Cross-language Facilitation, Repetition Blindness, and the Relation between Language and Memory: Replications of Altarriba and Soltano (1996) and Support for a New Theory

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MacKay and Miller (1994) presented mixed-language sentences via Rapid Serial Visual Presentation (RSVP) to Spanish-English bilinguals for immediate recall and found that when target words (T) were repeated in the same language within a sentence such as 1 (below; translation: "They saw horses, but horses were forbidden to enter"), T recall decreased compared to unrepeated Ts as in 2, replicating an effect known as repetition blindness (RB). They also demonstrated reduced recall when the T was a translation equivalent of the prior "pretarget" word (PT) as in 3 (T and PT underlined), rather than unrelated as in 4, an effect they called "semantic blindness" (SB).

1. They saw caballos, but caballos were prohibito to enter. (RB repeated T condition)

2. They saw ovejas, but caballos were prohibito to enter. (RB unrepeated T condition)

3. They saw horses, but caballos were prohibito to enter. (SB repeated T condition)

4. They saw sheep, but caballos were prohibito to enter. (SB unrepeated T condition)

However, Altarriba and Soltano (1996) noted that some of the mixed-language sentences in MacKay and Miller (1994) were ungrammatical, and using grammatical sentences and other seemingly minor procedural changes in their Experiment 1b, they found RB for within-language repetition (as in 1 vs. 2), but did not find SB for conceptual or cross-language repetition (as in 3 vs. 4). MacKay, Abrams, Pedroza, and Miller (1996) next conducted detailed analyses of the procedures, analyses, and experimental design in Altarriba and Soltano, and noted seven factors that may have worked to diminish SB in their results, such as long lags between PTs and Ts in the sentences, relatively slow presentation rates, use of a dependent measure that failed to exclude trials where the PT was undetected, and use of split-

language sentences with a single, predictable language switch in each sentence. In an attempt to resolve the conflicting results of these earlier SB studies, the present study tested whether SB would occur using the procedures, analyses, and experimental design of MacKay and Miller but with fully grammatical sentences as in Altarriba and Soltano.

A second goal of the present study was to replicate an interesting difference that Altarriba and Soltano (1996) reported for lists vs. sentences: With a translation equivalent (manejar) as PT, a T such as drive became easier to recall in lists but not in split-language sentences such as "Mike learned to drive and empesó a manejar al trabajo" (translation: "Mike learned to drive and began to drive to work"). To illustrate the list procedure in Altarriba and Soltano (Experiment 2), each contained three words as in 5-8 (PT and T underlined), preceded and followed by masking stimuli (symbol strings) that participants (proficient Spanish-English bilinguals) were instructed to ignore. The dependent variable was recall of the T (e.g., drive in 5-8) as a function of whether its PT was identical (as in 5), semantically identical (i.e., a translation equivalent, as in 7), or unrepeated (as in 6 and 8). The interesting finding was that when drive had a translation equivalent (manejar) as PT, participants exhibited a statistically reliable *facilitation* effect (relative to the unrepeated condition illustrated in 8), but exhibited the usual inhibitory effect (RB) with an identical PT (as in 5).

5. drive-(intervening word)-drive (RB repeated T condition)

6. steer-(intervening word)-drive (RB unrepeated T condition)

7. manejar-(intervening word)-drive (SB repeated T condition)

8. guiar-(intervening word)-drive (SB unrepeated T condition)

The present study tested an account of this list-sentence difference developed in detail in MacKay et al. (1996). This account involves three postulates for which there is already considerable support: (a) that the mechanisms for storing and retrieving verbal materials in lists are inseparable from mechanisms that have evolved for producing, comprehending, and representing sentences (see e.g., MacKay & Abrams, 1996); (b) that proficient bilinguals represent the meaning of translation equivalents via a single lexical node (see e.g., MacKay, 1982); and (c) that RB and SB occur when the same node must be activated and then reactivated in quick succession under RSVP (see e.g., Abrams, Dyer, & MacKay, 1996).

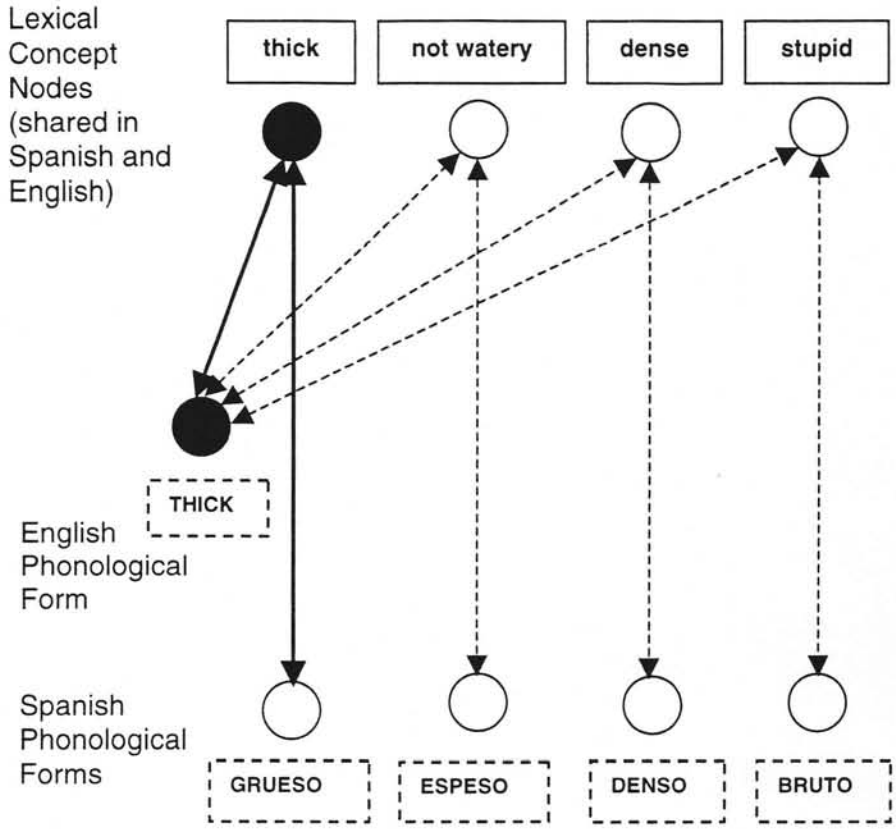

Figure 1. Connections in NST between the phonological form for thick, a sample of its (shared Spanish-English) lexical conceptual nodes, and phonological forms for corresponding Spanish words (grueso, espeso, denso, and bruto). Initial presentation of thick primes the unshaded nodes connected with broken lines (but does not activate them; see MacKay, 1990, for the priming-activation distinction), and activates the nodes connected with solid lines, resulting in self-inhibition (solid shading).

Given these assumptions, the cross-language equivalents had different effects for sentences vs. lists in Altarriba and Soltano (1996) because of a fact noted in MacKay and Bowman (1969): that a word such as thick has many possible meanings and translation equivalents when presented in isolation, but only a single meaning and translation equivalent (grueso)

within a sentence such as, "Mike likes comer queso grueso encima de thick bread." For example, taken in isolation, thick has at least four distinct meanings corresponding to the Spanish translation equivalents grueso, espeso, denso, and bruto, and under the theory, a single lexical node represents each of these meanings for proficient Spanish-English bilinguals. These four shared nodes are illustrated in Figure 1 (in rectangles), together with the phonological representations for thick, grueso, espeso, denso, and bruto (in dashed rectangles). As shown, the phonological representation for thick connects bottom-up with all four lexical nodes, which in turn connect top-down with phonological representations corresponding to grueso, espeso, denso, and bruto. This means that the occurrence of thick as a pretarget in lists such as thick horses thick, and thick caballos grueso would strongly prime the lexical nodes for all four meanings of thick, even though only one becomes activated and perceived, say the one that represents the meaning "not watery" (espeso). However, the phonological representations for grueso, espeso, denso, and bruto will all be primed or readied for activation (see Figure 1), so that when grueso occurs in this list, the phonological and lexical nodes for grueso, being already primed, are easier than normal to activate, giving rise to the facilitation effect observed in Altarriba and Soltano.

Experiment 1 directly tested an implication of this account of cross-language facilitation within lists. The implication is that only *lexically ambiguous* PTs with many Spanish-English equivalents should facilitate recall of cross-language Ts in lists (e.g., 7). The facilitation effect that Altarriba and Soltano observed should not be obtained for PTs with only a single meaning and only a single Spanish-English equivalent in split-language lists.

Experiment 1: Effects of Within- vs. Between-Language Repetition in Lists

Experiment 1 assessed the degree of RB and SB (if any) in RSVP lists using improved procedures noted in MacKay et al. (1996), but was otherwise similar to Altarriba and Soltano (1996, Experiment 2) except that half of the PTs were ambiguous and allowed many translation equivalents and half were unambiguous and allowed only one translation equivalent. We expected no facilitation effect for cross-language Ts with unambiguous PTs but we expected to replicate the facilitation effect of Altarriba and Soltano for Ts with ambiguous PTs (e.g., 7).

Participants

Participants were 48 college students (28 females, 20 males, mean age =19.7, mean years of education =14.1) who participated for course credit or payment. All were Spanish-English bilinguals who had approximately equal proficiency in Spanish and English as assessed via a background questionnaire and conversations in English and Spanish with a bilingual experimenter. The participants provided Likert-scale ratings in the background questionnaire that suggested only slightly more daily use of English than Spanish: On a 5-point scale (1 = mostly English, 3 = equal use of Spanish and English, and 5 = mostly Spanish), their mean rating was 2.44. Answers to a question on how often they switch languages mid-sentence in everyday conversation also suggested flexible proficiency in both languages: 77% of the participants indicated that they often or sometimes switch languages, while only 21% indicated that they rarely or never do so. Three other questions also suggested extensive proficiency in both languages. For one question, 35% of the participants reported speaking Spanish more often in everyday life, 25% reported speaking English more often, and 17% claimed to speak Spanish and English equally often. For another question, 85% of the participants indicated Spanish as their native language with English acquired during early childhood (mean age = 5 years old), and 15% indicated English as their native language. Finally, mean ratings on five-point scales assessing relative competence in English vs. Spanish (where 1=English much better, 2=English somewhat better, 3=Equal, 4=Spanish somewhat better, and 5=Spanish much better) were 1.91 for knowledge of grammar, 2.00 for vocabulary knowledge, 2.22 for spoken fluency, and 2.62 for spoken comprehension, indicating somewhat greater competence for grammar, vocabulary, and spoken fluency in English but almost equal competence for spoken comprehension in English and Spanish.

Materials

Materials were 40 filler and 72 experimental lists. Experimental lists are illustrated in Appendix A and contained three words in the order PT, intervening word, and T. Ts and PTs were either identical within a language (e.g. ants-ants: the within-language repeated T condition), semantically identical across languages (i.e., non-cognate translation equivalents such as hormigas-ants: the cross-language repeated T condition), or unrelated within or between languages (e.g., tie-ants: the unrepeated T condition). As in these examples, Ts were identical across these three basic conditions but

counterbalanced across subjects. For unrepeated conditions, Ts and PTs were equal in mean number of letters, and across all conditions, Ts and PTs were either English or Spanish translation equivalents selected from Dubois-Charlier, Pritchard, Senerth, and Sola (1987) by a proficient bilingual (native Spanish-speaker). Language of PT and T was crossed to yield two within-language combinations (English PT-English T, Spanish PT-Spanish T) and two between-language combinations (English PT-Spanish T, and Spanish PT-English T). The eight conditions that resulted were counterbalanced across participants so that every PT-T pair appeared in every condition. For between-language trials (English PT-Spanish T and Spanish PT-English T), the word intervening between PT and T was English for half the lists and Spanish for the remaining half. For unrepeated conditions, PT and T were always semantically and phonologically unrelated, and all three words were the same language in within-language lists. Finally, we manipulated ambiguity of the English words, yielding 16 conditions overall. Ambiguous words had four or more meanings listed in *Webster's College Dictionary* (1995), and three or more Spanish translation-equivalents in Dubois-Charlier et al. (1987). Unambiguous words had one distinct meaning in *Webster's* and one primary Spanish translation-equivalent in Dubois-Charlier et al. (see Appendix A). Because word forms increase in frequency with ambiguity (i.e., how many meanings dictionaries list for the word form; Zipf, 1949), word frequency was higher for ambiguous than unambiguous words in the present materials (M= 177 vs. 59 per million in Francis & Kucera, 1982, SD= 116).

Filler lists served to make word repetition, language, and number of words per list less predictable: Fillers were either two or four words long and contained words that were unrepeated and unrelated (semantically and phonologically), and were either in English (N= 10), Spanish (N= 10), or an unpredictable mix of English and Spanish (N= 20).

Procedure

Participants completed an informed consent form, a demographic questionnaire, a digit span test, and the language background questionnaire. Following general instructions regarding RSVP procedures and mixed-language sentences, participants received 8 practice trials with instructions to read and immediately recall each word in its presented position in the list. They were cautioned not to translate but to recall each word in the language presented. Responses were scored on-line by the experimenter and verified later from a tape recording of the session. Each trial began with a 2000 millisecond (ms) warning signal: "Get ready for the next list." Next

came seven 90 ms frames: a row of percent signs, a row of asterisks, the PT, the intervening word, the T, a row of dollar signs, and a row of percent signs. A string of question marks signaled the end of the list and called for recall, remaining on the screen until the participant pressed any key to trigger the next trial.

Results

As instructed, participants almost never recalled a list item in the wrong language, and overall, 64% of words were correctly recalled (SD = 13%), precluding floor and ceiling effects. Two lists were discarded due to stimulus flaws discovered *post hoc* (one list contained homophones, and one contained a non-word), giving 70 experimental trials per subject in our analyses. Trials were scored for correct inclusion of T in recall under three scoring criteria (lenient, strict, and Altarriba & Soltano, described shortly), and Figures 2a and 2b show mean correct T recall by condition using lenient scoring criteria.

Lenient scoring first removed trials containing incorrect or missing PTs and then required correct recall of both PT and T in the correct order, but otherwise ignored recall of the intervening word and did not penalize intrusions. For example, PT and T in the list "sky (PT) red dog (T)" were scored as correct given recall of "sky dog," "sky raw dog," "sky girl red dog," or "boy sky red dog." If PT and T were both recalled but in the wrong order relative to the intervening word, only the word in correct list position was scored as correct, for example, dog (T) in "raw sky dog" and sky (PT) in "sky dog red" and neither PT nor T was scored as correct in "dog red sky," or "red dog sky."

A 2 (repetition: repeated, unrepeated) x 2 (ambiguity: ambiguous, unambiguous) x 2 (combination: within-language, between-language) x 2 (target language: English, Spanish) repeated measures ANOVA yielded no main effect of ambiguity, but a main effect of repetition, $F(1,42)= 73.47$, $MSe = 0.09$, $p< .001$, with better recall of unrepeated than repeated Ts, a main effect of combination, $F(1,42)= 56.49$, $MSe = 0.13$, $p< .001$, with better recall of between- than within-language Ts, and a main effect of target language, $F(1,42)= 22.11$, $MSe = 0.06$, $p< .001$, with better recall of English than Spanish Ts. These effects were moderated by an interaction of repetition and combination, $F(1,42)= 142.25$, $MSe = 0.08$, $p< .001$, with RB for within-language repetition, $t(47)= -13.40$, $p<.001$, but facilitation for between-language repetition, $t(47)= 3.34$, $p<.01$, and a repetition by combination by ambiguity interaction, $F(1,42)= 4.34$, $MSe = 0.07$, $p<.05$.

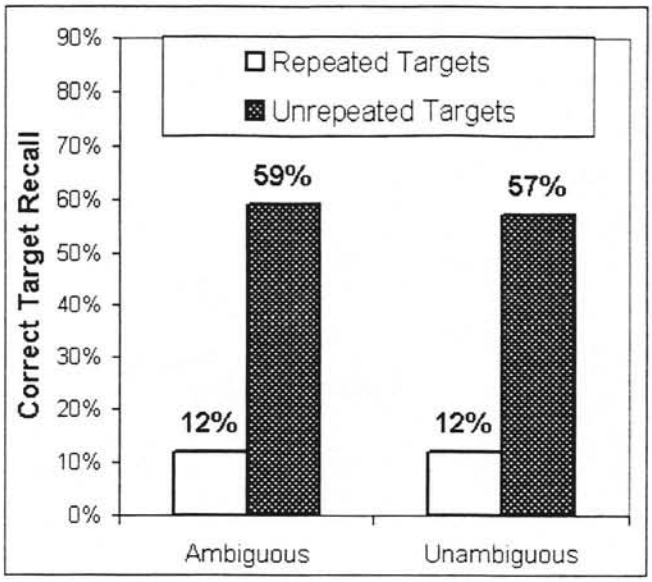

Figure 2a. Mean correct recall by condition (under lenient scoring) for within-language lists in Experiment 1.

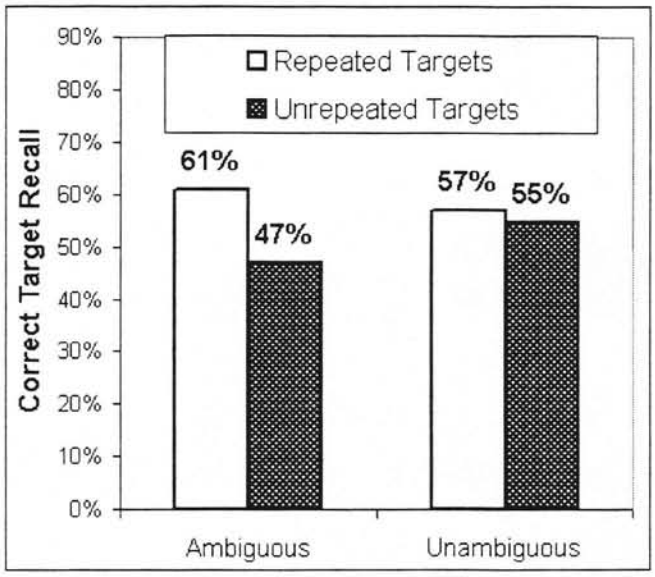

Figure 2b. Mean correct recall by condition (under lenient scoring) for between-language lists in Experiment 1.

For ambiguous targets, there was an interaction of repetition and combination, $F(1,47)= 110.46$, $MSe = 0.04$, $p<.001$ due to occurrence of RB for within-language repetition, $t(47)= -12.11$, $p<.001$, and facilitation for between-language repetition, $t(47)= 3.83$, $p<.001$. For unambiguous targets, there was a repetition by combination interaction, $F(1,47)= 64.13$, $MSe = 0.04$, $p<.001$, due to RB for within- language repetition, $t(47)= -11.54$, $p<.001$, but no effect for between-language repetition, $t(47)= 0.43$, $p=.67$. Within-language RB was equivalent for ambiguous and unambiguous words (37% vs. 35%; see Figure 2a), while between-language facilitation was 14% for ambiguous words versus only 2% for unambiguous words (see Figure 2b).

Strict scoring of correct T recall required that PT, the intervening word, and T all be recalled in correct order. Strict scoring yielded essentially the same pattern of results as lenient scoring. For example, a 2 (repetition: repeated, unrepeated) x 2 (ambiguity: ambiguous, unambiguous) x 2 (combination: within-language, between-language) x 2 (target language: English, Spanish) repeated-measures ANOVA yielded no main effect of ambiguity but a main effect of repetition, $F(1,29)= 44.85$, $MSe = 0.11$, $p< .001$, with better recall of unrepeated than repeated Ts, a main effect of combination, $F(1,29)= 18.91$, $MSe = 0.16$, $p< .001$, with better recall of between- than within-language Ts, and a main effect of target language, $F(1,29)= 10.05$, $MSe = 0.06$, $p< .01$, with better recall of English than Spanish Ts. However, these effects were moderated by an interaction of repetition and combination, $F(1,29)= 61.47$, $MSe = 0.11$, $p< .001$, with RB for within-language repetition but facilitation for between-language repetition.

Altarriba and Soltano scoring analyzed T recall without first removing trials containing incorrect PTs following Altarriba and Soltano (1996). This analysis yielded the same pattern of results as lenient scoring.

Subsidiary Results

Using lenient scoring to test for possible effects of Spanish vs. English Ts, recall of cross-language Ts was comparable for English and Spanish Ts overall (54% vs. 52%), as well as for unrepeated Ts in English vs. Spanish (51% vs. 47%) and repeated Ts in English vs. Spanish (58% vs. 57%), yielding a comparable facilitation effect for cross-language lists with English vs. Spanish targets (7% vs. 10%), $t(47)= -0.52$, $p>.60$. However, for within-language Ts, the level of target recall was much higher for English than Spanish Ts (44% vs. 26%), whereas recall was roughly proportional

for unrepeated Ts in English vs. Spanish (70% vs. 42%) and for repeated Ts in English vs. Spanish (18% vs. 10%), yielding a larger RB effect for English than Spanish lists (52% vs. 32%), $t(47)= 4.76$, $p<.001$. We currently lack a plausible explanation for this difference.

We also tested for possible effects of word frequency using lenient scoring, categorizing our English Ts as low frequency (LF) vs. high frequency (HF) via median split at 40.5 per million in Francis and Kucera (1982; LF= 40 or fewer per million, HF= over 40 per million). A 2 (repetition: repeated, unrepeated) x 2 (combination: within-language, between-language) x 2 (frequency: LF, HF) repeated-measures ANOVA on trials with English T yielded main effects of repetition, $F(1,42)= 44.56$, $MSe = 0.10$, $p<.001$, of combination, $F(1,42)= 12.94$, $MSe = 0.12$, $p<.01$, and repetition by combination interactions for both HF targets, $F(1,46)= 79.09$, $MSe = 0.07$, $p<.001$ and LF targets, $F(1,43)= 56.92$, $MSe = 0.05$, $p<.001$, but no main effect of frequency and no interactions involving frequency at $p<.05$, despite the fact that frequency covaried with ambiguity.

Discussion

Using procedures advocated in MacKay et al. (1996), present results replicated the basic findings of Altarriba and Soltano (1996, Experiment 2): the usual inhibitory effect (RB) for within-language repetition, but a reliable *facilitation* effect for between-language repetition. This between-language facilitation effect poses problems for token individuation theory in both its original and newer forms. The original token individuation theory (e.g., Kanwisher, 1987; Kanwisher & Potter, 1990) viewed token individuation to be purely visual or restricted to the processing of visual forms rather than orthographic, phonological, or semantic concepts, and cannot explain why translation equivalents become *especially* individuated whereas exact repetitions fail to become individuated. Newer token individuation theories (e.g., Bavelier, 1994) likewise cannot explain the semantic facilitation effect because they predict that orthographic, phonologic, or lexical repetition will lead to inhibition, but not facilitation under RB conditions.

However, the interactions of repetition and combination with ambiguity in Experiment 1 refined the Altarriba and Soltano (1996) cross-language facilitation effect: Between-language facilitation occurred for ambiguous targets with many translation equivalents, but not for unambiguous targets with only a single translation equivalent. These interactions were predicted and support the new theory of RB outlined in MacKay et al. (1996). The connections and processes for explaining cross-

language facilitation in lists in this theory has already been discussed in the introduction, and the same connections and processes explain RB in rapidly presented word lists such as thick shift thick: Initial presentation of thick in such lists primes and activates the phonological nodes for thick, which strongly primes the lexical nodes for all four meanings of thick, and activates the most primed one, say the one corresponding to the meaning grueso in Figure 1. As a result, phonological nodes for thick and the lexical node for the grueso meaning may be undergoing the self-inhibitory process that follows activation (represented via solid circles in Figure 1) at the time when the third word in the list appears. Since the third word in this example is thick, RB is a likely outcome because the self-inhibited phonological nodes for thick will be harder to activate than when the initial word is phonologically, orthographically, and semantically unrelated to thick.

Experiment 2: Effects of Within- versus Between-Language Repetition in Sentences

Experiment 2 had the same participants as Experiment 1 and always immediately followed Experiment 1 but the stimuli were grammatical mixed-language sentences. We expected to replicate the reliable SB effect observed in MacKay and Miller (1994).

Materials

Materials were 24 filler sentences and 24 mixed-language experimental sentences (shown in Appendix B). Experimental sentences were 9.4 words long on average (range 6-13 words) with 1.7 words on average intervening between PT and T. PTs and Ts were similar to those in Experiment 1 except that ambiguity was unmanipulated, PTs and Ts never occupied first or last position in a sentence, English PT-Spanish T was the only between-language combination, and with the T omitted, 88% of the sentences became ungrammatical. Language switched within the sentences 1.95 times on average (SD=0.37; range 1-3), and at unpredictable points across sentences. To further reduce predictability of word repetition and the occurrence and locus of language switches, filler sentences contained no repeated words and many were entirely in English (N=7) or entirely in Spanish (N=7).

Procedure

Experimental and scoring procedures resembled Experiment 1 with four exceptions: there were 12 experimental conditions (because there was no Spanish PT-English T condition); presentation rate was 70 ms/word for half the sentences and 90 ms/word for the other half, with rates for particular sentences counterbalanced across participants; there were only 6 practice trials; and "Get ready for the next sentence" was the prompt that immediately preceded each sentence.

Results

Analyses discarded two experimental sentences due to flawed computer assignment to conditions (yielding 22 experimental trials per subject), and ignored the rare instances where participants recalled words in the wrong language (mean probability per participant was .019 per word). Overall, 51% of the words in a sentence were correctly recalled (SD = 12%), precluding floor and ceiling effects.

Lenient scoring required correct recall of PT and T in the correct order, but otherwise ignored recall or misrecall of any other word in the sentences. To illustrate, for the sentence "I live at one(PT) three six(T) Elm Street," PT and T were scored as correct given recall as "I have one and six elms," or "I live at one four three six South Elm Street." Figure 3 shows mean correct T recall by condition (collapsed across rate) under lenient scoring. A 2 (repetition: repeated, unrepeated) by 2 (combination: within, between) by 2 (rate: 70 ms, 90 ms) repeated-measures ANOVA revealed a main effect of repetition, $F(1,25)= 7.94$, $MSe = 0.16$, $p< .01$, with better recall of unrepeated than repeated Ts, and a main effect of combination, $F(1,25)= 38.48$, $MSe = 0.19$, $p< .001$, with better recall of between- than within-language Ts. These effects were moderated by a marginally significant interaction of repetition and combination, $F(1,25)= 3.71$, $MSe = 0.12$, $p< .07$. However, rate neither yielded a main effect nor interacted with any other variable, which allowed us to collapse across rate, thereby reducing empty cells and increasing our power to detect differences. The resulting 2 x 2 ANOVA revealed the same main effects as the prior ANOVA, together with a highly reliable interaction of repetition and combination, $F(1,45)= 15.43$, $MSe = 0.05$, $p< .001$, such that within-language repetition yielded RB, $t(46)= -5.60$, $p<.001$, whereas between-language repetition yielded neither SB nor facilitation, $t(45)= 0.11$, $p>.91$. For within-language repetition, the level of recall was higher for English than Spanish Ts (24%

vs. 18%), but recall was roughly proportional for unrepeated Ts in English vs. Spanish (36% vs. 28%) and for repeated Ts in English vs. Spanish (11% vs. 8%), yielding a slightly larger RB effect for English than Spanish sentences (25% vs. 20%).

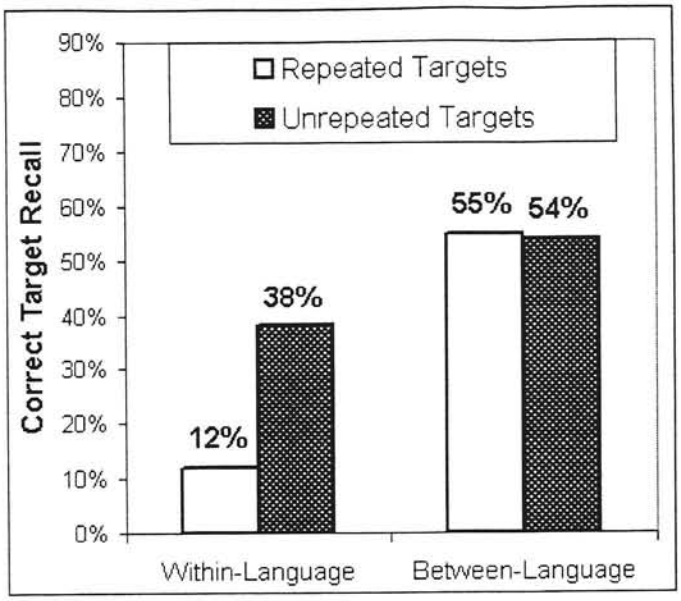

Figure 3. Mean correct recall by condition (under lenient scoring) for sentences in Experiment 2.

Strict scoring counted the PT as unrecalled (thus removing the trial from analysis) if one but not both T and PT were recalled and it was unclear which within the context of adjacent words. Strict scoring therefore biased against finding significant effects, but this more conservative procedure yielded the same pattern of results as lenient scoring except that the main effect of repetition was non-significant when collapsed across rate in a 2 (repetition: repeated, unrepeated) x 2 (combination: within-language, between-language) ANOVA, $F(1,39)= 0.83$, $MSe = 0.12$, $p> .37$. However, recall was again better for between- than within-language Ts, with a marginal repetition by combination interaction, $F(1,39)= 3.21$, $MSe = 0.07$, $p= .08$, due to occurrence of reliable RB for within-language repetition, $t(39)= -2.11$, $p<.05$, but neither SB nor facilitation for between-language repetition, $t(45)= 0.11$, $p>.91$.

Discussion

Like Altarriba and Soltano (1996), we observed reliable RB for within-language repetition but neither facilitation nor interference (SB) for cross-language repetition. Contrary to expectation, Experiment 2 failed to replicate the reliable SB effect observed in MacKay and Miller (1994). Present results therefore comport with the suggestion of Altarriba and Soltano that inclusion of ungrammatical sentences in MacKay and Miller may have increased the degree of SB, and this interpretation seems plausible in view of how semantic-syntactic congruence affected RB in Abrams et al. (1996; see also Miller & MacKay, 1996, and MacKay & Miller, 1996, for analogous effects). Abrams et al. presented English sentences via a modified RSVP procedure where each screen contained a single complete phrase or syntactic constituent, as in [They wanted][to play sports][but sports][were not allowed] (the phrase-congruent condition), or each screen contained parts of several phrases, as in [They wanted to][play sports but][sports were not][allowed] (the phrase-incongruent condition). Their results indicated exaggerated or greater-than-normal RB with phrase-incongruent screens and no RB with phrase-congruent screens. This Abrams et al. technique may therefore help resolve the issue of whether SB in sentences constitutes a real phenomenon or represents an artifactual and irreplicable result: If proficient bilinguals in a study currently ongoing in the MacKay-lab exhibit reliable SB in recalling mixed-language sentences presented in phrase-incongruent RSVP screens using the Abrams et al. technique, this would support the conclusion that SB is a real phenomenon that occurs under a restricted but theoretically interesting range of conditions (like RB; see Abrams et al., Miller & MacKay; and MacKay & Miller). However, if SB does not occur under these conditions, we will conclude that SB does not occur in grammatical sentences.

General Discussion

Having replicated the basic Altarriba and Soltano (1996) results and having noted how results in Experiment 1 support a new theory of RB and challenge current theories, we now address the relevance of our results to theories of the relation between language and memory. On the surface, differences between recall of lists versus sentences in Experiments 1 vs. 2 seem ready-made for the currently popular multi-store approach to relations between language and memory. Under this approach, list-sentence differences reflect a built-in dichotomy between systems for language

versus memory. For example, in the multi-store theory of Gathercole and Baddeley (1993, pp. 8-32), the phonological loop is a memory subsystem that is separate and distinct from the system for processing words in sentences (the central executive) and specializes in processing and storing word lists for short time-periods in phonological form (see e.g., Shiffrin & Nosofsky, 1994, and Zhang & Simon, 1985, for other multi-store theories that have postulated phonological, articulatory, or acoustic representations for short-term memory but not semantic representations).

However, contrary to multi-store theories, effects of ambiguity in word lists (Experiment 1) and cross-language facilitation (Experiment 2) indicate that very short-term memory includes semantic representations in addition to phonological, articulatory, or acoustic representations. Present results therefore add to the problems that multi-store theories currently face. One general class of problems concerns cases where sentence variables influence list processing in ways that would not be expected if fundamentally distinct and separate memory systems process sentences versus lists (for reviews, see Caplan & Waters, 1990; and Saffran, 1990). For example, consider another syntactic/semantic factor that improves immediate recall within rapidly presented lists. MacKay and Abrams (1994) compared immediate recall of identical words in two types of RSVP lists: One type contained familiar two-word phrases located at unpredictable positions in the lists (e.g., 9, below); The other type contained many of the same words in identical positions, but no phrases (e.g., 10, below). The results showed that the identical words were better recalled as parts of phrases than as unrelated words. For example, night was better recalled as part of the phrase night gown in 9 than as an unrelated word in 10, but the unrelated word mind was recalled equally poorly in both lists. Because phrases are fundamentally syntactic/semantic entities, these findings indicate that syntactic/semantic factors influence short term memory within rapidly presented lists. The problem for multi-store theories is to explain the role of such syntactic/semantic factors in a supposedly separate store that has traditionally been viewed as purely phonological in nature.

9. phrase good faith mind night gown film (phrases underlined)

10. phrase people faith mind night hose film (unrelated word list)

Another general class of problems that multi-store theories currently face is that some variables have parallel effects in immediate recall of both sentences and lists. The present study illustrates this problem for exact repetition with a language: If a distinct and separate memory system processes and stores lists, multi-store theories must explain why exact

repetition causes RB in both lists and sentences (see Miller & MacKay, 1996, for other examples within this general class of multi-store problems). By contrast, parallel effects across sentences and lists are unproblematic within distributed memory theories of the sort illustrated in the introduction and elsewhere, e.g., MacKay (1987); MacKay and Burke (1990); MacKay, Miller and Schuster (1994). Under distributed memory theories, there are no distinct and separate memory stores for lists vs. sentences, and short term memory is not an isolable system that is separate from cognition in general, as in the multi-store approach. Instead, immediate memory represents "an umbrella term for a heterogeneous array (of) capacities for temporary storage... distributed over diverse cognitive subsystems" (Monsell, 1984; p. 328). That is, a single set of memory capacities is involved in acquiring, comprehending, and producing words, whether in lists or in sentences, and these memory capacities are related to the formation and strengthening of connections between nodes distributed throughout the cognitive system (see e.g., MacKay, 1990). Of course, further development of distributed memory theories will be required to specify in detail the exact structure and processing characteristics of connections for representing lists versus sentences in general. However, the effects of ambiguity in Experiment 1 suggest that words in rapidly presented lists and sentences share at least one of the same basic processing characteristics (semantics), consistent with distributed memory theories.

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Appendix A: English (and Spanish Translation Equivalents) in the Three-word Lists in Experiment 1 (see text for explanation).

Unambiguous Targets (and Repeated Pretargets)	Unrelated Pretargets	Intervening Words
ants (hormigas)	easy (fácil)	tie (corbata)
aphid (pulgón)	bride (novia)	debt (deuda)
arrow (flecha)	brain (cerebro)	tomato (tomate)
bee (abeja)	beg (pedir)	son (hijo)
blond (rubio)	level (nivel)	narrow (angosto)
broom (escoba)	towel (toalla)	father (padre)
deaf (sordo)	belt (cinto)	panther (pantera)
elm (olmo)	widow (viuda)	blue (azul)
eye (ojo)	law (ley)	bed (cama)
fist (puño)	hair (pelo)	harp (arpa)
flea (pulga)	soap (jabón)	brother (hermano)
happy (alegre)	music (música)	mouth (boca)
hill (colina)	hand (mano)	bull (toro)
lake (lago)	rock (piedra)	delete (tachar)
lettuce (lechuga)	chapter (capítulo)	school (escuela)
lung (pulmón)	crib (cuna)	fork (tenedor)
mouse (ratón)	magic (magia)	steak (bistec)
myth (mito)	nape (nuca)	film (tela)
nanny (niñera)	snack (bocado)	ticket (boleto)
oar (remo)	wig (peluca)	plane (avión)
onion (cebolla)	tooth (diente)	silver (plata)
quarrel (discusión)	accused (acusado)	average (promedio)
rain (lluvia)	wall (pared)	arm (brazo)
red (rojo)	lid (tapa)	cold (frío)
rice (arroz)	moist (húmedo)	north (norte)
shark (tiburón)	realm (reino)	stick (palo)
shrimp (camarón)	pillow (almohada)	basement (sotano)
sky (cielo)	art (arte)	life (vida)
spinach (espinaca)	lobster (langosta)	water (agua)
log (leño)	cup (taza)	bird (pájaro)
thief (ladrón)	dwarf (enano)	finger (dedo)
thigh (muslo)	wind (viento)	cake (pastel)
thinker (pensador)	bottles (botellas)	neighbor (vecino)
woman (mujer)	spark (chispa)	ear (oreja)
wood (madera)	song (canción)	great (gran)
yolk (yema)	wine (vino)	half (mitad)

Appendix A (continued)

Ambiguous Targets (and Repeated Pretargets)	Unrelated Pretargets	Intervening Words
bank (orilla)	wait (espera)	youth (joven)
box (caja)	day (día)	cow (vaca)
brush (cepillo)	stain (mancha)	shade (sombra)
clear (claro)	hawk (halcón)	green (verde)
couple (pareja)	window (ventana)	office (oficina)
dark (oscuro)	best (mejor)	mail (correo)
dirt (tierra)	cord (cordón)	short (corto)
dock (muelle)	gray (gris)	nap (siesta)
face (cara)	boat (barco)	clock (reloj)
fast (rápido)	home (hogar)	white (blanco)
fire (fuego)	soft (suave)	bad (malo)
fly (mosca)	ball (pelota)	tomb (tumba)
free (libre)	focus (enfocado)	turtle (tortuga)
full (lleno)	baby (bebé)	sauce (salsa)
girl (chica)	bomb (bomba)	fall (otoño)
groom (novio)	moose (alce)	fresh (fresco)
hammer (martillo)	mirror (espejo)	sugar (azúcar)
high (alto)	train (tren)	soul (alma)
joke (chiste)	harm (daño)	beer (cerveza)
key (llave)	dye (tinte)	dog (perro)
leaf (hoja)	fake (falso)	honey (miel)
leak (gotera)	name (nombre)	farm (granja)
nail (clavo)	clue (pista)	game (juego)
party (fiesta)	bell (campana)	soup (caldo)
picture (pintura)	contest (concurso)	tired (cansado)
pink (rosa)	wolf (lobo)	sour (agrio)
play (obra)	town (pueblo)	age (edad)
record (apuntar)	socket (enchufe)	pasture (pastura)
shell (concha)	death (muerte)	milk (leche)
sign (gesto)	luck (suerte)	chicken (pollo)
store (tienda)	dream (sueño)	cucumber (pepino)
tape (cinta)	lime (lima)	pen (pluma)
thick (grueso)	shift (cambio)	neck (cuello)
thing (objeto)	leash (correa)	meat (carne)

Appendix B: Experimental sentences for the English-English, Spanish-Spanish, and English-Spanish conditions of Experiment 2. Targets and pretargets are underlined and unrelated pretargets appear in parentheses. (See text for explanation).

1. Cuando Joe screams (fights) he screams like un loco
   When José grita (pelea) él grita como un maniac
   When Joe screams (fights) él grita como un maniac

2. Cuando we sell grapes (juice) the grapes are en temporada
   When we vendemos uvas (jugo) las uvas están in season
   When we sell grapes (juice) las uvas están in season

3. Tiraron this dough (bread) because the dough did not se levantó
   They tiraron este masa (pan) porque la masa no se rise
   They threw out this dough (bread) porque la masa no se rise

4. Se fue de the church (chapel) when the church was pintada
   He left la iglesia (capilla) cuando la iglesia fue painted
   He left the church (chapel) cuando la iglesia fue painted

5. Nosostros asked for drinks (liquor) although drinks were cara
   We pedimos bebidas (licór) aunque las bebidas eran expensive
   We asked for drinks (liquor) aunque las bebidas eran expensive

6. Quería wear purple (that skirt) because purple matched with sus zapatos
   She wanted to vestirse de morado (falda) porque el morado coordinaba con her shoes
   She wanted to wear purple (that skirt) porque el morado coordinada con her shoes

7. Quiero abrir the door (house) but the door is cerrada con llave
   I want to open la puerta (casa) pero la puerta está locked
   I want to open the door (house) pero la puerta está locked

8. Those teachers (students) will be teachers of history el próximo año
   Esos maestros (alumnos) serán maestros de historia next year
   Those teachers (students) serán maestros de historia next year

9. Her nephew (cousin) and my nephew look like gemelos
   Su sobrino (primo) y mi sobrino parecen ser twins
   Her nephew (cousin) y mi sobrino parecen ser twins

10. Ese hombre washes the wheels (cars) when the wheels are sucias
    That man lava las llantas (los carros) cuando las llantas están dirty
    That man washes the wheels (cars) cuando las llantas están dirty

11. The letters (papers) were letters from la segunda guerra mudial
    Las cartas (Los papeles) eran cartas de la second world war
    The letters (papers) eran cartas de la second world war