EXAMINATION OF SENTENCE PROCESSING WITH CONTINUOUS VS. INTERRUPTED PRESENTATION PARADIGMS

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Running Head: Sentence processing with continuous vs. interrupted paradigms

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Abstract

This paper presents three studies which examine the susceptibility of sentence processing to intrusion by extra-sentential target words in two on-line dual-task techniques commonly used to study sentence processing: the cross-modal continuous-sentence (CMCS) paradigm and the unimodal visual sentence-interruption (UVSI) paradigm. It provides a direct empirical examination of issues raised by McKoon and Ratcliff, 1994; 1996 (see also Nicol, Fodor, Swinney, 1994) with and about these techniques.

In all three studies, sentential materials were presented to subjects together with a target word (to which a lexical decision was made) which either constituted a good or bad continuation of the sentence at the point at which the target word was presented (always some point before the end of the sentence). Materials were identical for all studies; only the manner of presentation of the sentence materials differed. The results demonstrated that a technique in which the probe target interrupts the presentation of the sentence encourages the integration of the probe word into the on-going sentence. Such was the case in Experiment 1, which used the word by word UVSI paradigm. In this, decisions to target items that constituted a 'good fit' were facilitated relative to 'bad fit' items. By contrast, the CMCS approach used in 'Experiment 2 involved presentation of a visual probe during the ongoing auditory presentation of the sentence (thus allowing the sentence to continue uninterruptedly). Results demonstrated no facilitation of the 'good fit' compared with 'bad fit' targets. Experiment 3 explored whether it was the cross-modality or the uninterrupted, fluent nature of the presentation which prevented integration of a target into the sentence in Experiment 2. A 'disrupted', nonfluent version of the CMSC paradigm (one hypothesized to be susceptible to Intrusion) was employed and intrusion was demonstrated via facilitation of 'good fit' compared with 'bad fit' targets.

These three studies support the view that online experimental techniques which provide standardly fluent and continuous (rather than interrupted) sentence presentation constitute sensitive, Intrusion resistant, paradigms with which to examine language comprehension. They thus provide empirical evidence strongly counter to arguments made by McKoon & Ratcliff (1994) concerning such techniques. In particular, cross-modal lexical priming techniques (Swinney, Onifer, Prather, Hirshkowitz, 1979; Nicol, Fodor, Swinney, 1994), when used appropriately, are demonstrated to be sensitive, unconfounded methodologies for monitoring structural processing.

A central concern in the study of language processing is the need to develop a detailed understanding of the nature of the experimental methodologies employed in examining language processing; models of . cognitive processing, in general, are inextricably tied to our accurate understanding of the tasks used to examine them.

Recently, there has been some interest in (and controversy about) one of the techniques involved In the on-line examination of structural processing during comprehension - the Cross Modal Lexical Priming task (CMLP; Swinney, Onifer, Prather, Hirshkowitz, 1979). This paper provides a direct examination of recent claims by McKoon & Ratcliff (1994; 1996) concerning the use of this task in the study of the processes by which structurally dependent elements are linked to their antecedents during ongoing sentence processing.

At issue is the following result. Some years ago, Swinney, Ford, Frauenfelder & Bresnan (1987; reported in Nicol & Swinney, 1989) examined relative clause constructions such as the following:

1) The policeman saw the boy that the crowd at the party accused of the crime.

Such structures are of interest because the relation between the verbs and their arguments is not, on the surface, straightforward. For example, in the relative clause construction cited in (1), the direct object of the embedded verb accused (i.e., the boy) does not appear in the canonical 'direct object position' of English, immediately following *accused;* this relation must be deduced by the listener. (The noun phrase (NP) which heads the relative clause (here, *the boy*) is typically referred to as the '*filler*' and the empty direct object slot following the verb as the 'gap'.) Determining how (and when) this relation is computed, and what factors, syntactic and semantic, affect this process, have been the focus of a great deal of past research (e.g. Clifton & Frazier, 1989; Crain & Fodor, 1985; Fodor, 1978, Frazier, 1987; Gamsey, Tanenhaus & Chapman, 1989, Hickok, Canseco-Gonzalez, Zurif & Grimshaw, 1992; Pickering & Barry, 1991; Stowe, 1986, Stowe, Tanenhaus & Carlson, 1991, among many others).

In their approach to this issue, Swinney et al. (1987) used the CMLP task to examine whether the filler (i.e., the understood direct object of the embedded verb) was immediately 'reactivated' in the post-verbal gap position during comprehension, or whether it was simply kept in an active state until the gap was postulated, or whether the structural relationship between the verb and the filler was only computed at some point after the gap occurred (perhaps at the end of the sentence). To do this, they measured reaction times for lexical decisions made to visually presented semantic associates of the fillers (e.g., *girl*, as an associate to *boy*) at various points during the auditory presentation of the sentence following the initial occurrence of the filler. (These were compared to responses to semantically unrelated control words, matched in length and frequency to the associates). They found relatively speeded response times for the associate (i.e., *priming*) at the offset of the embedded verb, but no such priming before that verb. This result suggested the filler was re-activated at the syntactically appropriate point (the canonical direct object position) in the sentence.[1] The conclusion that the authors reached was that filler-gap relations are deduced quickly (i.e., immediately) and that a consequence of establishing a connection of this type is the reactivation of the syntactically appropriate NP, the filler. This finding has been replicated a number of times with a number of different sets of materials (e.g., among others, Hickok, Canseco-Gonzalez, Zurif, Grimshaw, 1992; Love and Swinney, 1996; Nagel, Shapiro & Nawy, 1994; Nicol & Pickering, 1993;-Nicol & Swinney, 1989; Swinney, Zurif, Prather & Love, 1996).

In addition, this finding fit well with other existing evidence from different experimental methodologies which have shown that syntactic dependencies such as the filler-gap relation are computed immediately. For example, a number of studies using reading latencies as the dependent measure have found that, once readers have encountered a filler and a following verb, reading slows down if an NP appears in the position of the 'expected' gap. This can be seen In sentences like, *My brother wanted to know who Ruth will bring us home to*...(from Stowe, 1986), in which, following the filler *who* and the verb *bring*, the NP us appears in the first potential gap position. This "surprise" effect has been referred to as the "filled-gap effect", and has been reported by a number of investigators (e.g., Stowe, 1986, Clifton & Frazier, 1989, Crain & Fodor, 1985, Pickering, Barton & Shillcock, 1994, Tanenhaus, Boland, Gamsey & Carlson, 1989). Similarly, but with yet another methodology - the Event-Related Brain Potential (ERP) - Gamsey, Tanenhaus & Chapman (1989) had subjects read filler-gap sentences presented word-by-word on a computer screen, and make a 'sensibility' judgment at the end of the sentence. They compared ERPs to verbs in two contexts, one in which the filler is a plausible object of the verb, and the other in which the filler is an implausible object, and found that the implausible-filler sentence produced a N400 effect, (an effect typically associated with the perception of semantic anomaly). This suggests that immediately upon reading the embedded verb (the first point at which a gap may be posited), subjects have deduced that the filler is the direct object of this verb.

The study of these issues utilizing the CMLP technique has been particularly useful in that it allows investigation of these effects in normal listening/comprehension conditions - those involving fluent, continuous, auditory presentations of sentences. Happily, all of these techniques provide converging evidence for the immediate linking of fillers and gaps. In addition, the CMLP technique adds additional detail about the interaction between syntactic processing and the activation of particular word meanings, making it particularly useful In investigating the. question of 'continued activation' vs. 'reactivation' of the filler at the gap site. Hence the interest in and use of CMLP for these purposes.

McKoon, Ratcliff & Ward (1994), reported that they were unable to replicate the findings reported in Swinney, et al (1987). They claimed that this failure was due to Swinney et al's use of 'matched target' control words rather than 'switched target' controls (this latter involves a design in which response times to an associated word is compared to response times to that *very* same *word* when it Is paired with a sentence with which it is semantically unrelated). Further, they argued that given their lack-of-replication there was no evidence for reactivation of fillers at gap sites. This conclusion was in consonance with their Compound Cue model of priming, which provides no principled grounds for explaining structure-based (rather than word-association based) priming (see Ratcliff & McKoon, 1988,1994; but see McNamara, 1992). In a reply, Nicol, Fodor, and Swinney (1994) demonstrated that, contrary to the claims of McKoon et al, their apparent lack of replication was likely accountable for by a difference in processing complexity between the Swinney et al. and the McKoon et al. materials. Further, Nicol et al. argued that the concern over the 'correct' form of the matched controls rested on an unstated (and unfounded) assumption concerning where variability in this task occurred: examining response times to a particular target word in the two different sentence contexts (to which it is either semantically related or unrelated) seems tidy, but it assumes that the two sentence contexts that are paired with the single target word are equivalent in all respects except relatedness of the probe target, something that is typically not true (and was certainly not true in the McKoon et al study). Note that this assumption is particularly worrisome when one considers that the cross-modal lexical decision technique has been used effectively as a way of assessing processing load within sentences (e.g. Shapiro, Zurif & Grimshaw, 1987). If sentence complexity can affect lexical decision latencies to an extraneous word, one ought to go to some significant lengths to match the sentence pairs with which a particular target word appears. In our experience, it has been more pragmatic to match words rather than sentences? We return to this issue below, in our discussion of materials and design for Experiment 1, and with empirically relevant details in discussions of our results in all three studies.

A subsequent issue raised by McKoon and Ratcliff (1994) concerning the use of the CMLP technique in examining the processing of filler-gap sentences had to do with the particular materials that Swinney et al. (1987) had used. In that paper, McKoon and Ratcliff argued that any apparent reactivation of antecedents was caused by a possible confound between the experimental and control probes used by Swinney et al, such that reaction time to the experimental probes was faster than that for the control probes because they 'fit' more easily into the ongoing sentence than did the control probes.[3] This argument is based on the results of a study in which they used a subset of the sentences and target items originally employed by Swinney et al. (1987). They altered the sentences so that the filler NP appeared *after* the probe point, as in the following example (cf. example (1) above).

2) The crowd at the party accused the boy.

Here, what had been the head of the relative clause (*the boy*) now appears after the verb, and the sentence no longer contains a filler-gap relation. They presented this sentence visually, word by word, so that each new word in the sentence overwrote the preceding word. They presented the target (which appeared, also visually, offset to the right of the sentence presentation area, marked with asterisks) at one of two positions: immediately before and immediately after the verb . They used as targets a semantic associate of the direct object (e.g., *girl*) and a matched non-associate (e.g., *body*). They found speeded response times to *girl* (relative to the control) after the verb *accused*, but the reverse pattern before it. Their interpretation of this finding was that after the verb, the set of "related" target items (here "girl") simply fit better into the ongoing sentence than the controls. They then concluded that the results found by Swinney et al (1987) were entirely due to these differences in congruence of the targets with the sentences. A brief followup study (McKoon, Allbritton & Ratcliff, 1996) used the same set of materials with a cross-modality presentation, and found a similar (though not identical) pattern of response times.

Two points are worth noting at this juncture: First, there has long been an assumption, based on extensive experience with the CMLP task, that the visually presented probes are not typically integrated into the ongoing auditory sentence (and hence that the 'fit' of visual targets with the sentence was not a factor with this task). This assumption has been backed by evidence: First, in experiments which employ sentence recall (one measure often used to ensure that subjects are attending to the sentences), there is a consistent failure of subjects to mention (i.e., intrude) the probe word. Second, when sentence recognition 'comprehension check' has been employed with the CMLP task, there simply has been no evidence of false recognition of probes as being part of the sentence (probe words are used as one type of foil in this recognition task) (see, among others, Swinney, 1979, Onifer and Swinney, 1981, Swinney, 1981). We note also that, unlike 'syntactic priming' experiments, for which a successful outcome depends on the integration of a target word (see, e.g., Tyler & Marslen-Wilson, 1977), the standard use of the CMLP task explicitly avoids conditions where the visual target appears after the last auditory word in the sentence. Early experience with the task demonstrated that as long as subjects were required to listen to and understand the entire sentence, and the auditorily presented sentence continued without interruption past the point of the visual probe, subjects did not integrate the visual probe word into the auditory sentence (e.g., Swinney et al, 1979; Swinney, 1981). This seemed (and still seems) a logical way for a human processor to function. If the human parser integrated outside concurrent stimuli into an ongoing sentence, listeners engaged in conversation would too easily, and too often, be derailed by signs, billboards, and newspaper headlines which would provide ample opportunity for intrusion of visual words. In short, the concern expressed by McKoon & Ratcliff (1994) over potential differences among related and unrelated visual targets' ease of 'fit' into the original Swinney et al. (1987) materials was something that, while noticed, had been assumed to be inconsequential when the study was first conducted [4]. That said, however, it seems reasonable to us that one might argue that evidence from sentence-final report or sentence-final recognition may not accurately reflect what happens on-line, at the point at which the visual target word appears (indeed, the cross-modal technique was developed in order to avoid tapping in to post-perceptual processes) . Therefore, the integration question as it relates to use of the CMLP task definitely deserves explicit investigation.

A second point is this: the basic finding of Swinney et al (1987) on gap-filling has been replicated a number of times with the CMLP technique in studies that do not contain the potential confound of 'probe fit' pointed to by McKoon and Ratcliff (1994). Most recently, for example, Love & Swinney (1996), in a study which used relative-clause constructions, explicitly controlled for equivalence of fit' or 'integratability' into the auditory sentence of both related and unrelated targets; their findings fully replicated (and extended) the earlier findings obtained by Swinney et al (1987; reported in Nicol and Swinney, 1989). Thus, while we feel that it is critical to provide a serious examination of how the CMLP technique operates (more precisely, whether the auditory sentence is susceptible to intrusion by the visual target word), and to take seriously the potential confound raised by McKoon and Ratcliff (1994) for the set (or subset) of the materials used in the preliminary filler-gap study, we also feel that it is important to make clear that the effect demonstrating 'reactivation' of fillers at gap sites with the CMLP technique is secure and replicable, *independent* of any potential confound in the original Swinney et al 1987 materials.

The goal of this paper, is to critically examine the assumption that has been typically adopted by those using the cross-modal technique: that when subjects are understanding a fluent, auditorily presented sentence and also making a judgment about a visually-presented target word which appears concurrently with some portion of the auditory sentence (but before the end of that sentence), they will not integrate the visual word into the auditory sentence, and, all else being equal, will not respond more rapidly to 'good fit' targets than to 'bad fit' targets.

The purpose of the current experiment is examine the integration of target words into sentences-in the absence of semantic priming *per se*---with a new set of simple sentences designed to allow us to make a direct comparison between the unimodal visual sentence-interruption technique (as used by McKoon and Ratcliff, 1994) and two variants of the cross-modal continuous sentence technique: one with a fluent, normal rate of sentence presentation, which we expect will not allow the concurrently-presented visual word to intrude, and one with slower-than-normal presentation (as used by McKoon, Allbritton & Ratcliff, 1996), which may allow such intrusion. Throughout, we utilize, and hence perform an empirical comparison of, the two types of control - matching procedures discussed above (and previously, in some detail, McKoon et al, 1994; Nicol et al, 1994): the matched target procedure (in which the sentence is held constant), and the switched target procedure (in which the target is held constant).

MATERIALS DESIGN AND MATERIALS PRE-TESTS FOR EXPERIMENTS 1, 2 AND 3

Identical materials were created for all three experiments - the unimodal visual sentence interruption study (Experiment 1), the cross-modal continuous-sentence study (Experiment 2) and the cross modal noncontinuous sentence study (Experiment 3). In order to make certain that the congruent targets did, in fact, 'fit' with the preceding context better than the incongruent targets, these experimental stimuli were subjected to two pretests to assess congruence of the visual targets with the sentences up to the point the target was presented. The first of these, a *continuation judgment* task, required subjects to judge,to what extent the target word formed a good continuation of the sentence; the second, a *relatedness judgment* task, required subjects to judge how related the target word was to the sentence fragment overall.

Materials Design:

Twenty four pairs of experimental sentences were created. All sentences contained the following structure: noun phrase, prepositional phrase, verb, noun phrase, prepositional phrase; as in example (3) (probe point is indicated with an asterisk). Each pair of sentences was paired with two target words, one of which was intended to be more congruent with the sentence fragment (to provide a better fit with it, and continuation of it, than the other target), although neither target was meant to be predictable from the prior context. Members of each target pair were matched in length and frequency, and, most importantly, *a priori* lexical decision times (taken from a lexical decision test performed on the words presented in isolation) as well as for (to the degree possible, given *a priori* RT matching) length and frequency Thus, in (3), the word *apple* is more congruent with the sentence fragment than the word *agony* on the grounds that an apple may be pushed, but agony cannot.

3) The cat at our house *pushed* * the old soccer ball from the neighbor's roof.

Congruent target:	APPLE
Incongruent target:	AGONY

In addition, the target words were paired with a second sentence which provided a matched-sentence control case. As the example in (4) shows, the incongruent target for sentence (3) is the congruent target in sentence (4).

4) The mother with the pony instilled * great happiness in her young daughter.

Congruent target:	AGONY
Incongruent target:	APPLE

In sum, any given target-sentence pair has two different controls: one control is the matched target item that appears with the same sentence (*apple* vs. *agony*) (this is the *matched-target* procedure, which holds the sentence constant and varies the control word); the other control is the same target paired with a different sentence with which it differs in congruence (apple-congruent vs. *apple* incongruent) (this is the *switched-target* procedure, which holds the target word constant and varies the sentence with which it is paired). Hence, this design combines the two matching procedures discussed above. (See Appendix A for a list of experimental materials.)

Materials Pretests:

Two forms of pretests were made on the materials to determine congruence of the target with the sentence (up to-the point of presentation): a continuation-Judgment Pretest and a Relatedness-Judgment Pretest.

Continuation-Judgment Pretest.

In the continuation judgment study, 20 subjects[5] were provided with booklets containing written versions of the experimental sentence fragments up to the point where the targets were to be presented (after the verb). Subjects were asked to rate the degree to which each probe word constituted a good or plausible continuation of the sentence at that particular point. A five-point scale was used: a score of I was to be used to indicate a poor continuation and a score of 5 a good continuation. If subjects rated a sentence with a 2, 3, 4 or 5, they were instructed to complete the sentence using the target word as the next word, so that the basis for their judgments could be evaluated.

Relatedness-Judgment Pretest

In the relatedness judgment study, 22 subjects were asked to rate the degree to which the target word was related to the sentence fragment as a whole.

Results:

The mean ratings for both congruency judgment tasks are shown in Table 1. These show that, by both measures, the 'congruent' targets were significantly more congruent than the incongruent targets. (For the continuation judgments, t_{47}=-4.1, p=.0001; for the relatedness judgments, t_{47}=-16.3, p<.0001).[6]

Insert Table I about here

EXPERIMENT 1: UNIMODAL SERIAL VISUAL PRESENTATION

The first experiment used the unimodal visual sentence-interruption technique. The expected result of this study was a replication of the McKoon and Ratcliff (1994) results (assuming that target congruence produced those results); hence we predict that the congruence of the target item with the sentence fragment will affect response times, with faster times to more congruent targets.

Method

Subjects. 103 subjects participated in this experiment. All subjects were UCSD undergraduates who were participating for course credit. As is customary in our laboratory, subjects were screened prior to testing via a detailed subject questionnaire, in order to ensure homogeneity of the subject population. Subjects were included in testing only if they were native English speakers with no extensive or regular exposure to a foreign language (particularly before the age of 6), and if they had no uncorrected visual or auditory impairment and no history of brain injury or learning disability. Subjects were assigned to one of two presentation lists (see below).

Materials. The 48 experimental sentences (24 pairs of sentences; see earlier section) were combined with 48 sentences which were paired with nonword targets; these latter sentences were similar in length and structure to the experimental sentences. All 96 sentences were combined in a pseudo-random order, the only constraint being that no more than three experimental or nonword-paired sentences could occur in a row. In addition, 10 practice sentence-target items (half with nonword targets and half with 'sentence-unrelated' real word targets) were created; these were presented prior to the 96 test sentences to attune subjects to the task. Because each experimental sentence was paired with two target items, two different lists of the materials were produced, both containing the same 106 sentences, but with the experimental targets (congruent/incongruent) counterbalanced across the two lists so that each list contained equal numbers of congruent and incongruent targets. All other sentences and their targets (nonword, practice) were identical in the two lists.

Procedure. Each sentence was presented one word at a time in the center of a computer screen, using RTLAB software.[7] The length of time for which the word was presented varied, depending on word length: Following McKoon & Ratcliff (1994), each word was presented for 170 msec plus a variable amount of time (17 msec times the number of letters in the word); then the word disappeared from the screen, and the next word of the sentence was presented in the same location. The target word was presented (at the appropriate point in the sentence) five spaces to the right of the position of the other words, with two trailing asterisks off to the right hand side. Following McKoon and Ratcliff, all words (sentences and targets) were displayed in lower case except for the first letter of the.first word of the sentence. Again, as in McKoon & Ratcliff (1994), once subjects responded to the target word, the remaining words of the sentence were displayed.

Subjects were instructed that they would be reading sentences one word at a time and that the words would be appearing rapidly on the computer screen in front of them. They were told that they were to understand the sentences and that at some point during the sentence a string of letters marked by two asterisks would appear slightly to the right of the sentential words. Subjects were instructed to decide as quickly and accurately as possible if the letter string was a real English word (i.e., to make a lexical decision), and to signal their decision by pressing an appropriately-labeled response key. In order to assess and assure attention to the sentences, subjects were told that at various points during the experiment, a comprehension question about the previously presented sentence would appear on the computer screen; subjects were asked to write the correct answer to the question on an answer sheet. The question was displayed for five seconds, and the next sentence was initiated after another five seconds. The item after a question was never an experimental item. A total of eight comprehension questions were asked.

Results

All errors were excluded from reaction-time analyses (errors included incorrect responses on the lexical decision task (or failure to respond within 3000 ms). Following'our standard exclusion criteria, the data from any subject with more than 10% errors on the lexical decision task, and more than 25% errors on the comprehension questions were excluded from the analysis. These turned out to be stringent criteria for this task: out of 103 subjects, 61 were excluded on these grounds, 22 due to lexical decision errors and 39 due to errors in responding to comprehension questions. (However, with respect to their response time pattern, their performance was similar to the included subjects; see footnote 8 below).

The reaction time data for the remaining 42 subjects were then submitted to summary and inferential statistical analysis. Overall, mean response times for the critically different target types were as follows: 693 milliseconds for congruent targets and 712 milliseconds for incongruent targets (See Table 2). *A priori* planned comparisons (1-tailed) revealed this difference to be statistically reliable by the subjects analysis (t_{41}=3.71, p < .0006).[8] A separate items analysis was performed for each of the two types of 'control' condition-matched targets and switched targets (the means, of course, are identical for these two comparisons). Both were significant, to the same degree: t_{47}=1.68, p < .05, for matched targets, and t_{47}=1.79, p < .04 for switched targets.[9]

Discussion

These data replicate the results obtained by McKoon and Ratcliff (1994). In addition, our experiment extends the earlier work by *explicitly* testing congruency. Overall, these results show that response times to make a lexical decision correlate with the congruence of the target word with the preceding sentence fragment. This result is, moreover, exactly what one would expect based on the literature on lexical access in sentence contexts: when a sentence is continued with a word for lexical decision, how well the word may be integrated into the prior context affects decision latencies (Forster, 1990). Additionally, both the switched targets and the matched-targets designs were shown to demonstrate quite similar effects.

However, as we discussed earlier, whether or not any attempt is made to integrate a target word into an on-going sentence may depend on whether the ongoing sentence is interrupted or not. Experiment 2 was conducted to determine whether or not the congruence effect appears when sentences are presented fluently, without interruption, as in the CMLP technique.

EXPERIMENT 2: CROSS MODAL CONTINUOUS SENTENCE PRESENTATION (Normal Speed)

This experiment used the cross-modal presentation, in which visual target words are briefly presented concurrently with auditorily presented sentences. In this study, fluent, auditory sentential materials are presented at normal rates of speech. Based on prior evidence, we predict that subjects would not integrate the target into the sentence (i.e., they would keep separate the task of understanding continuous sentences and the task of making lexical decisions to visual targets), and hence, that they will not show the integration/congruence effect observed with the unimodal sentence-interruption task.

Method

Subjects. 46 undergraduate subjects participated in this experiment for course credit. All selection criteria specified in Experiment 1 applied equally to subjects in this study.

Materials. The materials were identical to those used in the study described in Experiment 1. The only difference was in the manner of presentation: the sentences were presented auditorily to subjects, and each was presented without interruption; (i.e., as is standard with CMLP, sentences did not 'pause' while the visual target was being presented or processed).

Procedure. The sentences were recorded by a male speaker of English at a normal speaking rate - an average of 5.8 syllables/sec (4.2 words/sec); a rate conforming closely to the standard speech rate of 6 syllables/sec. (see, e.g., Deese, 1984; Foss & Hakes, 1978).[10] The sentences were then digitized at a 48-kHz sampling rate and placed on high fidelity four-track audio tape. A digitized square-wave onset 1 kHz tone was placed on a parallel tape track to that containing the speech (a channel not audible to the subjects) to indicate (to the computer) the point at which the target was to be presented during each sentence. The visual target word appeared on a computer screen in front of each subject for 300 msecs at the specified point in the sentence (and, as is standard with this technique, the sentence never paused). Response timing began with onset of presentation of the target word and was terminated by the subject's button-press. Much as in Experiment 1, subjects were instructed that they had two tasks to perform: One was to listen to sentences presented over headphones and to understand them; and the other was to make word/nonword decisions to visually presented letter strings which would appear sometime while they listened to the sentences. Again, to ensure attention to and comprehension of the sentences, they were told that they would be tested periodically on their comprehension of these sentences throughout the course of the experiment. There were ten comprehension questions (the first eight of these were in identical positions to those in Experiment 1; this experiment contained two extra questions which were appeared at the end of the study to examine a small question extraneous to the current Issues).

Results and Discussion

By our customary exclusion criteria, data for any subject who made more than 10% lexical decision errors (seven subjects) or who made more than 3 errors (out of-.10)-on comprehension questions (one subject) were excluded from further analysis.

Summary and inferential statistics were performed on data from the remaining 38 subjects. The mean reaction times to make lexical decisions to the critical variables of interest were as follows: 561 msecs. for congruent targets and 565 msecs. for incongruent targets. This difference did not approach significance on any of the planned comparisons (one-tailed tests). (For the analysis employing subjects as a random factor, t_{37}= .786, p <.23[11]; with items as a random factor, t_{47}=.43, p <.33 for matched targets and t_{47}=.41, p <.34 for switched targets.)

The results of this experiment contrast sharply with those of Experiment 1. The utter lack of a congruence effect suggests that the cross-modal continuous-sentence presentation, at least when used with normal fluent speech, effectively prevents integration of visually-presented target words, as predicted.

It also appears that, as a dual task, the cross-modal presentation is substantially easier for subjects than the unimodal presentation. Two facts support this: one is that the mean response time in Experiment 1 is around 700 msecs, while the mean RT for this experiment is about 562 msecs. The other is that a far lower proportion of subjects were excluded in this experiment than in Experiment 1, suggesting, not surprisingly perhaps, that dual tasks are easier to perform when different modalities are employed (despite the presence, in the former, of a potentially helpful "pause" in presentation to allow for lexical decision).

EXPERIMENT 3: DISRUPTED CROSS-MODAL PRESENTATION- SLOWED SPEED

One question of importance in resolving the question of efficacy of experimental techniques is the determination of whether the 'intrusion' effect of probes into sentential material is solely a function of modality of probe and sentence (cross-modal vs. unimodal) or a function of more general pragmatic features of stimulus presentation that 'encourage' or 'discourage' such intrusion of targets into the ongoing sentence. To that end, we decided to examine processing in the (as thus far demonstrated) intrusion-resistant CMCS paradigm and introduce a manipulation that we felt might encourage integration of the target into the ongoing sentence. There are a large number of possible 'disrupters' to the normal use of the CMLP/CMCS task that we imagine would cause breakdown of normal comprehension and allow intrusion of the target into the sentence. One of the more obvious possibilities involves sentence presentation at slow rates of speech. When speech is quite slow, there is time for 'extraneous intrusions' in a way that has been demonstrated to change structural processing, among other things (Swinney, 1996; Swinney, Zurif, Prather & Love, 1996). By hypothesis, one thing that happens during slow speech input is that rapid automatic processing (e.g., lexical access, structural analysis) is completed quickly enough that the processor is effectively 'waiting around', and has sufficient time to integrate extraneous materials. Whether it is this reason, or one of several viable alternatives that underlies the effect, we have reason to believe that if speech is presented slowly enough, many intrusions into the ongoing comprehension process take place. We thus decided to examine susceptibility to intrusions of the CMCS paradigm with sentences presented at slowed rates of speech .

Method

The methods for Experiment 3 was identical to that for Experiment 2 , (the same number of subjects were tested using the same selection and exclusion criteria, the same materials, the same procedure and the same design) with a single exception: sentence stimuli were presented at an average rate of 4.1 syllables/second (2.97 words/second). This was accomplished by the original speaker (from Study 2) re-recording the materials at a slower pace (the target rate was approximately 1/3 slower than the rate in Experiment 2. While computer based slowing algorithms are available for this purpose, it was felt that naturalness would best be maintained by a practiced speaker. According to five judges, his method resulted in clear, comprehensible speech which simply sounded 'on the slow side' or "slightly stilted".

Results.

By our customary exclusion criteria, data for any subject who made more than 10% lexical decision errors (4 subjects) or who made more than 3 errors (out of 10) on comprehension questions (0 subjects) were excluded from further analysis.

Summary and inferential statistics were performed on data from the remaining 42 subjects. The mean reaction times to make lexical decisions to the critical variables of interest were as follows: 575 msecs. for congruent targets and 595 msecs. for incongruent targets (See Table 2) . *A priori* planned comparisons (1-tailed) revealed this difference to be statistically reliable by the subjects analysis (t_{41}=2.99, $p < .005$). A separate items analysis was performed for each of the two types of 'control' condition--matched targets and switched targets. Results were: t_{47}=1.65, $p < .05$, for matched targets, and t_{47}=1.37, $p < .09$ for switched targets.

Insert Table 2 about here

The results of this experiment contrast with those of Experiment 2. When the auditory sentence presentation was slowed by approximately 1/3 below normal rates of speech, there was priming for 'good fit' compared with 'poor fit' targets, supporting the hypothesis that disruption to normal sentence presentation may allow intrusion of the target into the sentence - thus allowing congruence of the target with the sentence to affect reaction time to that target.

Given the results of our Experiment 3, the results reported by McKoon, Allbritton and Ratcliff (1996), which uses a cross-modality presentation, certainly come as no surprise. McKoon et al. presented sentential materials at 390 msecs per word (approximately 2.5 words/sec), which is considerably slower even than the rate used in our 'slowed' Experiment 3. Both such presentations differ from the normal use of CMLP, which involves continuous, fluent, uninterrupted sentence presentation. In all, Study 3, and that of McKoon et al. (1996) demonstrate that the rate of presentation can be adjusted to allow for intrusion of extraneous target items into the sentence. However. Experiment 2 demonstrates that, at more normal rates of speech, CMLP resists such Intrusion.

General Discussion

The all-visual sentence interruption method examined in Experiment I showed faster decision times to the congruent targets compared to the incongruent targets. The lack of such an effect in the cross-modal continuous sentence method examined in Experiment 2, however, suggested that this congruence effect Is restricted to cases in which the sentence pauses or is interrupted, allowing for Integration of the target word into the sentence. Experiment 3 demonstrated that when sentence presentation is slowed sufficiently, even auditory presentations can become susceptible to target intrusion. These experiments confirm the contention that integration of a target word is affected by the way in which the sentence and target are presented, and, further, suggest strongly that our normal use of the cross-modal technique is immune to such integration.

Given the results of these studies, there are a number of issues that need to be considered. First, the issue was raised by McKoon, Ratcliff & Ward (1994) concerning the relative merits of matched-target vs. switched-target designs. The current study combined the two designs in such a way that they could be directly compared, and suggests that there is very little difference between the procedures. Indeed, all experiments both produced nearly identical results for the two approaches: there was virtually no difference between the variances associated with varying targets (and holding the sentence constant) vs. varying sentences (and holding the target constant).

Second, it is absolutely vital to point out that any given finding of a congruence effect does not mean that there is not also a reactivation effect (bringing this back to the issue that began the controversy - antecedent reactivation triggered by sentence structure). Rather, we have good reason to believe that these are two independent effects. As mentioned earlier, a recent cross-modal (continuous sentence) naming study by Love & Swinney (1996) used a matched-target design that employed items that were equated for *a priori* decision latency, length, frequency, and, critically, congruency with the sentence (using the same judgment tasks as in the current experiment). They examined relative clause sentences (e.g., "...Jimmy used the new pen that his mother-in-law recently *purchased...")* for which the target words were presented at the gap-site and also a control site, just before the embedded verb. The continuation judgments on the targets and sentences were uniformly low: subjects judged the targets - both related and unrelated - to be poor continuations of the sentence at all probe points . As a critical point, we note that, iiot`sug: isingly, the relatedness judgments showed high scores for the related targets and low scores for the unrelated targets. Importantly, however, the relatedness judgments did not differ across probe points; both sets of targets were judged to be equally related to the sentence fragment at both the gap site (after the verb) and at a non-gap site (before the verb), and although the two target sets differed in their mean ratings, *there* was not even *the slightest hint* of an *interaction with probe* site. In contrast, the lexical decision times did show a significant interaction: reaction times to the 'related' associate were faster than for the controls, but only *after* the verb, at the gap site, not before. This finding shows that, when congruence of targets is controlled, reactivation of a filler at the gap site still obtains.

The dissociation between reactivation effects and congruence effects is also apparent in other priming studies in which the gap site and the control non-gap probe site appear after nearly identical contexts (rather than post-verbally and pre-verbally, as in the original Swinney et al., 1987 experiment). For example, Nicol and Pickering (1993) compared priming in the following two sentence types, only the first of which contains a relative clause (and hence contains a filler and gap): '*The man told the judge that the secretary had called __..."* vs. *"The man told the judge* why the *secretary had called..." :* Priming for an associate of the filler was found in the former sentence type, not in the latter. Another cross-modal study, by Nagel et al. (1994) used sentence pairs, both members of which contained a filler and gap, but in which the gap location was signaled exclusively by prosodic cues. In fact, except for prosody, the sentences up to the probe point were identical. In both of these experiments, priming for the relevant NP was observed only when the NP was a filler (a structurally appropriate antecedent to the gap), and only at the point of a gap. Since the sentence context preceding the probe point in the two sentence versions is semantically and syntactically similar in these experiments, it is extremely unlikely that these effects are reducible to target-sentence congruence. If congruence were to play a role in these experiments (a possibility which seems highly improbable), it would most plausibly have an effect in both sentence types, and would not be restricted to just the sentence type that happens to contain a gap.[12]

In sum, we have seen that the intrusion of target items is possible in tasks in which the presentation of a sentence is not continuous and fluent, as shown by the current Experiments 1 and 3 and by a number of others (Cowart & Cairns, 1987, Gorrell, 1989, McKoon & Ratcliff, 1994, Tyler & Marslen-Wilson, 1977, Wright & Garrett, 1984). However, our research shows that when materials are controlled or equated for congruence, reactivation effects still emerge (Love and Swinney, 1996, Nagel et al, 1994, Nicol, 1993, and Nicol & Pickering, 1993). Thus, even when the manner of sentence presentation allows target-intrusion, this does not compromise the cross-modal lexical decision technique--or even, in principle, the unimodal presentation technique--as a useful tool for studying on-line sentence processing. As we have shown, one can control for target congruence at various probe sites either by equating congruence via goodness-of-fit ratings, or by constructing sentences in which the context preceding the probe point is minimally different.

This, then brings us back the issue that underlies this work: obtaining an understanding of the tools by which we examine language processing and the nature of the interaction between the process being studied and the tools of investigation. In the present context, we have shown that the rate and fluency of presentation of an auditory stimulus directly whether extraneous stimuli intrude into the auditory sentence. It is valuable to understand that quite similar-seeming tasks may be sensitive to different (potentially confounding) variables.

Endnotes

[1] Note that while the terms 'activation' and 'priming' have quite specific meaning and usage in some quarters, the reference to lexical activation and re-activation was and is purely descriptive here; that is, It is a reference to the availability of a lexical item to processing, rather than a dogmatic statement of inechanics of the process.

[2] Although the matched target design has been used more extensively in filler-gap research, the "matched sentence" technique had been used in a study presented at the Fifth Annual CUNY Conference on Human Sentence Processing in 1992 by Nicol, Pickering and Hickok (and in print by Nicol & Pickering, 1993). This study replicated findings from matched-probe versions of the technique; thus both approaches had been shown to viably reflect antecedent reactivation.

[3] McKoon and Ratcliff (1994) do not actually provide a definition of (or empirical verification of) what this fit' is a fit of; they variously refer to this as 'semantic-pragmatic fit' or simply as 'fit' and state that: "...the factors that contributed to the intuitive feeling that a word "fits" a test position may involve semantic interactions, pragmatic interactions, syntactic interactions..., associations in the language..., associations in the real world..., meaningfulness values, concreteness values, and the context formed by all the sentences in the experiments." (p. 1241). We will refer to all of these different types of 'fit' with the term 'congruence'.

[4] Data from the study by Swinney, Ford, Frauenfelder, and Bresnan, although presented in 1987, was actually run in 1982 and had been intended at that time for a paper in a book that never appeared. The authors of that original paper were: Ford, Frauenfelder, Bresnan and Swinney.

[5] Subject selection and inclusion criteria were identical for the pretests and the on-line experiments. Please refer to those areas, below, for details.

[6] We note that both means for the continuation judgments are relatively low; this is not surprising, given that the target words appeared without a determiner, making them awkward as continuations. In addition, for comparison with the study reported by McKoon and Ratcliff (1994), we also ran the same congruency judgements on the subset of materials that they had used from the Swinney et al (1987) study on the same groups of subjects. The results were extremely similar to the highly significant differences obtained here: The Relatedness judgements averaged 3.8 for the congruent and 2.1 for the incongruent Items and the Continuation judgements averaged 2.8 for the conguent and 1.7 for the incongruent Items for those same materials. Overall, the average rated differences are nearly identical for the subset of materials employed by McKoon and Ratcliff

and those used for the current experiments. (This, is, of course, confirmed by the replication of McKoon and Ratcliffs (1994) results found in Experiment 1, below).

[7] This software has been developed and refined over the past 10 years or so for DOS-based machines by the second author, and controls coordination, timing, and presentation of all visual (and, where relevant auditory - either from tape or internal computer-generated speech) stimulus materials and records voice or button press responses (and reaction times for those responses). All timings have been externally (to the computer) and independently verified to be accurate to within less than 1 millisecond, and all presentation conditions involve controls for the usual vagaries of video display (scan frequency, raster postion) etc. It is available upon request.

[8] A subjects-based ANOVA with lists as a between subjects factor was also conducted. This analysis revealed no main effect of list ($F(1,40) = .914$, $p=.345$), nor an interaction of list by congruence ($F(1,40) = 3.726$, $p = .06$). There was a main effect of congruence ($F(1,40) = 14.709$, $p < .0001$)).

[9] It may be a concern that, given the large number of subjects whose data were excluded from analysis by our standard exclusion criteria, the congruence effect might be limited to the better-performing subjects. However, analysis of the data from the 61 'rejected' subjects shows an identical difference in average response time to the two target types ($t_{47} = 1.673$, $p < .05$) (the matched target analysis). A separate items analysis of the data from the 39 subjects who were excluded on the basis of comprehension errors also shows this difference to be significant among this group (t47 = 2.05, $p < .023$). But analysis of the data from the 22 subjects excluded due to lexical decision errors (who again showed the same mean difference between target types) did not reach significance, possibly due to the relatively smaller number of subjects and the reduced set of correct responses per subject. ($t_{47} = 0.84$, $p < .2$).

[10] Standard speech rates are typically given as 6 syllables/second. (or, far less precisely, about 3 words/second) (see, e.g., Deese, 1984; Liberman, 1970; Yeni-Komshian,1993). Typically, stressed syllables last between 200-350 msecs and may contain up to 6 phonemes, and unstressed syllables may last less than 100 msecs (again, containing several phonemes) (see, e.g., Foss & Hakes, 1978). Phonemic segments occur, on average at a rate of under 70 msecs/segment.

[11] An analysis of variance which included the between subjects factor, list, was also conducted. Neither list nor congruence were significant (respectively, $F(1,36) = 2.12$, $p < .16$, and $F(1,36) = .76$, $p < .39$).

[12] Obviously, it is possible that the two contexts are different enough that associates are more congruent with the gap sentences than the non-gap sentences. Note also that if such slight differences do matter to

congruency, then *surely* the sentences tested by McKoon & Ratcliff, which drop the matrix clause from the Swinney et al. sentences, cannot be considered comparable to the unadulterated versions. Clearly, unless one can make a principled distinction between two sentences in terms of congruence with a target, it is reasonable to assume that similar contexts which terminate in the same stem provide an equally good fit for the target words.

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TABLE 1

Table 1. Mean continuation-goodness ratings for the congruent and incongruent targets.

	Target Type		
	Congruent		Incongruent
Continuation Judgments	*2.3*	--	1.8
Relatedness Judgments	*3.8*		*1.6*

Congruent vs. Incongruent differences significant at p<.0001

TABLE 2

Table 2. Mean reaction times (in msecs) to congruent and incongruent targets for Experiments **1,2 & 3.**

	Target Type		
	Congruent	....Incongruent	
Experiment 1(UVSI paradigm)	693	712	* p<.0006
Experiment 2 (CMLP paradigm)	561	565	NS
Experiment 3 (Disrupted CMLP)	575	595	* p<.005

Appendix A

Experimental Materials for Experiments 1 and 2. For each set, The first target (e.g., APPLE in set #1) is congruent with Sentence a) and Incongruent with sentence b). The reverse relationship holds for the second target (e.g. AGONY in set #1) and Sentences a) and b).

1 a) The cat at our house pushed * the old soccer ball from the neighbor's roof.
1 b) The mother with the pony instilled * great happiness in her young daughter.

Targets: **APPLE**
AGONY

2a) The wife of the mayor heard * the boring speech at the wedding during the reception.
2b) The baby in the stroller carried * the empty bottle with him on the ride.

ROAR
CAKE

3a) The soldier in dress whites brought * the polished sword to the office of the commander.
3b) The chef in the kitchen recited * the epic poem to her assistant.

PENCIL
PHRASE

4a) The prince on the horse wore * the brightly colored hat during the hunt.
4b) The tiger from the zoo had injured * the novice trainer during a show.

TIE
EAR

5a) The chemist in the store placed * the heavy book on the dusty table.
5b) The salesman in the car regretted * the sudden loss of a valued customer.

CUP
SIN

6a) The butler in the mansion mastered * the difficult recipe in moments.
6b) The attendant in the hotel folded * the clean towels for the new guests.

TECHNIQUE
NEWSPAPER.

7a) The mayor on the grandstand planned * the long meeting for the community.
7b) The speaker from the conference drank * the fresh coffee while he waited.

MARCH
BLOOD

8a) The owner of the dog had lived on * little money for the last six years.
8b) The plumber under the sink attended * the short meeting the next night.

ROAD
PLAY

9a) The clown at the show caught * the mean ringmaster with the whip.
9b) The scientist in the laboratory cleaned * the antique desk with the damp rag.

NURSE
ATTIC

10a) The hounds in the field chased * the tiny mouse into the dark cave.
10b) The millionaire from Hollywood entered * the old house that he once owned.

BABY
SHOP

11 a) The addict from the city sold * the damaged car to the man at the garage.
11 b) The attorney at the podium questioned * the hostile witness about the murder.

BALLOON
HONESTY

12a) The neighbor in the car followed * the simple map to her friend's house.
12b) The broken machine impeded * the meticulous task of decorating all the cookies.

PATTERN
JUSTICE

13a) The kids from the suburbs threw * the brick at the haunted house.
13b) The family from the city toured * the green countryside for a full day.

ARROW
GROVE

14a) The widow on the bench computed * the large amount of time needed to finish the task.
14b) The paramedic with the gloves learned * the new procedures form his partner.

DISTANCE
LANGUAGE

15a) The supervisor at the factory fired * the angry woman after the strike ended.
15b) The head of the household doubled * the small amount of juice by adding more water.

WAITRESS
DONATION

16a) The owner of the building installed * the storm window on the first floor.
16b) The man with the mask scared * the young children on Halloween..

TUBE
BIRD

17a) The man in the bedroom emptied * the smelly hamper nearly every day.
17b) The cashier at the register shouted * the reduced price to her manager.

SINK
JOKE

18a) The secretary at the desk tried * the new message service last week.
18b) The baby in the stroller heard * the loud rattle shaking over her crib.

REMEDY
GOSSIP

19a) The clerk in the storeroom wore * a protective brace on his back.
19b) The family at the supermarket invited * the new neighbors to their block party.

OUTFIT
PRIEST

20a) The manager in the supply store bought * a new computer for his office.
2.0b) The professor in her office organized * her lectures for the following day.

TICKET
CLOSET

21 a) The family with the baby hired * the experienced nanny to help raise the child.
21 b) The sheriff on his break ate * the stale doughnuts from his favorite bakery.

DEPUTY
CEREAL

22a) The busboy in the restaurant tasted * the special meal -of-the day.
22b) The sergeant in the army screamed * the acceptance speech to his supervisor.

JUICE
LYRIC

23a) The president of the club invited * the other club members to visit his home.
23b) The father on the phone solved * the small problem with one phone call.

NEPHEW
PUZZLE

24a) The grandmother in the kitchen sliced * the warm bread for her grandchildren.
24b) The boy in the treehouse built * the wooden ladder out of branches and twine.

FRUIT
BENCH