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Bilingual Dual-Coding Theory and Semantic Repetition Effects on Recall

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A bilingual version of dual-coding theory was tested with French–English bilinguals who free recalled lists of concrete and abstract words repeated at different interitem lags. Repetitions involved the same words, translation equivalents, or same-language synonyms. The results extended previous findings and generally supported predictions from dual-coding theory and the independence storage hypothesis of bilingual memory: (a) Relative to single words, semantic repetitions (translations and synonyms) had additive effects on type recall even at short lags, whereas identical repetitions were less than additive at zero lag; (b) recall of identical repetitions increased more with lag than recall of semantic repetitions, so that differences between these conditions were diminished and sometimes reversed; (c) semantic repetition effects were weaker for synonyms than for translations, especially for abstract words; and (d) intrusion errors and pair recall were higher for translations than for synonyms, especially for concrete words at long lags.

Our purpose was to investigate memory implications of a bilingual version of dual-coding theory and to resolve some empirical questions from previous studies that have used a semantic repetition paradigm in which free-recall lists contain translation equivalents (e.g., church, église; proof, preuve) or same-language synonyms (e.g., church, chapel; proof, evidence), as well as identically repeated and once-presented words. For brevity, we shall refer to the two forms of semantic repetition as bilingual and synonym repetitions. We first review the theory and then the most relevant of the semantic repetition studies.

According to dual-coding theory (Paivio, 1986, chap. 4), words are encoded by a verbal representational system (V) and objects by a nonverbal system, also referred to as the imagery system (Im) because image generation is among its more salient functions. The assumptions of dual-coding theory relevant to the present study are (a) verbal representations are joined to one another by multiple V-V associative connections and to imaginal representations by V-Im referential connections; (b) experience determines the number and strengths of the interconnections, with concreteness being particularly relevant to the development of referential connections, and verbal context to the development of associative connections; (c) activation of associative and referential connections depends upon situational factors so that connected representations are functionally independent and can be activated separately or together; and (d) episodic memory is determined by the aggregate of these various externally and internally generated traces.

Paivio and Desrochers (1980; Paivio, 1986, chap. 11) proposed a theory of bilingualism based on these general assumptions along with specific hypotheses necessary to accommodate different languages within the verbal system. The bilingual model includes two sets of verbal representations (V_1 and V_2) corresponding to the bilingual's two languages, as well as the separate imagery system. The different verbal subsystems and the imagery system are interconnected, but activation of referential and associative connections is probabilistic. Several features of this elaborated model are particularly relevant to the semantic repetition paradigm. The prominent role of verbal representations in dual-coding theory implies potential differences between identical and semantic repetitions. Identical repetitions involve redundant traces based on the same words, whereas semantic repetitions produce distinct verbal traces that might have additive or summative effects on recall. Episodic memory is not based solely on these directly stimulated verbal traces, however, and other features of bilingual dual-coding theory suggest differences between bilingual and synonym repetitions, and between concrete and abstract semantic repetitions.

Associative connections between and within languages enable bilinguals to translate words from one language to another, to generate synonyms within a language, and to produce common associates to different words. Such indirect activation would facilitate memory for semantic equivalents, but the activation might not occur because functional independence implies that even words with identical meanings can be activated either separately or jointly. One factor that governs the probability that words will indirectly activate one another is the diversity or uncertainty of the associative connections. The bilingual version of dual-coding theory incorporates the plausible assumption that within-language V-V connections are more uncertain and less constrained than

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between-language V_1-V_2 connections. Between-language connections involve primarily translation-equivalent terms that are experienced frequently together. Within-language connections, on the other hand, are rich and diverse because they result from varied verbal contexts and experiences. Consistent with this hypothesis, the number of different free or same-meaning associations is greater within languages than between languages (Harbluk, Paivio, & Clark, 1987). Semantic repetition effects should also be stronger for translations than for synonyms.

Verbal and imaginal representations can also activate one another via the established referential connections that underlie naming objects and generating images to words. The bilingual dual-coding model includes referential connections between Im and both V_1 and V_2 systems, so that, under appropriate circumstances, translation equivalents and synonyms (Paivio, 1986, pp. 128–130) may converge on common imaginal representations. Shared images, however, are assumed to be more available for concrete words than for abstract words. Therefore, connections between concrete semantic equivalents, whether translations or synonyms, should be stronger than connections between abstract equivalents. Consistent with this hypothesis, free associations to translations (Kolers, 1963) and synonyms (Clark, 1978) are more similar for concrete words than abstract. The same mechanisms predict that semantic repetition effects in free recall will be stronger for concrete than abstract equivalents.

The present research evaluated three interrelated implications of bilingual dual-coding theory for the semantic repetition paradigm (a) to the extent that episodic memory is based on distinct externally activated verbal memory traces, semantic repetitions should have additive effects on recall even under conditions (specified later) in which repeating the same word usually does not have an additive effect; (b) to the extent that episodic memory benefits from associative connections between semantic equivalents, translations with their constrained associative relations should show more pronounced semantic repetition effects than synonyms based on less certain within-language associations; and (c) to the extent that episodic memory benefits directly or indirectly from referential connections between semantic equivalents, semantic repetition effects should be stronger for concrete words than for abstract words.

The evidence most relevant to these hypotheses comes from studies that have examined the effects of bilingual or synonym repetitions and other studies that have used memory tasks to test dual-coding predictions concerning semantic intrusion errors. The semantic repetition effects become particularly meaningful when viewed in relation to the effects of identical word repetitions. The most important typical finding is that repeated words are remembered progressively better as interitem spacing or lag increases. The form of this lag function is such that massed (zero-lag) repetitions produce a recall increment that is less than additive relative to recall of unrepeated items, whereas recall increases to additive or greater than additive levels at long lags (e.g., Glanzer, 1969; Madigan, 1969; Paivio, 1975; Waugh, 1963).

These effects of identical repetitions are quite consistent and dual-coding theory (Paivio, 1974) is compatible with several of the competing explanations for spacing effects (e.g., encoding variability and attenuated processing). Despite these promising foundations, comparisons between identical and semantic repetitions are complicated by several factors: (a) None of the explanations for spacing effects are sufficient to account for all of the available evidence (e.g., Hintzman, 1974; Hintzman, Summers, Eki, & Moore, 1975; Rundus, 1971) and (b) semantic repetitions implicate verbal associative relations, free recall of which often decreases with increased spacing although the specific effects vary with different measures (e.g., Batchelder & Riefer, 1980; Glanzer, 1969). Nevertheless, the results for identical repetitions still provide a general benchmark for interpreting similarities and differences that emerge from semantic repetition studies.

Semantic Repetition Studies

Several studies have demonstrated that, at long interitem lags, subjects free recall approximately the same number of *types* (i.e., at least one member of a semantically related pair) for bilingual repetitions as for identical repetitions (Glanzer & Duarte, 1971; Kolers, 1966; Kolers & Gonzales, 1980). As is generally expected with distributed spacing, both identical and bilingual repetitions have summative effects that are additive or even superadditive relative to once-presented items. Different results occur at short interitem lags, however. Glanzer and Duarte (1971) studied lags of 0, 1, 2, or 5 intervening items and found that type recall was significantly higher for bilingual repetitions than for identical repetitions at short lags but not at long lags. Recall of bilingual repetitions approached additivity (statistical independence) even at zero lag, whereas identical repetitions showed the typical effects: less than additive recall for massed presentations and additive or greater than additive recall at long lags.

Paivio and Lambert (1981) obtained additional evidence for the independence hypothesis at short lags. French–English bilinguals in one experiment wrote down English words for a mixed list including pictures, French nouns, and English nouns. In a second experiment, subjects imaged, translated, or copied English words. Both groups were unexpectedly asked to recall the English words they had either written or seen. The encoding tasks are analogous to massed repetitions in that the subject generates an identical word or a semantically equivalent word to a presented item. Thus, the generated item is essentially a subjective, zero-lag repetition of the presented item. In both studies, recall of translated words was approximately twice that of copied words, suggesting that the two linguistic codes were at least additive and, therefore, mnemonically independent.

Explanations for the relative effectiveness of bilingual repetitions at zero lag include (a) additive independent verbal traces for bilingual repetitions and less than additive redundant traces for identical repetitions, (b) reduced processing of identical repetitions at short lags versus unattenuated processing of bilingual repetitions, and (c) mnemonic benefits for massed bilingual repetitions from associative processes that weaken with increasing lag. Irrespective of the mechanism, the zero-lag data primarily reveal the functional independence of the translation equivalents in a better way than compari-

sons between identical and bilingual repetitions at long interitem lags. That is, the mnemonic superiority of bilingual repetitions over identical repetitions depends in some way on the distinct verbal representations available for the former, but not the latter.

The reduced lag effect for semantic repetitions is particularly compelling given evidence that lag effects for recall of individual words are not attenuated by a variety of other stimulus and coding variations (e.g., Glenberg & Smith, 1981; Maskarinec & Thompson, 1976; Paivio, 1974; Shaughnessy, 1976), although related paradigms with sentences have sometimes weakened or erased the effects of spacing (e.g., D'Agostino & DeRemer, 1973; Dellarosa & Bourne, 1985). From a dual-coding perspective, what stimulus changes are necessary to effect additivity at short lags is an empirical question because both verbal and imaginal systems are assumed to contain specific sensorimotor codes derived from the different modalities of verbal and nonverbal experiences (Paivio, 1986, pp. 56–58). These heterogeneous codes include distinct and apparently additive linguistic representations within the verbal system.

With respect to synonyms, Kolers and Gonzales (1980) replicated and extended the Kolers (1966) study by comparing randomly spaced synonym repetitions with bilingual repetitions. Bilingual repetitions again produced a level of recall equivalent to or greater than identical repetition, but synonym repetitions produced a significantly lower level of type recall than did identical repetitions. Although Kolers and Gonzales did not test for independence, their Figures 1 and 2 suggest that synonym repetitions were less than additive, whereas bilingual repetitions were more than additive and identical repetitions were approximately additive. The bilingual dual-coding model would account for these results in terms of associative processes that contribute to memory over and above externally stimulated verbal traces. The greater associative uncertainty between synonyms than between translations makes trace contact and mutual facilitation relatively more likely in the bilingual case. Kolers and Gonzales proposed a similar interpretation in terms of stronger "bonds" between languages than within languages.

The effects of lag on semantic repetition have been studied less extensively for synonyms than for translations. Stern and Hintzman (1979) investigated the effect of varied spacing of semantic repetitions on recognition memory using synonyms presented in sentence contexts. They did not report main effects, but the data show that recognition was higher for synonym repetitions than for identical repetitions, especially at short lags. In contrast with lag effects for bilingual repetitions, however, recognition scores were higher for synonyms at short lags than at long lags. Stern and Hintzman (1979) attributed this reverse spacing effect (reduced recognition at long lags) to incomplete semantic overlap of synonyms. As was noted earlier, reverse lag effects have also been found for recall of associatively related words.

Consistent with the dual-coding hypothesis that concrete synonyms are more equivalent than abstract synonyms, Clark (1984) found with token scoring (i.e., word recall) that synonym repetitions were recalled as well as identical repetitions for concrete words, but that identical repetitions surpassed synonym repetitions when the words were abstract. Moreover, the conditional probability of recalling a word given its synonym was recalled decreased with lag for abstract synonym repetitions, but not concrete. Negative lag effects suggest that synonymity may be based primarily on verbal associations for abstract words.

Because it was not controlled in other studies, concreteness may explain some of the findings that we have already discussed. The synonyms used by Stern and Hintzman, for example, were adjectives and adverbs, which are generally lower in imagery value than nouns (e.g., Paivio, 1971, p. 80). Therefore, synonym abstractness could account for the negative lag effect they observed. The bilingual items used by Kolers and Gonzales may also have been more concrete than their synonyms, which, according to the dual-coding model, would lead to the reported differences between bilingual and synonym repetitions relative to identical repetitions. Analogous studies which show that forgotten items produce savings (i.e., transfer) for translations (MacLeod, 1976), but not for synonyms (Nelson, Fehling, & Moore-Glascock, 1979) also implicate concreteness because MacLeod used all concrete nouns, whereas Nelson et al. used other parts of speech or mixed concrete and abstract nouns.

Most semantic repetition studies have emphasized type scores, but pair recall and intrusion error measures should be more sensitive to the degree of connectedness between words within pairs. The dual-coding model predicts that pair recall and semantic intrusions would be higher for bilingual than for synonym repetitions. Kolers and Gonzales (1980) report type-to-token ratios, which reflect pair recall, and intrusions consistent with these predictions. The model also predicts higher pair recall and intrusions for concrete than for abstract semantic repetitions. Clark's (1984) conditional recall data are consistent with the prediction about pair recall. The prediction for intrusions has also been tested with bilingual subjects by presenting concrete and abstract translation equivalents; in one case, the error patterns were as predicted (Saegert & Young, 1975) but in another case they were not (Winograd, Cohen, & Barresi, 1976). Monolingual studies have generally found more synonym errors with concrete than with abstract verbal material (Anderson & Hidde, 1971; Begg & Paivio, 1969; Bower, 1972; Kuiper & Paivio, 1977), although negative results have also been reported (Brewer, 1975).

Specific Features of the Present Studies

Our experiments used the list construction and recall procedures of Glanzer and Duarte (1971), with several modifications: (a) We used French–English bilingual subjects and corresponding word lists rather than Spanish–English ones; (b) we used equal numbers of concrete and abstract nouns under all conditions, a feature not considered by Glanzer and Duarte; and (c) we conducted a second experiment in which within-language synonym repetitions occurred in the same list positions as bilingual repetitions in the first experiment.

On the basis of dual-coding theory and previous experimental results, we should observe (a) elevated type recall at statistically additive levels for semantic repetitions (both bi-

lingual and synonym) contrasting with less than additive recall for identical repetitions at short lags, and converging in each case on additive or superadditive levels at long lags; (b) stronger repetition effects in the case of bilingual than synonym repetitions; (c) a general recall superiority of concrete over abstract items, which is augmented in the case of semantic repetitions; (d) an interaction of concreteness and lag on pair recall scores for semantic repetitions, taking the form of a negative lag effect (decreased recall as lag increases) in the abstract but not the concrete case; and (e) proportionally more translation than synonym intrusion errors and more errors of both types to concrete than abstract words.

Method

The bilingual and synonym studies were conducted successively by using list construction and experimental procedures modeled on those of Glanzer and Duarte (1971), except for modifications required by the addition of concreteness and synonym repetitions, and some variation in the instructions. Subjects were presented 24 lists of 24 words. Each list contained 8 once-presented words, 8 semantic repetition words (bilingual or synonym), and 8 identical repetition words. Half of the items of each type were concrete and half were abstract.

Bilingual Repetition Study

Materials. We prepared 384 English–French translation equivalent pairs, determined through bilingual dictionaries and the judgments of two bilingual assistants. In *spoken* form, the words were familiar, distinctly different from their translations, and unambiguous in language and meaning both within and between languages. Half of the pairs were judged by the experimenters to be concrete and half abstract. It was more difficult to obtain distinct-sounding abstract pairs than concrete. The Eaton (1940) frequency categories were translated into a numerical code (1 = first 500, 2 = second 500, etc.) with a maximum score of 12. The means on this scale were 4.73 and 5.06 for the concrete and abstract French words, and 3.00 and 5.08 for the concrete and abstract English words. Although it is large, the latter difference does not provide an adequate explanation for the effects to be reported (see General Discussion). Examples of concrete and abstract translation equivalents are *dog–chien* and *need–besoin.* Translation pairs were divided into 24 sets each with 8 concrete and 8 abstract pairs that were unrelated to other pairs in the set. By assigning these sets to lists, the list construction procedures described below reduced extraneous associations among items within lists.

Lists. Each of the 24 lists contained 24 words representing 16 different pairs: 8 single presentations of one word from each of 8 pairs, 8 identical repetitions of 4 twice-presented words from each of 4 pairs, and 8 bilingual repetitions made up of 8 words from 4 pairs. Across the lists, there were 192 once-presented words (from 192 pairs), 192 bilingual repetition words (from 96 pairs), and 192 identical repetition words (from 96 pairs). The 192 once-presented items formed four sets of 48 items each from factorial combinations of concreteness (concrete or abstract) and language (English or French). Two items from each of the four sets occurred in every list and in every serial position across the 24 lists. Within each list, half of the once-presented words occurred in serial positions 1 to 12, and half in positions 13 to 24.

The 96 identical repetitions consisted of 6 pairs in each of 16 cells defined by factorial combinations of concreteness, language, and lag (0, 1, 2, or 5 intervening items). Identical repetitions were assigned to serial positions so that items for each of the 16 cells occurred at every serial position across pairs of yoked subjects. For each subject, identical repetitions occurred twice at every serial position, with half of the repetitions of each type in positions 1 to 12 and half in positions 13 to 24. The same counterbalancing was done for the 96 bilingual repetition pairs, which consisted of 6 pairs in each of 16 cells defined by concreteness, order (English–French or French–English) and lag. For each list, orthogonal levels of concreteness, lag, and the four repetition types (English–English, French–French, English–French, and French–English) were used to select the 8 repeated items. Thus, repeated items in each list consisted of 4 concrete and 4 abstract items with one of each from each lag and type of repetition possibility.

We constructed 32 variations of the 24 lists so that each of the 192 concrete pairs and the 192 abstract pairs occurred 16 times as once-presented items and in all of the 16 possible repetition conditions defined by 4 levels of lag and 4 types of repetition. Serial positions of concrete and abstract items were reversed for half of the variations and the order of the 24 lists was randomized separately for each variation. Lists were recorded by one of two fluently bilingual males at a rate of 2 s per item, recordings were verified, and lists with errors were recorded a second time. Two practice lists with materials and conditions representative of the main list structure were prepared in a similar manner.

A programming error resulted in 18 subjects receiving lists that lacked either concrete English or abstract English unrepeated items. We collected data on an additional 6 subjects with corrected lists selected so as to balance items across lag and type of repetition but not necessarily language or order of repetition. The data of faulty subjects were retained because the language variable was not of primary interest for unrepeated items, the perceptible effect on the lists was small, and the 20 subjects with correct lists demonstrated no main effects or interactions with language of unrepeated items.

Subjects. Paid bilingual subjects (10 male and 28 female) were recruited through advertisements and notices at McGill University. All subjects were "balanced" bilinguals, that is, they possessed comparable skills in the two languages. The criteria for balance were (a) self-ratings of competencies in French and English, (b) personal interviews with native speakers who judged each subject's verbal fluency in the two languages, and (c) speed of processing in the two languages as measured by a bilingual Stroop test (see Vaid & Lambert, 1979).

Procedure. The language questionnaire and other tests of bilingual proficiency were administered first and followed by recorded instructions for the memory task, in English for half the subjects and in French for the other half. The instructions described the free-recall task, mentioned that some of the items would be repeated and some would be related, and directed the subjects to remember the exact English and French words presented but to guess when they were uncertain about a word. Unlike Glanzer and Duarte (1971), our lists were presented auditorily and we did not require subjects to pronounce each word as it was presented. A tone preceded the first item by 2 s and followed the last item to cue subjects to begin written recall. Three minutes were allotted for recall, versus 90 s in the Glanzer and Duarte experiment. Subjects studied and recalled the two practice lists before the experimental lists.

Synonym Repetition Study

The general design was identical to the bilingual repetition study except that semantic repetitions within lists were synonyms rather than translations and half of the lists were presented in English and half in French.

Materials. We prepared 384 quartets composed of two English synonyms and two French synonyms that were also translations of the English synonyms (see later). Starting with the items from the bilingual study, we selected synonyms from various published norms and from French and English dictionaries and thesauruses. Additional

quartets replaced those for which familiar synonyms were not available. Half of the quartets consisted of words that were concrete and relatively high in imagery value and half were relatively abstract and low in imagery according to the experimenters' judgments. The mean Eaton (1940) frequency scores were 5.67 and 5.27 for the more frequent members of the concrete and abstract quartets, and 9.48 and 9.25 for the less frequent members. Concrete and abstract words were equated on Eaton frequency in this study, but both included less frequently occurring words than were used in the translation study (see General Discussion). Examples of concrete and abstract quartets are *dwelling, shelter, logis, abri*; and *reasoning, logic, raisonnement, logigue*. Again, within-list associations other than synonymity were reduced by putting obviously related items in different lists.

Lists and procedure. The structure of the synonym repetition lists was identical to the bilingual lists. However, the semantic repetitions were based on the two members of each synonym pair within each language rather than on translations. Words within same-language pairs were designated as low or high frequency on the basis of their relative Eaton frequencies. Once-presented items consisted of 24 items from each of 8 cells defined by orthogonal levels of concreteness, language, and word frequency. The 96 identical repetitions included three repeated items at each orthogonal combination of concreteness, language, word frequency, and lag. The 96 synonym repetitions included three synonym pairs at each combination of concreteness, language, word order (low–high or high–low), and lag. With the exception of language, these variables were all counterbalanced within and across lists in a manner identical to that described for the bilingual repetition study. Language was introduced as an orthogonal factor by selecting for each subject half of the lists to be presented in French and half in English.

Quartets were divided into sets of unrelated words and assigned to conditions as in the bilingual repetition experiment. However, given that language was varied over lists, twice the number of subjects would have been required in order to present each word in every condition. We chose instead to assign each quartet to every condition and let language be determined randomly, subject to the other constraints of the design. Tapes were recorded and administered in the same manner as in the bilingual study with similar instructions.

Subjects. Subjects (11 male and 21 female) were recruited and selected as in the bilingual repetition study. One female subject participated in both studies.

Results and Discussion

Type scores are most commonly used in semantic repetition experiments and are appropriate for testing the independence hypothesis, which concerns the degree of additivity demonstrated by semantic repetitions relative to identical repetitions and once-presented items. These scores reflect the proportion of pairs from which at least one of the semantically related words was recalled. Thus, recall of either one or both of *chair* and *chaise* counts as one type response. We also examined pair recall and semantic intrusion errors to test hypotheses concerning the degree of connectedness between semantic equivalents. Pair recall scores count the number of semantic repetition pairs from which both members were recalled, whether adjacent or not in the recall protocols, and intrusion scores count the number of once-presented or identically repeated words for which semantic equivalents were erroneously recalled.

We analyzed the bilingual and synonym studies separately because they had been performed at different times with different subjects and items, but we also performed combined analyses to evaluate the similarity of our results to earlier research, especially Glanzer and Duarte (1971), and to confirm interactions between semantic type and other variables. Supplementary tests for simple effects and trends made use of the error terms from the corresponding main effects in the overall analysis and treated the distances between the successive lags (0, 1, 2, or 5 items) as equal, in essence a transformation that made the effect of lag linear.

Global Comparisons Across Studies

We first compare our results with Glanzer and Duarte (1971), ignoring concreteness because it was not considered in their study. The main prediction was that semantic repetitions would have additive effects on recall at all lags and, therefore, would surpass identical repetitions at short but not long lags. Figure 1 shows the proportion of types recalled at different lags for semantic and identical repetitions from Glanzer and Duarte (1971, p. 628, Figure 1) and our two experiments. The patterns of recall are generally comparable. In all three studies, recall was higher for semantic (bilingual and synonym) repetitions than for identical repetitions, especially at short lags, and recall converged on a common higher level of recall at long lags.

The overall pattern of results is as predicted and a combined analysis of our two data sets demonstrated that more types were recalled for semantic repetitions than for identical repetitions, $F(1, 68) = 43.02$, $p < .001$, $MS_e = .026$, and at longer lags than at shorter lags, $F(3, 204) = 35.0$, $p < .001$, $MS_e = .020$. The interaction between type of repetition and lag in our studies parallels that of Glanzer and Duarte (1971) in that the difference between semantic and identical repetitions is greater at short lags than at long lags. This predicted interaction was significant, $F(3, 204) = 7.06$, $p < .001$, $MS_e = .017$.

The combined analysis also produced a marginally significant interaction of semantic type, repetition type, and lag, $F(3, 111) = 2.47$, $p = .06$, $MS_e = .017$. A separate analysis of the bilingual study showed that the interaction between lag and type of repetition was not significant, $F(3, 111) = 1.29$, $p = .28$, $MS_e = .018$. Nevertheless, pair-wise comparisons justified by the predictions showed that bilingual repetitions were significantly superior to identical repetitions at all lags, $Fs(1, 37) \geq 9.34$, $p < .01$, except the longest, $F(1, 37) = 2.11$, $p > .10$. In the case of synonym repetitions, the predicted lag by type of repetition interaction was clearly significant, $F(3, 93) = 8.74$, $p < .001$, $MS_e = .016$. Simple comparisons showed that recall was significantly higher for synonym than identical repetitions only at zero lag, $F(1, 31) = 33.1$, $p < .001$. For all other comparisons, $Fs(1, 31) \leq 2.52$, $p > .10$. Thus, the effects of synonym repetitions were generally similar to those of bilingual repetitions and the pattern of results generally replicates and extends to synonyms the findings of Glanzer and Duarte, although the interaction between repetition type and lag was slightly weaker in our bilingual study.

Concreteness and Additivity

In spite of the similarities between bilingual and synonym repetitions, somewhat different patterns emerge when con-

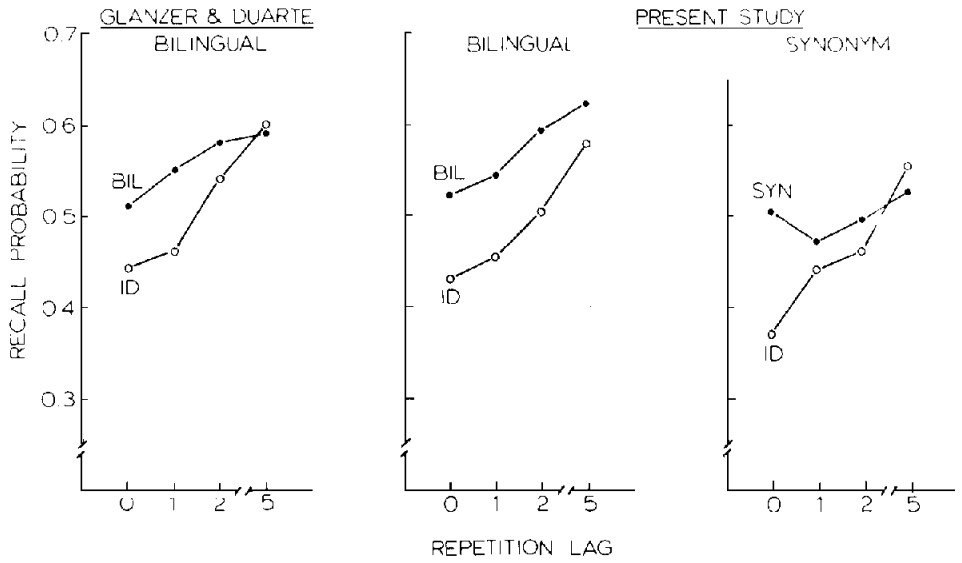

Figure 1. Recall probabilities for identical (ID), bilingual (BIL), and synonym (SYN) repetition type scores as a function of lag in Glanzer and Duarte (1971) and the present study.

creteness is included as a variable, as demonstrated in the overall analysis of variance by a significant interaction among concreteness, semantic type, and repetition type, $F(1, 68) = 4.41$, $p < .05$, $MS_e = .013$. The analyses that follow, including direct tests of the independence of repeated events, are the main focus of our theoretical concerns.

Concreteness and bilingual repetitions. Figure 2A shows recall proportions at different lags separately for concrete and abstract words in the bilingual experiment. As expected, recall was generally higher for concrete words than for abstract words, $F(1, 37) = 22.3$, $p < .001$, $MS_e = .036$. The overall pattern of results just described was essentially the same for the two classes of words in that concreteness did not interact with any of the other variables. Separately analyzed, concrete and abstract items both showed the lag by type of repetition interaction trend that appeared in the overall analysis, so that,

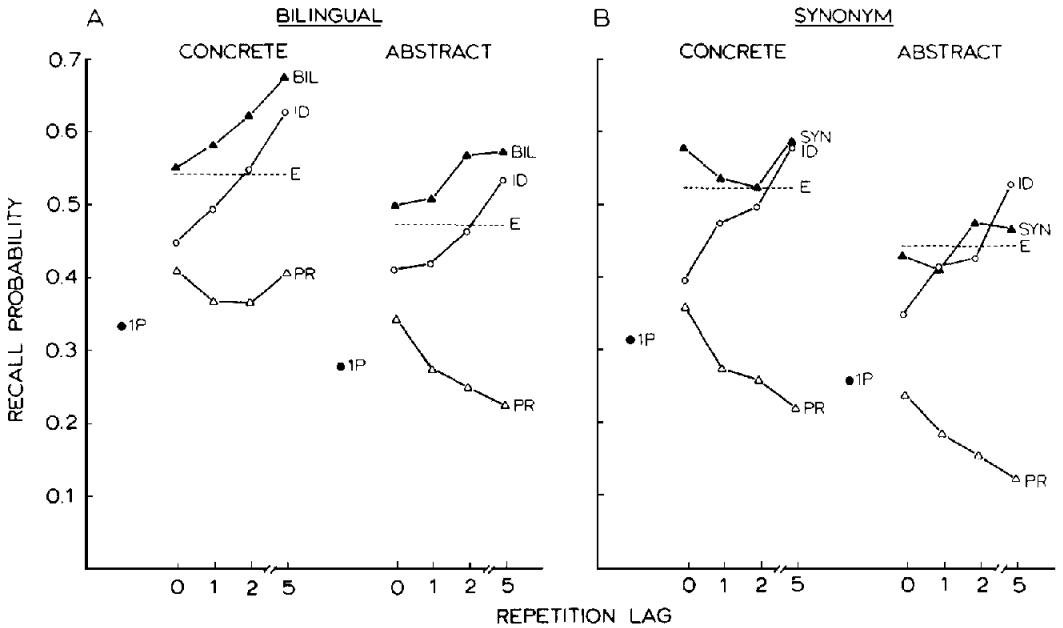

Figure 2. Recall probabilities for concrete and abstract words as a function of lag in the bilingual (A) and synonym (B) repetition experiments. (Probabilities are for bilingual [BIL], synonym [SYN], and identical [ID] repetition type scores as well as for pair recall [PR], once-presented words [1P], and levels expected [E] from the independence hypothesis.)

with one exception, bilingual recall significantly exceeded identical word recall at all but the longest lag for both word classes, Fs(1, 37) $\geq$ 4.44, $p < .05$; $MS_e = .033$ for all tests. The one exception was for concrete repetitions at Lag 2, $F(1, 37) = 3.03$, $p < .10$. At the longest lag, recall of bilingual repetitions, whether concrete or abstract, was not significantly higher than recall of identical repetitions, Fs(1, 37) < 1.34.

Figure 2A also shows the obtained recall proportions for once-presented concrete and abstract items, as well as the proportions predicted for independent repeated words. Expected levels of recall were calculated separately for each subject using the standard formula for the union of two independent events, $p_i + p_j - p_i p_j$, where the proportion of once-presented words recalled (averaged over French and English words) gave a single estimate used for p_i and p_j. The results confirmed the predictions from the bilingual dual-coding hypothesis of independent verbal traces. For identical repetitions, obtained recall at zero lag was below the predicted levels for independent repeated events (i.e., less than additive) for both concrete and abstract words, $t(37) = -3.94$ and -2.57. For bilingual repetitions, however, recall was additive at zero lag in that the obtained and expected proportions did not differ significantly for either word class, $t(37) = .36$ and 1.05. Recall increased to a level exceeding additivity (a) at the longest lag for both concrete and abstract identical repetitions, $t(37) = 4.22$ and 2.37, and (b) at Lags 2 and 5 for both concrete and abstract bilingual repetitions, $t \geq 3.38$, $p < .01$. Superadditivity presumably represents the contribution of factors other than directly activated verbal traces (e.g., contextual changes and extra processing made possible by associative or referential retrieval of earlier items).

Concreteness and synonym repetitions. The type recall results for the synonym study, shown in Figure 2B, were in many respects similar to the results for bilingual repetitions, including the recall superiority of concrete over abstract words, $F(1, 31) = 34.9$, $p < .001$, $MS_e = .026$. However, for synonyms, concreteness interacted with repetition type, $F(1, 31) = 10.5$, $p < .01$ $MS_e = .009$, an effect not observed for bilingual repetitions. Analysis of simple effects showed that the superior recall of synonym over identical repetitions was significant in the case of concrete words, $F(1, 31) = 18.6$, $p < .001$, but not abstract words, $F(1, 31) = .92$; $MS_e = .017$.

The interaction between concreteness and repetition type for synonyms is specifically relevant to the dual-coding emphasis on nonverbal referential processes and also provides a qualification of the Kolers and Gonzales (1980) finding of lower recall for synonym than for identical repetitions. Because their random spacing resulted in long average lags, the most direct comparison is with our Lag 5 data. Figure 2B shows the Kolers and Gonzales effect at Lag 5 only with abstract items. Analysis of simple effects at that point indicates that recall was marginally worse for abstract synonyms than identical repetitions, $F(1, 31) = 3.75$, $p < .10$, whereas no such trend emerged in the case of concrete repetitions, $F(1, 31) = .06$. At zero lag, by contrast, synonyms were recalled better than identical repetitions in the case of both concrete words, $F(1, 31) = 31.8$, $p < .001$, and abstract words, $F(1, 31) = 6.23$, $p < .025$. These findings suggest that the Kolers and Gonzales synonym effects are likely to occur only at long lags and especially when the words are relatively abstract.

With respect to independence, differences between observed and predicted values were generally similar to those in the bilingual study, but more so for concrete words. Identical word repetitions were again less than additive at zero lag for both concrete and abstract words, $t(31) = -5.16$ and -4.14 both ps $< .001$, and increased to a level above additivity at the longest lag, $t(31) = 2.17$, $p < .05$, and 3.14, $p < .01$. As in the bilingual case, synonym repetitions were at least additive even at zero lag for both concrete and abstract words, $t(31) = 2.21$, $p < .05$, and $t(31) = -0.52$, $p > .05$, and the obtained recall scores for concrete synonyms once more became superadditive at Lag 5, $t(31) = 2.81$, $p < .01$. However, the pattern departed from the bilingual one in that, for abstract synonyms, obtained levels of recall were not significantly higher than predicted at any lag, including Lag 5, $t(31) = 1.02$, $p < .05$.

Pair Recall and Semantic Intrusions

We hypothesized that concrete semantic equivalents would be more likely than abstract equivalents to activate each other because of the common imaginal representations available for concrete words. In addition, bilingual dual-coding theory suggests that translations are more closely connected than synonyms because of the greater uncertainty of within-language associative linkages. Several indications of these effects were apparent even in the type score results, but the differences should be particularly clear in measures of pair recall and semantic intrusion errors, which appear more sensitive than type scores to connections between semantic equivalents. The general predictions were that pair recall and semantic intrusions would be greater for concrete semantic equivalents than for abstract equivalents and for bilingual repetitions than for synonym repetitions, especially at long lags.

Pair recall. Pair recall scores for the semantic repetition conditions are presented in Figure 2 as a function of semantic type, concreteness, and lag. As was predicted, recall was higher for concrete than abstract pairs, $F(1, 68) = 67.4$, $p < .001$, and higher in the bilingual than in the synonym study, $F(1, 68) = 16.17$, $p < .001$, $MS_e = .095$. Figure 2 also suggests that the flatter function predicted for concrete pair recall occurred only for bilingual repetitions. This impression was confirmed by a significant three-way interaction among concreteness, semantic type, and the linear component of the lag effect, $F(1, 204) = 4.82$, $p < .05$, $MS_e = .015$, as well as by the following separate analyses of the bilingual and synonym data.

The bilingual results (Figure 2A), were completely as expected in that (a) more concrete than abstract pairs were recalled, $F(1, 37) = 29.8$, $p < .001$, $MS_e = .070$; (b) recall decreased with lag, $F(3, 111) = 4.94$, $p < .01$; and (c) concreteness interacted with lag, $F(3, 111) = 2.73$, $p < .05$, $MS_e = .030$. The simple linear (negative) effect of lag was significant for abstract pairs, $F(1, 111) = 8.01$, $p < .01$, but not for concrete pairs, $F(1, 111) = .08$, which showed no significant effects as a function of lag.

The results for the synonym study (Figure 2B), differed in that synonym pair recall unexpectedly decreased over lag in the case of both concrete and abstract pairs. The analysis of variance yielded only main effects of concreteness, $F(1, 31) = 46.3$, $p < .001$, $MS_e = .015$, and lag, $F(3, 93) = 15.9$, $p <$

.001, $MS_e = .011$, with no hint of an interaction between the two variables, $F(3, 93) = .20$. The simple linear (negative) effect of lag was significant for both concrete and abstract items, $F(1, 93) = 25.9$ and 19.7, $p < .001$ in both cases.

Semantic intrusions. The results for incorrect recall of the translation or synonym equivalent of a presented word conformed to expectations in that more semantic intrusions occurred in the bilingual study than in the synonym study, especially for concrete words at long lags. Intrusion error percentages for identical repetitions are shown in Table 1 as a function of experiment and lag. A combined analysis of intrusions for identical repetitions, which should be interpreted with caution because of the low means (and hence little variability) in some synonym conditions, confirmed that semantic errors occurred more frequently with concrete than with abstract words, $F(1, 68) = 8.87$, $p < .01$, $MS_e = .0057$, and with translations than with synonyms, $F(1, 68) = 20.7$, $p < .001$, $MS_e = .012$.

A separate analysis performed on translation intrusions for identical repetitions in the bilingual study confirmed several predictions from bilingual dual-coding theory. In particular, the proportion of such errors was higher for concrete than for abstract words, $F(1, 37) = 6.96$, $p < .02$, $MS_e = .0096$, and increased linearly with lag, $F(1,111) = 4.75$, $p < .05$, $MS_e = .0058$. These effects were qualified by a marginal interaction between concreteness and the linear component of the lag variable, $F(1, 111) = 3.00$, $p < .10$, $MS_e = .0083$. Translation errors increased linearly with lag only for concrete words, $F(1, 111) = 9.06$, $p < .01$, and not abstract words, $F(1, 111) = .01$, and were significantly greater for concrete words only at Lag 5, $F(1, 37) = 6.45$, $p < .025$. Few translation errors occurred for once-presented words, but as expected, intrusions were more likely for concrete words (1.44%) than for abstract words (.87%).

Erroneous recall of semantic equivalents was rare in the synonym study and was not analyzed further. The small differences among the cell means appear orderly in the sense that intrusions were more frequent for concrete than for abstract words (.31% and .16% for concrete and abstract once-presented items; also see Table 1) and tended to increase with lag.

General Discussion

We focus here on the predictions from bilingual dual-coding theory concerning the additivity of semantic repetitions and the effects of semantic type and concreteness on both the mnemonic independence of semantic repetitions and on more direct measures of the connectedness between semantic equivalents.

Table 1
Percentage of Semantic Intrusion for Identical Repetitions as a Function of Experiment, Concreteness, and Lag

Condition	Lag 0	Lag 1	Lag 2	Lag 5
Bilingual experiment				
Concrete	3.51	6.58	6.14	9.22
Abstract	3.51	3.08	3.51	3.52
Synonym experiment				
Concrete	0.50	0.50	2.10	1.00
Abstract	0.00	0.00	1.60	0.80

Consistent with the independence hypothesis, recall of semantic repetitions exceeded identical repetitions at short lags but not at long lags for both bilingual and synonym repetitions. Moreover, zero-lag semantic repetitions produced a statistically independent (i.e., additive) effect on recall relative to recall of once-presented items, whereas zero-lag identical repetitions were less than additive. These results replicate and extend to synonyms the general pattern obtained by Glanzer and Duarte (1971) despite several differences in procedure and the inclusion of concrete and abstract words, which demonstrated similar general patterns for type recall. The results also replicate other studies that have found bilingual repetitions to be additive at short lags (Paivio & Lambert, 1981) or equal to identical repetitions at long lags (Kolers, 1966; Kolers & Gonzales, 1980). The effect of lag on identical repetitions in our two studies also replicates previous findings, although long lags are not always superadditive (i.e., greater than additive), which is itself a phenomenon that we do not yet understand (cf. Watkins & Kerkar, 1985).

These type recall results support the hypothesis that semantic equivalents activate functionally independent verbal memory traces. Semantic repetitions result in additivity even at zero lag presumably because the distinctiveness of the words is mnemonically helpful in terms of either the terminal memory traces or the nature of encoding processes prompted by distinct words as opposed to identical repetitions. The central role of verbal representations is also suggested by the fact that the additive benefits of semantic repetitions occurred for both concrete and abstract words. The results at short lags are less consistent with the common memory store hypothesis of bilingual memory and its extension to synonyms. Common coding views assert that both semantic and identical repetitions are encoded in the same abstract conceptual form and therefore should produce identical recall effects at all lags, assuming that episodic memory is primarily determined by the underlying semantic code rather than lexical or verbal codes.

The results also confirmed two more specific hypotheses of bilingual dual-coding theory: (a) that concrete semantic repetitions are more effective than abstract semantic repetitions because of the shared common images for concrete equivalents, and (b) that bilingual repetitions are more effective than synonym repetitions because associative relations are more constrained between than within languages. These effects emerged as various interactions in analyses of type scores, pair recall, and semantic intrusions.

For type scores, semantic repetitions surpassed identical repetitions except in the case of abstract synonyms, which were less potent than either concrete synonyms or abstract translations relative not only to identical repetitions but also to predicted recall levels based on independence. Abstract synonym repetitions were in fact marginally worse than identical repetitions at the longest lag, a finding that dual-coding theory attributes to a debilitating combination of diffuse associative connections and low image availability for abstract

synonyms. This result also raises questions about the generality of previous research showing bilingual repetitions to surpass synonym repetitions (Kolers & Gonzales, 1980). We only found that result for abstract synonyms. However, longer lags may also produce a crossover for concrete words and many other differences exist between the two studies, including a number of factors that should influence the effectiveness of semantic repetitions (e.g., rate of presentation, number and length of lists, control of extraneous associations).

Also consistent with specific predictions, pair recall was higher for bilingual repetitions than for synonym repetitions. The specificity of this effect was demonstrated by the fact that recall of translation equivalent pairs exceeded recall of once-presented words by 1.3%, whereas recall of synonym pairs was 6.2% *lower* than recall of the once-presented component words. The difference was particularly marked in the case of abstract items. This finding confirms the hypothesis that translation equivalents are more directly related than synonyms. Bilingual repetitions also clearly showed another predicted pattern in that pair recall remained at a constant level for concrete words but declined with increasing lag for abstract words. We attribute the decrease for abstract words to associative processes that are disrupted by increasing distance between related pairs. Shared images for concrete translations are assumed to either counteract these associative processes or make concrete equivalents less dependent on them.

Our synonym study did not demonstrate this pattern. Failing to replicate an earlier study (Clark, 1984), we found instead that pair recall decreased with lag for both concrete and abstract synonyms. More research will be needed to clarify the empirical inconsistencies, but one possible explanation is that the studies are not directly comparable because even fluent bilinguals may have less ready access to synonyms than do monolingual subjects. The lack of an interaction for synonyms also weakens the argument that the negative lag effects of Stern and Hintzman (1979) resulted from their use of relatively abstract verbal material.

Also as predicted, translation intrusions were more frequent than synonym intrusions, especially for concrete identical repetitions at long lags. The intrusions could reflect associations elicited during presentation (including imagery), decoding errors at the time of recall, or simply guessing. These alternatives are all compatible with bilingual dual-coding theory, which states only that activation of semantic equivalents, at whatever point in memory, will be more probable for concrete than for abstract words. Pair recall reflects similar processes and might also benefit from guessing. That is, the presence of related items might encourage subjects to guess, and this tendency could vary as a function of concreteness and semantic type. Guessing is compatible with dual-coding theory, but whatever its role in pair recall, it cannot account similarly for type scores, which are unaffected by whether pairs or individual words are recalled.

A final point concerns how research on item attributes is complicated by correlations with other item characteristics (Paivio, 1968). For example, word frequency influences the availability of semantic equivalents (Clark & Paivio, 1984) and may have contributed to the present results, because Eaton scores favored concrete pairs for the English bilingual items and were generally lower for synonyms than translations. A frequency explanation is contradicted by several facts, however, in that concreteness effects were stronger for synonyms than translations, and the difference between synonyms and translations was greater for abstract words than concrete. The frequency hypothesis predicts the opposite effects. In addition, the frequency measure itself is clouded by Galbraith and Underwood's (1973) finding that concrete words have the same subjective frequency as abstract words with much higher objective frequencies in Thorndike and Lorge (1944), an earlier version of which provided the Eaton norms. The contribution to semantic repetition effects of frequency, degree of semantic relatedness, and other relevant variables will eventually be determined by direct investigations.

In conclusion, bilingual dual-coding theory postulates distinct verbal representations for different languages. The distinct verbal codes can be independently activated by external stimuli, but spreading activation sometimes activates related words via V-V or V_1-V_2 associative connections. Between-languages connections entail less uncertainty than within-language connections. In addition to intraverbal associations, V-Im referential connections enable concrete words to activate the common imaginal representations upon which concrete translations and synonyms converge. Episodic memory is determined by these various codes, which are directly or indirectly activated in a probabilistic way. Although some findings are complicated by interactions with other variables or by inconsistencies with other research, the bilingual dual-coding model is generally consistent with (a) the additive effects of semantic versus identical repetitions at short lags, (b) differences between bilingual and synonym repetitions, and (c) effects of concreteness on semantic repetition effects.

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