were introduced by when. Syntactic form and supportiveness were varied factorially. There were 64 subjects.

TABLE 4

MEAN READING TIMES PER WORD (MSEC) IN TARGET SENTENCES

	Clause Format		Word Format	
	Active	Passive	Active	Passive
Neutral Context	322	436	465	477
Supportive Context	294	316	439	497
Facilitation-Overall	28	120	26	-20
Facilitation-Skilled	40	168	59	24
Facilitation-Average	17	72	-7	-63

RESULTS AND DISCUSSION

Outliers (4.1%) were replaced with a value of 900 msec in the clause format and 1100 msec in the word format. Subjects read actives faster than passives, F (1, 60) = 10.3, $p < .01$. They read target sentences faster in supportive contexts than in neutral contexts, F (1, 60) = 6.8, $p < .05$, and faster in the clause format than in the word format, F (1, 60) = 16.6, $p < .01$.

Table 4 shows that supportive contexts facilitated reading times more for passives in the clause format, F (1,60) = 9.8, $p < .01$, but more for actives in the word format, F (1,60) = 4.9, $p < .05$. In fact, the numerical effect of supportive contexts on passives in the word format was to INCREASE reading time. For passive sentences in the word format, the slowing effect was 63 msec/word in the initial noun phrase, F (1,60) = 14.5, $p < .01$, and 39 msec/word in the final noun phrase, F (1,60) = 6.4, $p < .01$; in contrast, the only effect of supportiveness on reading active sentences was a 53 msec/word facilitation in the final noun phrase, F (1,60) = 7.5, $p < .01$. Table 4 also shows greater facilitation for skilled than for average processors, F (1, 60) = 16.9, $p < .01$. The interaction between syntactic form, supportiveness and format was virtually identical for the two groups of subjects, producing the surprising consequence that in the word format, average processors read passives more slowly in supportive contexts than in neutral contexts.

Discourse supportiveness interacts in different ways with linguistic processing as a function of the size of the imposed reading unit. When subjects read whole clauses, supportiveness facilitates the processing of all sentences, but especially those that are otherwise structurally complex. But when subjects are forced to read one word at a time, supportiveness facilitates only active sentences; most striking about this condition is that supportiveness actually slows down the processing of sentences with non-canonical word order, especially for subjects who normally focus more on linguistic representations. This suggests that both reading format and expertise influence the form in which expectations are represented.

GENERAL DISCUSSION

The observed contextual facilitation of performance on linguistic tasks superficially supports the claim that conceptual knowledge informs linguistic processing. Several findings, however, indicate important constraints on interactive processing: the effects of contextual support depend on the integrative processes that sentential connectives elicit, they are stronger at the boundaries of linguistic units, and they depend on the way in which anticipated events are represented. These results support an interactive model which explains variations in discourse processing skill in terms of emphasis on integrating levels of representation: skilled processors shift attention more frequently between conceptual and linguistic representations. They show greater interactions of contextual information with connectives, but the interactions of context with linguistic processing occur more naturally when information from different sources is represented in similar formats, such as when the reader reaches a linguistic boundary, or when the reading format encourages representations in a particular form.

ACKNOWLEDGEMENTS

This research was supported by grant BNS-8120463 from NSF, Separately Budgeted Research awards and a Princeton Faculty Fellowship from Montclair State College, and a Faculty Fellowship from the Army Research Institute for Behavioral Sciences to the author. Portions of this report were presented at the Human Sentence Processing Conference at the City University of New York and the Practical Aspects of Memory Conference at the University of Swansea.

REFERENCES

Bower, G., Black, J., & Turner, T. (1979). Scripts in memory for text. Cognitive Psychology, 11, 177-220.

Clark, H. (1973). The language-as-a-fixed-effect fallacy: A critique of language statistics in psychological research. Journal of Verbal Learning and Verbal Behavior, 12, 335-359.

Clifton, C. & Frazier, L. (1986). The use of syntactic information in filling gaps. Journal of Psycholinguistic Research, 15, 209-224.

Crain, S. & Fodor, J. (1985). How can grammars help parsers?. In D. Dowty, L. Kartunnen, & A. Zwicky (eds.), Natural Language Parsing. Cambridge University Press, Cambridge.

Riesbeck, C., & Schank, R. (1978). Comprehension by computer: Expectation-based analysis of sentences in context. In W. Levelt & G. Flores d'Arcais (eds.), Studies in the perception of language. New York: Wiley.

Townsend, D. J. (1983). Thematic processing in sentences and texts. Cognition, 13, 223-261.

Tyler, L., & Marslen-Wilson, W. (1977). The on-line effects of semantic context on syntactic processing. Journal of Verbal Learning and Verbal Behavior, 16, 683-692.