Research Report

REPETITION BLINDNESS INTERACTS WITH SYNTACTIC GROUPING IN RAPIDLY PRESENTED SENTENCES

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Abstract—*This study tested for predicted effects of syntax on a repetition deficit (RD) known as repetition blindness, the reduced probability of recall for repeated words in rapid serial visual presentation (RSVP) sentences. The syntactic variable was phrase-congruent versus phrase-incongruent grouping within simultaneous RSVP displays. With phrase-congruent grouping, each RSVP display contained a syntactic phrase (e.g., "to play sports" in the sentence "They wanted to play sports but sports were not allowed"), whereas with phrase-incongruent grouping, RSVP displays contained nonphrases (e.g., "sports but sports"). RD was extensive with phrase-incongruent grouping (29%), but nonsignificant (6%) with phrase-congruent grouping, as if phrase-congruent groups free up the extra processing time needed to connect repeated words into phrases in rapidly presented sentences, enabling top-down retrieval of the phrases during recall. The present results comport with effects of syntax and prosody on auditory RD, and suggest that visual and auditory RD are identical underlying phenomena.*

Repetition deficits (RD) refer to a difficulty in encoding and recalling repeated letters in words (e.g., MacKay, 1969) and repeated words in lists and sentences (e.g., Bavelier & Potter, 1992; Kanwisher, 1987, 1991; MacKay & Miller, in press; MacKay, Miller, & Schuster, 1994; Miller & MacKay, 1994, in press). The present study examines RD for the second of two repeated words in sentences such as "They saw horses but horses were forbidden there." When such sentences are presented at 90 ms/word in a rapid serial visual presentation (RSVP) task, older subjects (mean age of 73) experience an RD of 43%, failing to report the second (repeated) "horses" 43% more often than the (unrepeated) "horses" in "They saw sheep but horses were forbidden there" (MacKay, Miller, & Schuster, 1994).

The present study tested a theoretical account of RD developed within node structure theory (NST; MacKay, 1987; Miller & MacKay, 1994). Under NST, a single node represents a lexical concept in long-term memory, and sentence encoding proceeds in part by forming connections from lexical nodes to phrase-level nodes. For example, consider how a listener encodes the sentence "They saw horses but horses were forbidden there." The single lexical node for the repeated concept ("horses") must quickly connect with two nodes, for the verb phrase "saw horses" and for the proposition "horses were forbidden" (see Fig. 1). Lexical nodes for unrepeated concepts (e.g., "they," "saw," "were," and "forbidden" in Fig. 1) likewise become connected with phrase nodes, except that these connections are one-to-one (see Fig. 1) and can be formed in parallel, whereas connections from repeated concepts are one-to-many and must be formed in sequence, requiring additional time (see MacKay, Abrams, & Miller, 1994; Miller & MacKay, 1994). Given time pressure, as in RD experiments, the first connection from a repeated concept may be formed successfully, but not the second, so that the second concept is unencoded, making its phonology or orthography unrecallable during the top-down retrieval process.

Support for the NST account of RD comes from several sources. As predicted under NST, young adults experience reduced RD relative to older adults, who generally require more time to form new connections, thereby reducing the time available for forming the two connections required to encode a repeated word (MacKay & Abrams, 1994; MacKay & Miller, in press; MacKay, Miller, & Schuster, 1994). Also as predicted, RD decreases linearly as time per word is increased (see MacKay, Miller, & Schuster, 1994), thereby providing the extra time needed to link a repeated word to its phrase nodes (see also MacKay & Miller, in press). Again as predicted, occurrence of RD was demonstrated (MacKay & Miller, 1994) at a purely conceptual level for proficient Spanish-English bilinguals reading mixed-language RSVP sentences such as "They saw horses but caballos were prohibitir to enter there" ("horses" and "caballos" are conceptually identical translation equivalents). RD occurred solely at conceptual levels, and not at orthographic or phonological levels of these sentences, because RD for conceptually identical targets (e.g., "horses" and "caballos") and RD for completely identical targets (e.g., "caballos" and "caballos"; "horses" and "horses") were of equal magnitude in the data (see also MacKay, Abrams, & Miller, 1994).

The present study tested two new NST predictions concerning effects of syntax on visual RD. To test these predictions, we developed a multiword variant of the standard RSVP technique. For standard RSVP, words appear one at a time, with each word centered on the screen, but for our multiword variant, two or three words usually appeared at the same time, with each word group centered on the screen. These word groups either did or did not correspond to phrases in the sentence. For example, the words "they saw horses" form a phrase-congruent group, or natural constituent, of the sentence "They saw horses but horses were forbidden there." However, the words "horses but horses" form a phrase-incongruent group containing parts of several different constituents of this sentence.

Our dependent variable was the degree of RD in immediate recall of identical target words in sentences that differed by a single word: The prior, or pretarget, word was identical to the

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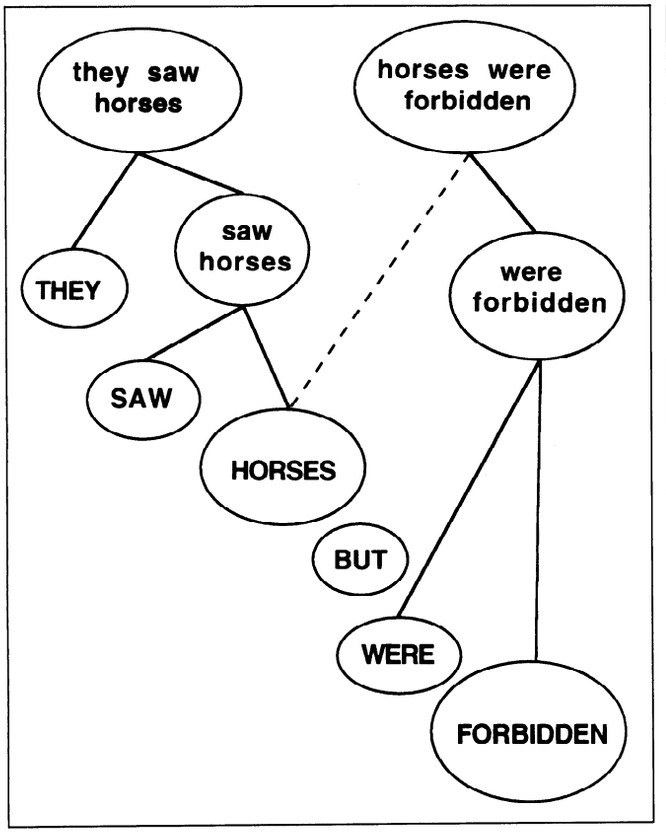

Fig. 1. Selected lexical and phrase nodes for encoding the sentence "They saw horses but horses were forbidden there." Note that a single lexical node represents the repeated word "horses." The broken line indicates a connection that is difficult to form under time pressure (see the text for explanation).

target word for repeated-target sentences but different for unrepeated-target sentences. For example, we compared recall of the target word "horses" in two sentences: "They saw sheep but *horses* were forbidden there" (unrepeated target in italics, pretarget underlined) versus "They saw horses but *horses* were forbidden there" (repeated target in italics). Thus, our independent variables were repeated versus unrepeated targets, and phrase-congruent grouping (each RSVP frame contained a phrase) versus phrase-incongruent grouping (each RSVP frame contained part of one or more phrases).

NST predicts that, with time per word held constant, phrase-incongruent groups will reduce overall recall relative to phrase-congruent groups. The reason is that phrase-congruent groups immediately signal what words to link together into phrases, enabling participants to form these links quickly and effectively, thereby facilitating recall relative to phrase-incongruent groups. For example, when participants encounter the phrase-incongruent group "work so" in an RSVP sentence that begins "It was time to work so," they must wait for the next frame to determine whether "so" and "work" connect directly, as in "to work so hard," or not, as in "It was time to work so we left." The increased processing time required for phrase-incongruent groups will also cause greater RD under NST: By making it harder to determine what words to link together into phrases, phrase-incongruent groups will reduce the time available for forming the two connections needed to retrieve a repeated word, thereby increasing RD relative to phrase-congruent groups.

METHOD

Participants

Participants were 24 undergraduates (6 men, 18 women; mean age of 20) at the University of California, Los Angeles. They participated for partial course credit in an introductory psychology course. All were native speakers of English and reported normal or corrected-to-normal vision.

Materials and Design

Materials were identical to those in MacKay, Miller, and Schuster (1994) and are discussed in greater detail there. Each participant saw 32 sentences, 16 experimental sentences randomly interspersed among 16 fillers. Each of the 16 experimental sentences came in four versions that were counterbalanced across subjects and crossed two levels of repetition with two levels of phrase grouping (see Table 1 for typical examples). Repeated- and unrepeated-target versions of a sentence had similar meaning and syntax, and differed only in their pretarget words. Pretargets and targets were identical in repeated-target versions, and were similar in average length and frequency in unrepeated-target versions. Phrase-congruent and phrase-incongruent versions differed in whether the RSVP frames contained phrases or nonphrases. In the congruent condition, RSVP frames maintained the integrity of units such as noun phrases (e.g., those tall men), verb phrases (e.g., are leaving), infinitive phrases (e.g., to play soccer), and prepositional phrases (e.g., in the afternoon). In the incongruent condition, RSVP frames disrupted the integrity of such phrases and contained unnatural groups such as soccer in the and afternoon but (see Table 1). Identical across the congruent and incongruent versions were the actual words, time per word, number of frames per sentence (M = 4; range: 3–5), and mean number of words per frame (M = 2.5; range: 1–5).

Sentences occurred in eight different random orders across participants. Fillers were presented at fixed rates (either 50 ms/word or 110 ms/word), whereas each experimental sentence was presented at both 70 ms/word and 90 ms/word, with rates counterbalanced across participants and conditions. We chose these rates because pilot data indicated correct target recall in the range from 30% to 80%, ruling out floor or ceiling effects that could distort the relative degree of RD for congruent versus incongruent conditions. Our design was a 2 × 2 × 2 factorial with grouping (congruent vs. incongruent), repetition (unrepeated vs. repeated target), and presentation rate (70 vs. 90 ms/word) as within-subjects factors. Duration of a frame was the simple product N × ms/word, where N was the number of words in the frame (see Table 1).

Procedure

Participants were told that they would see sequences of words in groups of one to five presented at the center of the

Table 1. *Examples of displays for two counterbalanced sentences presented at 70ms/word*

Frame number	Frame duration	Unrepeated-target version	Repeated-target version
		Congruent versions	
1	140 ms	They wanted	They wanted
2	210 ms	to play **ball**	to play **sports**
3	140 ms	but **sports**	but **sports**
4	210 ms	were not allowed	were not allowed
		Incongruent versions	
1	210 ms	They wanted to	They wanted to
2	210 ms	play **ball** but	play **sports** but
3	210 ms	**sports** were not	**sports** were not
4	70 ms	allowed	allowed

Note. Pretargets are in bold; targets are bold and underlined. See the text for details.

screen, and that they were to say the entire sequence aloud immediately following the last group. They were warned that the sequences would be speeded up to varying degrees, and that they were to report each sequence exactly as it had appeared, whether it was grammatical or not. There followed four representative practice sentences presented at four different rates. A Macintosh Plus computer presented the stimuli using a general-purpose program (GenPrime; Banks, Burke, Krajicek, & Whetstone, 1990). Each trial began with a 2-s "Get ready" prompt, followed by a 1.2-s blank screen before the first frame. A string of asterisks (*******) followed the last frame, indicating that participants were to recall the sequence verbally. The experimenter transcribed participants' recall on-line, but also recorded the output via tape recorder. Participants pressed the space bar when ready to begin the next trial.

RESULTS AND DISCUSSION

Each trial was scored for inclusion of the pretarget, target, or both in the participant's response. We then determined a conditional measure of recall (mean percentage of correct target report) that we believe most accurately represents the degree of RD (see arguments in MacKay, Miller, & Schuster, 1994). For this conditional measure, repeated and unrepeated targets counted as correct only if their pretargets were recalled. Data for a trial were discarded if the pretarget was not recalled. Table 2 shows standard deviations for these data, together with RD, calculated as the recall of unrepeated targets minus the recall of repeated targets.

Because presentation rate had no main effect ($p < .21$; see Table 2) and did not interact with either grouping or repetition ($p > .05$) in a 2 × 2 × 2 multivariate analysis of variance

Table 2. *Mean percentage of correct target report (CTR), standard deviations, and repetition deficit (at each rate and collapsed across rates) for congruent, incongruent, and standard (word-by-word) rapid serial visual presentation (RSVP)*

	Congruent-grouping RSVP				Incongruent-grouping RSVP				Standard RSVP[a]			
	70ms/word		90ms/word		70ms/word		90ms/word		70ms/word		90ms/word	
Target condition	CTR	*SD*	CTR	*SD*	CTR	*SD*	CTR	*SD*	CTR	*SD*	CTR	*SD*
Unrepeated	80	32	93	18	63	44	73	37	86	26	86	29
Repeated	83	31	90	21	47	35	57	42	73	28	78	28
Repetition deficit (N = 15)	−3	48	3	22	17	45	17	67	13	31	8	40
Repetition deficit collapsed across rates (N = 23)			6	33			29	42			13	24

Note. Discrepancies between data separated by rate versus collapsed across rates reflect differential data discard in the conditional analysis. For the separate rates, 9 participants had missing data in one or more of the 2 × 2 × 2 cells, leaving only 15 valid cases. For the collapsed rates, only 1 participant had missing data from one or more of the 2 × 2 cells, leaving 23 cases.
[a]Data from MacKay, Miller, and Schuster (1994).

(MANOVA), we collapsed across rate in Figure 2 and in a 2 × 2 MANOVA that revealed main effects of grouping ($F[1, 22] = 48.01$, $MSE = 1.46$, $p < .001$) and repetition ($F[1, 22] = 6.46$, $MSE = 0.68$, $p < .019$), and a Grouping × Repetition interaction ($F[1, 22] = 8.25$, $MSE = 0.30$, $p < .009$). Post hoc tests indicated that this interaction reflected a large and reliable effect of repetition in the incongruent condition ($F[1, 22] = 10.94$, $MSE = 0.94$, $p < .003$), but not in the congruent condition, in which unrepeated targets were recalled no more often than repeated targets ($F[1, 22] = 0.69$, $MSE = 0.04$, $p < .41$). Confidence in this nonsignificant outcome is warranted because of the power in our design (computed using Woodward, Bonett, & Brecht, 1990), which sufficed to detect nontrivial differences (e.g., power was .80 for the Congruency × Repetition interaction; power was .90 for the effect of repetition in the incongruent condition), and to ignore trivial differences (e.g., power at $p < .05$ was .13 for the nonsignificant effect of repetition in the congruent condition).

The main effect of grouping indicates greater overall recall for phrase-congruent groups than for phrase-incongruent groups (see Fig. 2), as predicted under NST. Also as predicted, RD was greater for phrase-incongruent groups than for phrase-congruent groups. This difference cannot be attributed to the reduced recall of phrase-incongruent groups because, in general, RD is unrelated to level of recall, all other factors being equal (see Park & Kanwisher, 1994). Rather, the present results suggest that RD varies in magnitude with the time available for forming the one-to-many links required for retrieving repeated words (see Miller & MacKay, 1994; also see MacKay, Miller, & Schuster, 1994, and MacKay & Miller, in press, for functions relating RD to encoding time). The effect of phrase-congruent grouping on RD is also consistent with the conceptual nature of RD postulated in NST (see MacKay, Abrams, & Miller, 1994; MacKay & Miller, 1994). RD in the present study must reflect semantic or syntactic processes because semantic and syntactic characteristics rather than phonological or orthographic characteristics determine whether a group is phrase-congruent or phrase-incongruent.

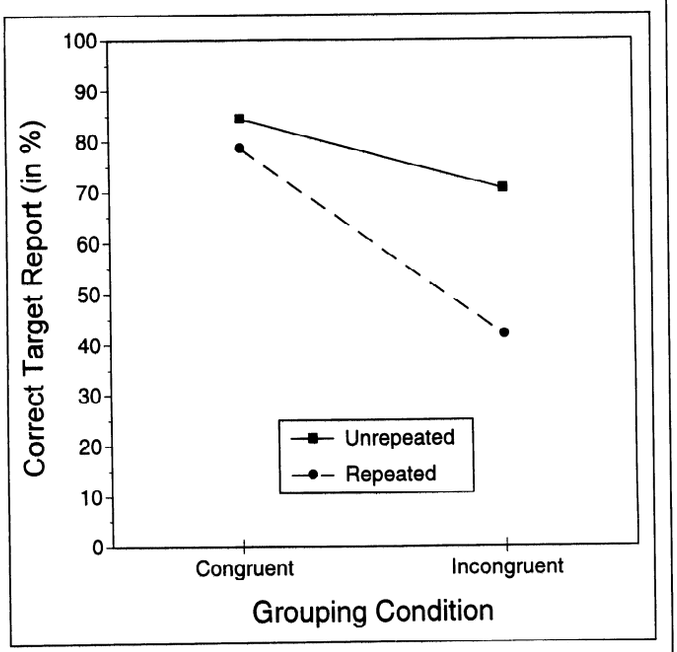

Fig. 2. Percentage of correct target report (conditional data) for repeated versus unrepeated targets in congruent versus incongruent groups (see the text for explanation).

THE NST MODULATION PRINCIPLE, GROUPING PROCEDURES, AND INPUT MODALITY

Under the NST modulation principle, RD will increase as the time available for forming word-to-phrase links decreases, regardless of whether presentation is visual or auditory. One implication of this modulation principle is that procedural details that increase encoding time for phrases will magnify RD. For example, consider the standard RSVP procedure, in which words of differing length receive identical processing times (see, e.g., MacKay, Miller, & Schuster, 1994). Because encoding time may be more than sufficient for short function words, but not for long content words, standard RSVP may disrupt the formation of word-to-phrase links, and augment RD relative to phrase-congruent grouping. As a preliminary test of this possibility, we examined the data for the 16 young participants in a previous study (MacKay, Miller, & Schuster, 1994). These participants saw exactly the same sentences as in the present study, and at exactly the same rates (70 ms/word and 90 ms/word), except via standard word-by-word RSVP. As can be seen in Table 2, RD for standard RSVP ($M = 13\%$) fell between RD for our congruent condition ($M = 6\%$) and our incongruent condition ($M = 29\%$), suggesting that standard RSVP may disrupt the process of forming appropriate links between words and phrases more than phrase-congruent RSVP, but less than phrase-incongruent RSVP.

Auditory versus visual presentation is another important procedural detail under the NST modulation principle. The present study capitalized on the fact that for visual inputs, associations are readily formed between simultaneously presented items (see Penney, 1989), as when phrase-congruent words occupy the same RSVP frame. However, for auditory inputs, associations are more readily formed between successively presented words (see Penney, 1989), so that a different set of surface factors will modulate auditory RD via the same basic principle of modulation. The surface factors are known as prosody, unconsciously processed acoustic variations in timing, stress, pitch, and intonation that signal how words combine into phrases in sentences (see, e.g., Wingfield & Butterfield, 1984). By way of illustration, consider how prosodic timing (i.e., selective word lengthening and brief pauses) helps listeners encode the acoustic sentence "Lashley instructed Teuber to go without hesitating." If the speaker lengthens the word "go" and follows it with a pause, the listener can quickly link "without hesitating" to Lashley's manner of instructing. However, a short "go" followed by no pause indicates that listeners must link "without hesitating" to Teuber's manner of going.

Under the NST modulation principle, the prosody of normally produced sentences will reduce RD in a rapid auditory processing (RAP) task: Prosodic cues enable listeners to determine quickly what words to link together into phrases, thereby

increasing the time available for forming the one-to-many links required to encode and retrieve repeated words. However, RAP word lists and RAP sentences produced with listlike or word-by-word prosody lack such prosodic cues to phrases, which should make word-to-phrase links more difficult to form, and augment auditory RD under the modulation principle. Consistent with these predictions, a previous study (Miller & MacKay, 1994) found significant RD for RAP word lists, but not for normally produced RAP sentences, whereas another study (Miller & MacKay, in press) found significant RD when these same RAP sentences were produced with listlike or word-by-word prosody. In sum, the present results comport with effects of syntax and prosody on auditory RD, and suggest that visual and auditory RD are fundamentally analogous phenomena that obey the same basic principle of modulation.

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