Identifying exceptions in a database of recognition failure studies from 1973 to 1992

LARS-GÖRAN NILSSON
University of Umeå, Umeå, Sweden

and

JOHN M. GARDINER
City University, London, England

This paper presents a database of all published studies based on the recognition failure paradigm, which involves the study of pairs of items followed by a recognition test of the second item of each pair and a recall test of the same target item with the first item of each pair provided as a context cue. The paper also identifies, on the basis of a quantitative analysis, exceptions to the recognition failure function encompassing most data in the database. The database includes reference information about each study and a short description of materials and the manipulations made in each of the 302 experimental conditions reported. The database also includes information about the total number of observations for each condition, the overall hit rate in free or forced choice recognition, the overall probability of recall, the observed probability of recognition given recall, the predicted probability of recognition given recall, the difference between observed and predicted values, and the critical ratio between these difference scores and their overall standard deviation.

In this article, we review all the published studies of the phenomenon of recognition failure of recallable words with two aims in mind. One goal is to provide a database of all existing data on this phenomenon with the specific purpose of examining the claim that these data conform with a mathematical function proposed by Tulving and Wiseman (1975). A second goal is to test the hypothesis that some exceptions, as previously discussed in the literature (e.g., Nilsson & Gardiner, 1991), really do deviate markedly from this function. Exceptions to this function have never before been evaluated quantitatively with respect to *all* the recognition failure data available. A database is needed for this evaluation, along with a quantitative analysis that will identify large deviations in it.

This recognition failure function occurs in a particular situation, in which a recognition test for a particular set of target items is followed by a recall test for the same items, given item-specific contextual cues. In this situation, first clearly articulated by Tulving and Thomson (1973) and Watkins and Tulving (1975), the relation between recognition and recall of the same target items can be expressed by the probability of recognition given recall, or $p(Rn|Rc)$. Tulving and Wiseman (1975) discovered that from all 40 of the known conditions that conformed with the recognition failure paradigm, there was a simple quadratic function relating the probability of recognition given recall to the overall probability of

recognition—the recognition hit rate. This relation is summarized by the following equation:

$$p(Rn|Rc) = p(Rn) + .5[p(Rn) - p(Rn)^2]. \quad (1)$$

In a later summary, Flexser and Tulving (1978) found that all 89 conditions from published studies yielded observations close to values expected on the basis of Equation 1. More recently, however, some exceptions to this function have been observed. But these exceptions are principled, and they define the specific—as opposed to the situational—boundary conditions of the function (Gardiner, 1989; Gardiner & Nilsson, 1990, 1993; Nilsson, Dinniwel, & Tulving, 1987; Nilsson & Gardiner, 1991; Nilsson, Law, & Tulving, 1988).

We have proposed before that all exceptions to the function can be classified into one of two broad categories (Gardiner & Nilsson, 1990; Nilsson & Gardiner, 1991; Nilsson et al., 1988). In the first category, exceptions occur because the contextual cues are poorly related to their target words. In such circumstances, a nominally cued recall test becomes functionally like free recall, because the cues fail to provide any additional contextual information about the targets. So exceptions of this kind may be thought of as *free-recall* or *encoding exceptions*. If contextual items have not been encoded in relation to their targets, they will not, when presented as recall cues, be directed at the appropriate memory traces.

Exceptions in the second category occur because the information provided by contextual cues is largely inherent in the target words—that is, the recall cues are implicit in the recognition targets. In such circumstances, a nominally uncued recognition test becomes functionally

This research was supported by a grant to L.-G.N. from the Swedish Council for Research in the Humanities and Social Sciences. Requests for reprints should be sent to L.-G. Nilsson, Department of Psychology, University of Umeå, S-901 87 Umeå, Sweden.

like a cued recognition test. So exceptions of this kind may be thought of as *cued-recognition* or *retrieval exceptions*. The identification of exceptions falling into these two categories constitutes the major aim of this paper, in addition to the aim of making the database publicly available.

THE DATABASE

The database presented in the Appendix lists in order of publication (1) the specific experimental conditions included from each study, (2) the independent variables, (3) the type of recognition test (free vs. forced choice), (4) the overall recognition hit rate, (5) the overall probability of recall, (6) the observed probability of recognition given recall, (7) the predicted probability of recognition given recall, (8) the difference between observed and predicted values, and (9) the critical ratio between these difference scores and their overall standard deviation.

Following Tulving and Wiseman (1975) and Flexser and Tulving (1978), we have included in the database *only* experimental conditions in which uncued recognition preceded cued recall. In a number of studies, which are partially represented in the database, other sequences of combinations of tests have been used (e.g., Wallace, 1978). Such conditions are excluded from the database.

It should be noted that the very nature of the recognition failure function precludes the possibility of detecting large deviations from the function under certain circumstances. One such situation occurs when the level of recognition performance is quite high. In that circumstance, deviations may remain undetected because of ceiling effects (e.g., Nilsson & Shaps, 1980). Another such situation occurs when the level of recall performance is quite high and exceeds the level of recognition. Tulving (personal communication, September 1977) showed that there are then mathematical constraints on $p(Rn|Rc)$, which increase as the level of recall increases, and more recently, Hintzman (1991, 1992) has argued that these mathematical constraints actually explain the function—a possibility that Tulving had rejected on empirical grounds (see Tulving & Flexser, 1992).

Conversely, it is always possible that even large deviations from the function might reflect only experimental error, especially considering the large number of observations involved. This suggests that any purely quantitative definition of exceptions is likely to be unsatisfactory, and that an optimal definition requires both qualitative and quantitative criteria. Moreover, without the qualitative criteria, the definition of exceptions would be entirely circular because every large deviation would be called an exception, regardless of whether it could be categorized as an encoding or retrieval exception.

A further problem is that some of the exceptions that have been identified as such in the literature come from studies in which no attempt was made to evaluate the magnitude of the deviation statistically. This is particularly

the case, of course, with some of the earlier studies (e.g., Bartling & Thompson, 1977; Salzberg, 1975).

Given that the function summarizes the distribution of a set of observations—a set of observations that obviously entails an appreciable amount of natural variation—how is one to distinguish between deviations that reflect no more than natural variation and deviations that can be regarded as being abnormally large and falling outside the normal range?

We propose that the optimal solution to this problem is to analyze all the deviations from the function—that is, all differences between observed and predicted values—by using *critical ratio* measures (Gardiner & Nilsson, 1990; Nilsson & Gardiner, 1991). The critical ratio (CR) is a measure of the ratio between single difference scores and the standard deviation for the whole set of difference scores. This approach has several distinct advantages over other possible ways in which the difference scores might be analyzed. Most obviously, it treats the entire set of scores as a single corpus of data. It does not involve carrying out a large number of individual pairwise comparisons. And the criterion value can be easily adjusted by, for example, adopting different confidence intervals. Furthermore, the *lower* the criterion is set, the less chance there is that difference scores that tend to be atypically large will be classified as being within the normal distribution of scores. These CR measures are listed in the final column of the Appendix. For confidence intervals of 95% and 90% the critical CR values are 1.96 and 1.64, respectively.

It should be emphasized that exceptions are conceived as a matter of degree. There is no clear-cut dichotomy between exceptions and nonexceptions, but rather a continuum between them. This continuity is encapsulated by our use of the CR measure and by comparing the 95% and 90% confidence levels.

These critical values can be used to see how well the deviations excluded on these grounds correspond with those that have been previously identified as exceptions in the literature. Given the nature of these quantitative criteria, one would of course expect a reasonable degree of correspondence. But nonetheless these criteria could reveal relatively large deviations that have not been identified as exceptions. Equally, they could indicate that some of the deviations previously identified as exceptions are not so atypically large when placed in the context of the entire corpus of data summarized in the Appendix.

The conditions in the database that exceed the 95% confidence level are: Conditions 129 and 130 (Begg, 1979); Condition 142 (Fisher, 1979); Conditions 160 and 164 (Gardiner & Tulving, 1980); Condition 168 (Nilsson & Shaps, 1980); Condition 201 (Muter, 1984); Conditions 249, 252, and 254 (Jones & Gardiner, 1990); Conditions 269, 271, and 280 (Sandberg, 1990); Conditions 281, 284, and 285 (Bryant, 1991); and Conditions 297, 298, 301, and 302 (Årlemalm & Nilsson, 1992). At the 90% confidence level, the following exceptions would also be included: Condition 9 (Tulving, 1974); Condition 127

(Begg, 1979); Condition 189 (Neely & Payne, 1983); Condition 239 (Nilsson et al., 1988); and Condition 282 (Bryant, 1991). This analysis thus results in the inclusion at the 95% confidence level of a total of 20 deviations from the function summarized in Equation 1. Inclusion of deviations at the 90% confidence level adds another five conditions to the total set of exceptions in the present database. In the database, these 25 conditions are indicated by an asterisk.

Exceptions to the recognition failure function are defined as positive deviations, but the Appendix shows that there are also two large negative deviations from the function; that is, there are two deviations whose CR values exceed the 90% confidence interval that we have proposed as the quantitative criterion for defining exceptions. These are Conditions 103 and 133. It is possible that these negative deviations might reflect some unknown factor; but the conditions giving rise to them appear to have nothing in common, and so they most likely reflect experimental error. We therefore classify these deviations as aberrant observations that should also be excluded from the set of observations held to reflect the recognition failure function.

Encoding Exceptions

If the qualitative analysis in terms of two types of exceptions is correct, and if we then go through the experimental conditions that were identified as exceptions on the basis of the quantitative CR analysis, all of them should fit one or the other of the two categories. For ease of exposition, we review each of the categories in turn, beginning with free-recall or encoding exceptions. The major studies of exceptions of this kind are those of Begg (1979), Fisher (1979), Gardiner and Tulving (1980), Bryant (1991), and Årlemalm and Nilsson (1992). The relevant conditions from these studies are characterized by weak encoding, brought about through "rote learning" instructions, poorly related cue-target materials, or both.

In Begg's (1979) Experiments 1 and 2, half the subjects were given instructions to encode unrelated word pairs by rote learning and half the subjects were given instructions to integrate the word pairs meaningfully. In the former conditions, it should have been difficult for subjects effectively to encode designated cue words in relation to their targets, and so these conditions should have given rise to exceptions. These are Conditions 120 and 127-132 in the Appendix, which shows that they did in general give rise to quite large positive deviations, though not in Conditions 128 and 132. Conditions 129 and 130 reached statistical significance by means of the CR analysis.

Similar results were obtained from similar conditions in Fisher's (1979) Experiment 2. These are Conditions 142 and 143, in which subjects were given instructions for "repetition rehearsal" and there were low association values between the cues and their targets. Of these two conditions, only the former reached statistical reliability. With high association values between the cues and their targets, however, no large deviations were observed, even

with repetition rehearsal, presumably because subjects then had little difficulty in effectively relating the cue-target pairs (Conditions 144 and 145). Similarly, with "meaningful rehearsal" instructions, the subjects were able to effectively relate cue-target pairs even when the association between them was low (Conditions 146 and 147), and no exceptions were observed.

Gardiner and Tulving (1980) used materials consisting of unrelated pairs of abstract words, or digit-word pairs, and compared "standard" encoding conditions with "special instructions" designed to train subjects effectively to relate these cue-target pairs. Under standard conditions of encoding (Conditions 159, 160, 163, and 164) there were relatively large deviations from the function. Conditions 160 and 164 reached statistical significance by the critical ratio analysis. With special conditions of encoding (Conditions 161, 162, 165, and 166), there was a much closer correspondence between observed and predicted values.

Sandberg (1990) used materials consisting of words or nonwords. The lists of pairs were so constructed that the two words of a pair could form either a word (e.g., foot-BALL) or a nonword (e.g., cup-PEAK); pairs of nonwords could also form a word (e.g., vasc-ULAR) or a nonword (e.g., rog-LUB). The word pairs were presented either once or five times. The prediction was that combinations of items forming nonwords would be more difficult to integrate, thus leading to a positive deviation from the function. It was also expected that such an exception would be more pronounced for one presentation than for five presentations. The predictions were confirmed, leading to large deviations for Conditions 269, 271, and 280, which were statistically significant by the CR analysis.

Bryant (1991) based one of his recognition failure experiments on the levels-of-processing paradigm (Craik & Tulving, 1975). The results showed large statistically significant deviations from the function for the shallow structural or phonetic encoding conditions (Conditions 281 and 282) as measured by CR, but not for the deep semantic encoding condition (Condition 283). In a second experiment, Bryant manipulated the degree of association between the cue-target pairs. In line with the prediction, Bryant was able to demonstrate that the condition with no cue-target association (Condition 284) and that with a weak cue-target association (Condition 285) led to statistically reliable encoding exceptions as measured by CR.

Årlemalm and Nilsson (1992) manipulated three variables: type of word pair, number of presentations, and type of instructions. Adjective-noun or noun-adjective pairs were presented once or five times after instructions for a subsequent recall test or for both a recognition and a recall test. The number of times a word pair was presented at study seems to have been the critical variable to produce large deviations from the function in this experiment. There were statistically significant exceptions, as measured by CR, in all four cases of one presentation. For none of the four conditions with five presentations

did the observed value differ significantly from the predicted value. It seems reasonable to interpret these data as showing that one presentation gives rise to a weaker cue-target association than do five presentations.

It is important to note that although free-recall or encoding exceptions are likely to occur when either the instructions or the materials (or both) make it difficult for subjects to relate cues to their targets, it does not follow that such conditions will invariably give rise to exceptions, because subjects will sometimes be able to overcome the limitations imposed by the instructions or by the materials. This probably explains why exceptions of this kind have also appeared in what seem to be more idiosyncratic circumstances—idiosyncratic, because they are isolated observations from different experiments, and because these experiments include other encoding conditions that, on the face of it, may not seem all that dissimilar.

Four such cases have been identified in the literature previously. They come from the studies by Salzberg (1975), Bartling and Thompson (1977), Neely and Payne (1983), and Nilsson et al. (1988).

Condition 57, from Salzberg's (1975) study, and Conditions 78 and 79, from Bartling and Thompson's (1977) study, appear to give rise to positive deviations and involve relatively abstract adjective cues. It seems reasonable to suppose that these deviations could be classified as encoding exceptions, because such cue-target pairs may have been difficult to integrate together. A similar interpretation can be made of the deviations shown in Condition 189, from Neely and Payne's (1983) study, and Condition 231, from Nilsson et al.'s (1988) study. Condition 189 involved nonfamous, rather than famous, names, so these names were therefore unrelated words. Condition 231 involved contextual phrases and geographical targets, which subjects had rated as being low in meaningfulness (e.g., *Hat first made in MOROCCO*), presumably because they had difficulty in relating the cues to the targets.

Retrieval Exceptions

We now review the second category of exceptions, cued-recognition or retrieval exceptions. Exceptions of this kind occur when subjects can implicitly retrieve much of the information provided by the recall cues from the targets in the recognition test. The major studies in relation to these exceptions are those of Muter (1984), Nilsson et al. (1987), Nilsson et al. (1988), and Jones and Gardiner (1990).

The first study in which deviations from the function would be expected on this basis is that of Tulving (1974). In this study, there were two conditions in which the recall cues were actually identical to their targets; that is, the recall cues were simply copies of the very same words. As it happens, however, only one of these two conditions showed a relatively large positive deviation reaching statistical significance (Condition 9, but not Condition 12).

The probable reasons for this have recently been clarified by Jones and Gardiner (1990). The hypothesis they

tested was that the extent to which exceptions are observed with identical recall cues depends on the extent to which subjects adopt a guessing strategy in recall, on the basis of their knowing that some of the cues are copies of their targets. So, confronted by a recall cue that does not lead them to retrieve any specific contextual information, subjects may simply copy it. Jones and Gardiner therefore compared recognition and recall with identical cues when guessing was prohibited and when guessing was compelled—that is, when both recognition and recall were forced choice. Large positive deviations were observed when guessing was prohibited (Conditions 249, 252, and 254), but not when guessing was compelled (Conditions 257, 260, and 262), thereby confirming the guessing strategy hypothesis and clarifying the conditions under which identical cues give rise to exceptions. All these three conditions (249, 252, and 254) reached statistical significance.

Deviations from the function have also been observed when the target words are category exemplars and the recall cues are the names of the categories. In these circumstances, when presented with the target words in the recognition test, subjects can retrieve the category names. Here too the information provided by the recall cues is implicit in the targets. Such materials were used in the studies by Nilsson and Shaps (1980, 1981). But, as can be seen in the Appendix, only in one condition from these studies is there a relatively large deviation from the function—Condition 168, which reached statistical reliability. Almost certainly, the reason for this is that in other relevant conditions from these studies the level of recognition performance was so high that deviations from the function cannot be detected. This conjecture is confirmed by the results of some unpublished experiments in which similar materials have been used with much longer retention intervals (Gardiner, Nilsson, & Mäntylä, 1993). At these longer retention intervals, recognition performance was appreciably lower than in the studies done by Nilsson and Shaps (1980, 1981). And in each case, large deviations from the function were observed.

Evidence in support of this interpretation was provided by Nilsson et al. (1987). Lists were constructed in such a way that although some category instances were paired with category name cues, others were not, and so the category name cue was not predictable from the recognition target. Under these conditions (204–211 and 216–221), the data points were much as predicted, and no exceptions to recognition failure occurred.

The last exception of this kind was reported by Muter (1984). In Muter's experiment, there was no study list. Subjects were presented with surnames of famous people that were either unique names or common names (e.g., ATATURK, COOPER), and they were asked to indicate whether they recognized each name as being that of a famous person. On the subsequent recall test, the subjects were given a descriptive phrase for the person whose name was to be recalled (e.g., *First president of the republic of Turkey, Kemal _____*; *Author of the last of the*

Mohicans, James Fenimore _____). Muter found that for the common names, recognition failure conformed closely to the function (Condition 200), but that for the unique names, there was almost complete dependency between recognition and recall (Condition 201)—an outcome that he interpreted as providing strong support for generate-recognition theory. As demonstrated by the critical ratio analysis, the deviation in Condition 201 reached statistical significance.

However, when subjects recognize ATATURK, for example, as being the name of a famous person, in so doing they are likely to retrieve information about him, including information about his being president of Turkey. So in this situation too, the information provided by the recall cues was largely implicit in the recognition targets. Evidence in support of this interpretation was obtained by Nilsson et al. (1988), who constructed a study list in which unique names of famous people were paired with apt but unexpected contextual phrases, phrases consisting of information unlikely to be retrievable from the names themselves (e.g., A scientist of uncertain ancestry: CHARLES DARWIN). Delayed tests of recognition of study list names, and then recall of the names given the contextual phrases as recall cues, showed that under these conditions, unique famous names did not give rise to any deviations from the function (Conditions 228, 229, and 230). Nilsson et al. also obtained similar results for unique geographical names (Conditions 232 and 233), except when, as has already been discussed, the subjects had given the materials low meaningfulness ratings.

The use of CR measures to define exceptions leaves open the possibility that there might be individual cases of positive deviations that are not large enough to meet the CR criterion but that reflect statistically significant differences between observed and predicted values by other tests such as binomial tests. There are only four such cases in the Appendix. Two of them, Conditions 192 and 196, were from the study by Neely and Payne (1983), and in each case there was significantly greater dependency between recognition and recall than expected from a binomial test. Word pairs were related in Condition 192 and unrelated in Condition 196, so the latter condition might indicate an encoding exception. Neely and Payne attributed the former difference to sampling error themselves. The other two conditions (245 and 246) were from the study done by Svensson and Nilsson (1989). In Condition 245, the degree of dependency observed was lower than expected. However, the level of recognition performance was very high, so this observation might reflect a ceiling effect. In Condition 246, significantly greater than expected dependency was observed for reasons that remain obscure. Any of these differences may, of course, reflect experimental error; or they may be due to some as yet undiscovered factor.

This completes our review of exceptions as they have been investigated and discussed in the literature. We conclude from this review of identified exceptions that all such exceptions do appear to be readily classifiable as belong-

ing to one or the other of the two categories that we have defined. That is, whenever there is a large deviation from the recognition failure function, the reason is either that the cue-target pairs were weakly encoded or that much of the information provided by the recall cues can be implicitly retrieved from the targets in the recognition test. However, in concluding this, it is important, once again, to emphasize that there is no clear-cut dichotomy between exceptions and nonexceptions; their occurrence is a matter of degree.

THEORIES

Elsewhere, we have reviewed the two types of exception—the free-recall or the encoding exception and the cued-recognition or the retrieval exception—in terms of existing memory theory (Nilsson & Gardiner, 1991). Ratcliff and McKoon (1989) have also reviewed memory theories in relation to the recognition failure function. Since these reviews are already available, the aim here is merely to summarize the main conclusions; the interested reader is referred to these chapters for details. We considered four specific theories directly pertinent to the issue of the phenomenon of recognition failure of recallable words: vandal theory (Begg, 1979), dual mechanism theory (Jones, 1978, 1983, 1987), the retrieval independence model (Flexser & Tulving, 1978), and the backward retrieval model (Rabinowitz, Mandler, & Barsalou, 1977). It was concluded that none of these theories could account for both types of exception. The vandal theory and the dual mechanism theory can account for the encoding exceptions but not the retrieval exceptions. Conversely, the models of retrieval independence and backward retrieval can account for the retrieval exceptions but not for the encoding exceptions.

With respect to more general theories of memory Nilsson and Gardiner (1991) considered the ACT* model (Anderson, 1983), the SAM model (Gillund & Shiffrin, 1984), MINERVA 2 (Hintzman, 1987), the matrix model (Humphreys, Bain, & Pike, 1989), TODAM (Murdoch, 1979, 1982, 1983), and CHARM (Metcalf, 1992). We concluded that the ACT* model and MINERVA 2 can account for encoding exceptions and that TODAM can be extended to accommodate encoding exceptions. The matrix model can account for retrieval exceptions but not for encoding exceptions. The SAM model, it was found, can account for the phenomenon of recognition failure of recallable words, but there is no mechanism that would account for either encoding or retrieval exceptions.

Metcalf's (1992) CHARM model, finally, was found to be best equipped to account for the exceptions to the function. This is the only model that has so far been shown to account for both types of exception. The encoding exceptions can be accounted for without any restrictions, and the retrieval exceptions can be accounted for by assuming that relatively few features are encoded in the item vectors.

MATHEMATICAL CONSTRAINTS

Hintzman (1991, 1992) has claimed that the Tulving-Wiseman function is an artefact due to mathematical constraints on the conditional probability of recognition given recall, particularly when the level of recall exceeds the level of recognition. In this circumstance, the value of $p(R_n|R_c)$ cannot reach unity, and the severity of this constraint increases with higher levels of recall. Thus, the argument is that data points fall on the function or close to the function because they are mathematically compelled to do so. Hintzman (1991, 1992) also claimed that exceptions to the function occur when these constraints are absent.

Tulving and Flexser (1992) and Gardiner and Nilsson (1993) have recently argued against these claims of Hintzman's on empirical grounds. Tulving and Flexser based their analysis on the Flexser and Tulving (1978) database, whereas Gardiner and Nilsson based their analysis on a slightly earlier version of the database reported here. Both Tulving and Flexser (1992) and Gardiner and Nilsson (1991) rejected the mathematical artifact hypothesis because neither the function nor the exceptions can be related causally to these mathematical constraints. Data points conform to the function even when the mathematical constraints are absent (i.e., the level of recognition exceeds the level of recall) and exceptions do occur even when the mathematical constraints are present (i.e., the level of recall exceeds the level of recognition). Further evidence that there is no causal relation between these mathematical constraints and the function is discussed by Årlemalm and Nilsson (1992).

However, such empirical refutations of Hintzman's mathematical model might not be conclusive—partly because the model is probabilistic, not deterministic, and therefore predicts only that exceptions are more likely to occur when the constraints are absent. It is also possible to regard Hintzman's model and our empirical account as being complementary. The model may or may not eventually prove to be falsifiable, on either formal or empirical grounds. But the model involves a complex set of assumptions that make it rather difficult to refute empirically. Our account is simple by comparison, and easier to test empirically, as our review here has shown.

CONCLUSION

The purpose of this article has been to provide a database of all existing data on the phenomenon of recognition failure of recallable words and to analyze this database to test the hypothesis that exceptions to the Tulving-Wiseman function really do deviate markedly from the function when all available data are taken into account. Critical ratio measures identify 25 abnormally large deviations. We have reviewed these deviations and shown on the basis of a qualitative analysis that they all fall into one of the two categories of exceptions described. These excep-

tions occur either because recall cues are not functionally well related to the accompanying target words or because the recall cues are functionally equivalent to the target words. Thus, all large positive deviations from the function are principled, and the claim that the function is lawful is fully justified. Finally, we have also briefly considered Hintzman's (1991, 1992) mathematical model of the function and exceptions to it and the suggestion that at present this formal account and our empirical account can be regarded as being complementary. The database that we provide here can be used to further evaluate these—and other—controversial issues surrounding the phenomenon of recognition failure of recallable words.

REFERENCES

- ANDERSON, J. R. (1983). *The architecture of cognition*. Cambridge, MA: Harvard University Press.
- ÅRLEMALM, T., & NILSSON, L.-G. (1992). Recognition failure of recallable words: Exception due to poor integration. *Scandinavian Journal of Psychology*, **33**, 266-276.
- BARTLING, C. A., & THOMPSON, C. P. (1977). Encoding specificity: Retrieval asymmetry in the recognition failure paradigm. *Journal of Experimental Psychology: Human Learning & Memory*, **3**, 690-700.
- BEGG, I. (1979). Trace loss and the recognition failure of unrecalled words. *Memory & Cognition*, **7**, 113-123.
- BOWYER, P. A., & HUMPHREYS, M. S. (1979). Effect of a recognition test on a subsequent recall test. *Journal of Experimental Psychology: Human Learning & Memory*, **5**, 348-359.
- BRYANT, D. J. (1991). Exceptions to recognition failure as a function of the encoded association between cue and target. *Memory & Cognition*, **19**, 210-219.
- CRAIK, F. I. M., & TULVING, E. (1975). Depth of processing and the retention of words in episodic memory. *Journal of Experimental Psychology: General*, **1**, 268-294.
- DONNELLY, R. E. (1988). Priming effects in successive episodic tasks. *Journal of Experimental Psychology: Learning, Memory, & Cognition*, **14**, 256-265.
- FISHER, R. P. (1979). Retrieval operations in cued recall and recognition. *Memory & Cognition*, **7**, 224-231.
- FLEXSER, A. J., & TULVING, E. (1978). Retrieval independence in recognition and recall. *Psychological Review*, **85**, 153-171.
- GARDINER, J. M. (1988). Recognition failures and free-recall failures: Implications for the relation between recall and recognition. *Memory & Cognition*, **16**, 446-451.
- GARDINER, J. M. (1989). The Tulving-Wiseman law and exceptions to it. In A. F. Bennett & K. M. McConkey (Eds.), *Cognition in individual and social contexts* (pp. 253-260). Amsterdam: North-Holland.
- GARDINER, J. M., KAMINSKA, Z., JAVA, R. I., CLARKE, E. F., & MAYER, P. (1990). The Tulving-Wiseman law and the recognition of recallable music. *Memory & Cognition*, **18**, 632-637.
- GARDINER, J. M., & NILSSON, L.-G. (1990). *Relation between recognition and recall: The Tulving-Wiseman law* (Umeå Psychological Reports No. 205). Umeå, Sweden: University of Umeå, Department of Psychology.
- GARDINER, J. M., & NILSSON, L.-G. (1993). *Mathematical constraints and the Tulving-Wiseman law: A rejoinder*. Manuscript submitted for publication.
- GARDINER, J. M., NILSSON, L.-G., & MÄNTYLÄ, T. (1993). *Recognition failure of categorized words: List length and retention interval*. Manuscript in preparation.
- GARDINER, J. M., & TULVING, E. (1980). Exceptions to recognition failure of recallable words. *Journal of Verbal Learning & Verbal Behavior*, **19**, 194-209.
- GILLUND, G., & SHIFFRIN, R. M. (1984). A retrieval model for both recognition and recall. *Psychological Review*, **91**, 1-67.

- HINTZMAN, D. L. (1987). Recognition and recall in MINERVA 2: Analysis of the "recognition-failure" paradigm. In P. Morris (Ed.), *Modeling cognition* (pp. 215-229). London: Wiley.
- HINTZMAN, D. L. (1991). Contingency analysis, hypotheses, and artefacts: Reply to Flexser and to Gardiner. *Journal of Experimental Psychology: Learning, Memory, & Cognition*, **17**, 341-345.
- HINTZMAN, D. L. (1992). Mathematical constraints and the "Tulving-Wiseman Law." *Psychological Review*, **99**, 536-542.
- HUMPHREYS, M. S., (1976). Relational information and the context effect in recognition memory. *Memory & Cognition*, **4**, 221-232.
- HUMPHREYS, M. S. (1978). Item and relational information: A case for context independent retrieval. *Journal of Verbal Learning & Verbal Behavior*, **17**, 175-187.
- HUMPHREYS, M. S., BAIN, J. D., & PIKE, R. (1989). Different ways to cue a coherent memory system: A theory for episodic, semantic, and procedural tasks. *Psychological Review*, **96**, 208-233.
- JONES, G. V. (1978). Recognition failure and dual mechanisms in recall. *Psychological Review*, **85**, 464-469.
- JONES, G. V. (1983). Structure of the recall process. *Philosophical Transactions of the Royal Society of London*, **302B**, 373-385.
- JONES, G. V. (1987). Independence and exclusivity among psychological processes: Implications for the structure of recall. *Psychological Review*, **94**, 229-235.
- JONES, G. V., & GARDINER, J. M. (1990). Recognition failure when recognition targets and recall cues are identical. *Bulletin of the Psychonomic Society*, **28**, 105-108.
- LIEURY, A. (1979). La memoire episodique est-elle emboitee dans la memoire semantique? *L'Année Psychologique*, **79**, 123-142.
- METCALFE, J. (1992). Recognition failure and the composite memory trace in CHARM. *Psychological Review*, **98**, 529-553.
- MURDOCK, B. B., JR. (1979). Convolution and correlation in perception and memory. In L.-G. Nilsson (Ed.), *Perspectives on memory research* (pp. 105-120). Hillsdale, NJ: Erlbaum.
- MURDOCK, B. B., JR. (1982). A theory for the storage and retrieval of item and associative information. *Psychological Review*, **89**, 609-662.
- MURDOCK, B. B., JR. (1983). A distributed memory model for serial order information. *Psychological Review*, **90**, 316-338.
- MUTER, P. (1978). Recognition failure of recallable words in semantic memory. *Memory & Cognition*, **6**, 9-12.
- MUTER, P. (1984). Recognition and recall of words with a single meaning. *Journal of Experimental Psychology: Learning, Memory, & Cognition*, **10**, 198-202.
- NEELY, J. H., & PAYNE, D. G. (1983). A direct comparison of recognition failure rates for recallable names in episodic and semantic memory tests. *Memory & Cognition*, **11**, 161-171.
- NILSSON, L.-G., DINNIWELL, M., & TULVING, E. (1987). Recognition failure of categorized words. *Memory & Cognition*, **15**, 389-396.
- NILSSON, L.-G., & GARDINER, J. M. (1991). Memory theory and the boundary conditions of the Tulving-Wiseman law. In W. E. Hockley & S. Lewandowsky (Eds.), *Relating theory and data: Essays on human memory* (pp. 57-74). Hillsdale, NJ: Erlbaum.
- NILSSON, L.-G., LAW, J., & TULVING, E. (1988). Recognition failure of recallable unique names: Evidence for an empirical law of memory and learning. *Journal of Experimental Psychology: Learning, Memory, & Cognition*, **14**, 266-277.
- NILSSON, L.-G., & SHAPS, L. P. (1980). A functional view of memory. In F. Klix & J. Hoffmann (Eds.), *Cognition and memory: Interdisciplinary research of human memory activities* (pp. 40-46). Berlin: Deutscher Verlag der Wissenschaften.
- NILSSON, L.-G., & SHAPS, L. P. (1981). A reconstructive processing interpretation of the recognition failure phenomenon. *Acta Psychologica*, **47**, 25-37.
- PAYNE, D. G., & NEELY, J. H. (1983). Recognition failure of recallable famous names in a hybrid semantic-episodic memory task. *Bulletin of the Psychonomic Society*, **21**, 85-88.
- POSTMAN, L. (1975). Tests of the generality of the principle of encoding specificity. *Memory & Cognition*, **3**, 663-672.
- RABINOWITZ, J. C. (1984). Aging and recognition failure. *Journal of Gerontology*, **39**, 65-71.
- RABINOWITZ, J. C., MANDLER, G., & BARSALOU, L. W. (1977). Recognition failure: Another case of retrieval failure. *Journal of Verbal Learning & Verbal Behavior*, **16**, 639-663.
- RATCLIFF, R., & MCKOON, G. (1989). Memory models, text-processing, and cue-dependent retrieval. In H. L. Roediger III & F. I. M. Craik (Eds.), *Varieties of memory and consciousness* (pp. 73-92). Hillsdale, NJ: Erlbaum.
- REDER, L. M., ANDERSON, J. R., & BJORK, R. A. (1974). A semantic interpretation of encoding specificity. *Journal of Experimental Psychology*, **102**, 648-656.
- RÖNNBERG, J., LYXELL, B., SAMUELSSON, S., ERNBRUND, K., & NILSSON, L.-G. (1991). Recognition failure of prose-embedded words. *Journal of Experimental Psychology: Learning, Memory, & Cognition*, **17**, 288-301.
- SALZBERG, P. M. (1975). On the generality of encoding specificity. *Journal of Experimental Psychology: Human Learning & Memory*, **2**, 586-596.
- SANDBERG, K. (1988). Recognition failure of recallable words: Free and cued recall compared. *Scandinavian Journal of Psychology*, **29**, 129-136.
- SANDBERG, K. (1990). Integration and cue overlap in recognition failure of recallable words. *Scandinavian Journal of Psychology*, **31**, 302-314.
- SHAPS, L. P., & NILSSON, L.-G. (1980). Encoding and retrieval operations in relation to age. *Developmental Psychology*, **16**, 636-643.
- SVENSSON, T., & NILSSON, L.-G. (1989). The relationship between recognition and cued recall in memory of enacted and nonenacted information. *Psychological Research*, **51**, 194-200.
- TAJKA, H. (1977). Features of recognition tasks in encoding specificity: Types of frequency associates in extralist cue words types of recognition tasks. *Psychologia*, **20**, 151-158.
- TAJKA, H. (1978a). Features of recognition tasks in encoding specificity: The function of context in recognition tasks. *Japanese Psychological Research*, **20**, 93-100.
- TAJKA, H. (1978b). Features of recognition tasks in encoding specificity: The function of free associates tasks and non-verbal tasks. *Japanese Journal of Psychology*, **48**, 344-347.
- TAJKA, H. (1979). Memory processes in recall and recognition. *Psychologia*, **22**, 146-154.
- TULVING, E. (1974). Recall and recognition of semantically encoded words. *Journal of Experimental Psychology*, **102**, 778-787.
- TULVING, E., & FLEXSER, A. J. (1992). On the nature of the Tulving-Wiseman function. *Psychological Review*, **99**, 543-546.
- TULVING, E., & THOMSON, D. M. (1973). Encoding specificity and retrieval processes in episodic memory. *Psychological Review*, **80**, 352-373.
- TULVING, E., & WATKINS, O. C. (1977). Recognition failure of words with a single meaning. *Memory & Cognition*, **5**, 513-522.
- TULVING, E., & WISEMAN, S. (1975). Relation between recognition and recognition failure of recallable words. *Bulletin of the Psychonomic Society*, **6**, 79-82.
- VINING, S. K., & NELSON, T. O. (1979). Some constraints on the generality and interpretation of the recognition failure of recallable words. *American Journal of Psychology*, **92**, 257-276.
- WALLACE, W. P. (1978). Recognition failure of recallable words and recognizable words. *Journal of Experimental Psychology: Human Learning & Memory*, **4**, 441-452.
- WATKINS, M. J., & TULVING, E. (1975). Episodic memory: When recognition fails. *Journal of Experimental Psychology: General*, **104**, 5-29.
- WISEMAN, S., & TULVING, E. (1975). A test of confusion theory of encoding specificity. *Journal of Verbal Learning & Verbal Behavior*, **14**, 370-381.
- WISEMAN, S., & TULVING, E. (1976). Encoding specificity: Relation between recall superiority and recognition failure. *Journal of Experimental Psychology: Human Learning & Memory*, **2**, 349-361.

APPENDIX Summary of Published Recognition Failure Experiments

Cond	Study	Exp	Independent variables	Rn-t	N	Rn	Rc	Obs	Pred Diff	CR			
1	Tulving & Thomson (1973)	1	type of retrieval cue	fr	178	.26	.63	.38	.36	.02	.25		
2		type of retrieval cue	fr	170	.22	.62	.62	.31	.31	.00	.00		
3		Reder, Anderson & Bjork (1974)	2	frequency of targets: high	fr	275	.35	.63	.46	.46	.00	.00	
4			frequency of targets: high	fr	280	.38	.64	.64	.51	.50	.01	.13	
5			frequency of targets: low	fr	236	.81	.74	.85	.89	-.04	-.51	-.51	
6			frequency of targets: low	fr	265	.85	.81	.88	.91	-.03	-.38	-.38	
7	Tulving (1974)	1	type of cue word: incongruous	fr	144	.26	.52	.37	.36	.01	.13		
8		type of cue word: congruous	fr	140	.37	.46	.55	.49	.06	.76	.76		
9		type of cue word: identical	fr	146	.25	.40	.48	.34	.14	1.78	1.78		
10		type of cue word: incongruous	fr	107	.41	.50	.49	.53	-.04	-.51	-.51		
11	Postman (1975)	2	type of cue word: congruous	fr	104	.47	.59	.57	.59	-.02	-.25	-.25	
type of cue word: identical			fr	91	.25	.36	.39	.34	.05	.63	.63		
2		type of association for Rn: high; lenient Rc scoring	fr	576	.50	.38	.53	.63	-.10	-1.27	-1.27		
		type of association for Rn: mixed lenient Rc scoring	fr	576	.46	.33	.60	.58	.02	.25	.25		
		Rn control-noncue; lenient Rc scoring	fr	576	.59	.42	.77	.71	.06	.76	.76		
		type of association Rn: high; strict Rc scoring	fr	576	.50	.38	.53	.63	-.10	-1.27	-1.27		
2		type of association for Rn: Mixed; strict Rc scoring	fr	576	.46	.24	.58	.58	.00	.00	.00		
		Rn control-noncue; strict Rc scoring	fr	576	.59	.32	.74	.71	.03	.38	.38		
		conventional Rn test; free choice	fr	384	.40	.49	.51	.52	-.01	-.13	-.13		
		conventional Rn test; forced choice	fo	384	.47	.51	.64	.59	.05	.63	.63		
21	Watkins & Tulving (1975)	3	subject made Rn test	fr	384	.32	.62	.42	.43	-.01	-.13	-.13	
22		experimenter made Rn test	fr	384	.35	.56	.45	.46	-.01	-.13	-.13		
23		subject made Rn test	fo	384	.49	.62	.53	.61	-.08	-1.02	-1.02		
24		experimenter made Rn test	fo	384	.52	.56	.58	.64	-.06	-.76	-.76		
25		4	generated targets	fr	384	.33	.63	.38	.44	-.06	-.76	-.76	
26			nongenerated targets	fr	384	.41	.63	.48	.53	-.05	-.63	-.63	
27			generated targets	fo	384	.47	.63	.56	.59	-.03	-.38	-.38	
28			nongenerated targets	fo	384	.54	.63	.67	.66	.01	.13	.13	
29		5	type of lures: related	fr	216	.67	.75	.75	.74	.78	-.04	-.51	-.51
30			type of lures: unrelated lures	fr	216	.62	.73	.77	.77	.74	.03	.38	.38
31	type of lures: related		fo	216	.71	.75	.77	.81	-.04	-.51	-.51		
32	type of lures: unrelated		fo	216	.67	.73	.84	.78	.06	-.76	-.76		
33	6	number of set lists: 0	fr	288	.38	.58	.45	.45	.50	-.05	-.63	-.63	
34		number of set lists: 1	fr	288	.47	.55	.55	.59	-.04	-.51	-.51		
35		number of set lists: 2	fr	288	.30	.48	.40	.41	-.01	-.13	-.13		
36		number of set lists: 0	fo	288	.52	.58	.66	.64	.02	.25	.25		
37		number of set lists: 1	fo	288	.53	.55	.64	.65	-.01	-.13	-.13		
38		number of set lists: 2	fo	288	.35	.48	.53	.46	.07	.89	.89		
39		type of lures: related	fr	432	.40	.56	.46	.52	-.06	-.76	-.76		
40		type of lures: unrelated	fr	432	.37	.51	.47	.49	-.02	-.25	-.25		
41		type of lures: related	fo	432	.50	.56	.63	.63	.00	.00	.00		
42		type of lures: unrelated	fo	432	.45	.51	.59	.57	.02	.25	.25		

APPENDIX (continued)

43	Wiseman & Tulving (1975)	1	generated targets, order of critical list: 1st	fr	288	.46	.61	.55	.58	-.03	-.38
44			generated targets, order of critical list: 2nd	fr	288	.41	.62	.51	.53	-.02	-.25
45			generated targets, order of critical list: 3rd	fr	288	.34	.59	.43	.45	-.02	-.25
46			generated targets, order of critical list: 4th	fr	288	.37	.57	.51	.49	.02	.25
47			nongenerated targets, order of critical list: 1st	fr	288	.56	.64	.74	.68	.06	.76
48			nongenerated targets, order of critical list: 2nd	fr	288	.49	.62	.67	.61	.06	.76
49			nongenerated targets, order of critical list: 3rd	fr	288	.47	.64	.61	.59	.02	.25
50			nongenerated targets, order of critical list: 4th	fr	288	.47	.57	.67	.59	.08	1.02
51	Humphreys (1976)		B terms	fr	768	.71	.68	.77	.81	-.04	-.51
52	Salzberg (1975)	2	concrete cue: root noun	fr	175	.57	.70	.63	.69	-.06	-.76
53			concrete cue: derived adjective	fr	175	.59	.60	.72	.71	.01	.13
54			concrete cue: root adjective	fr	175	.69	.52	.81	.80	.01	.13
55			concrete cue: derived noun	fr	175	.71	.43	.84	.81	.03	.38
56			abstract cue: root noun	fr	175	.68	.54	.83	.79	.04	.51
57			abstract cue: derived adjective	fr	175	.67	.35	.89	.78	.11	1.40
58			abstract cue: root adjective	fr	175	.65	.42	.81	.76	.05	.64
59			abstract cue: derived noun	fr	175	.66	.55	.78	.77	.01	.13
60	Wiseman & Tulving (1976)	1	cue-target relation: weak	fr	576	.26	.59	.33	.36	-.03	-.38
61		2	cue target relation: arbitrary	fr	576	.18	.34	.24	.25	-.01	-.13
62		3	cue target relation: unrelated	fr	672	.52	.38	.69	.64	.05	.63
63			cue target relation: unrelated	fo	672	.68	.38	.85	.79	.06	.76
64		4	cue target relation: related	fr	864	.54	.64	.63	.66	-.03	-.38
65			cue target relation: unrelated	fr	864	.51	.34	.62	.64	-.01	-.25
66			cue target relation: mixed, Rn target-lure ratio 1:7	fr	288	.53	.50	.62	.65	-.03	-.38
67			cue target relation: mixed, Rn target-lure ratio 1:1	fr	576	.52	.48	.62	.64	-.02	-.25
68			cue target relation: mixed, Rc cue-lure ratio 1:1	fr	288	.56	.53	.64	.68	-.04	-.51
69			cue target relation: mixed, Rc cue-lure ratio 1:0	fr	576	.50	.46	.61	.63	-.02	-.25
70			cue target relation: related	fo	864	.71	.64	.78	.81	-.03	-.38
71			cue target relation: unrelated	fo	864	.71	.34	.80	.81	-.01	-.13
72			cue target relation: mixed, Rn target-lure ratio 1:7	fo	288	.63	.50	.72	.75	-.03	-.38
73			cue target relation: mixed, Rn target-lure ratio 1:1	fo	576	.76	.48	.84	.85	-.01	-.13
74			cue target relation: mixed, Rc cue-lure ratio 1:1	fo	288	.74	.53	.81	.84	-.03	-.38
75			cue target relation: mixed, Rc cue-lure ratio 1:0	fo	576	.68	.46	.77	.79	-.02	-.25
76	Bartling & Thompson (1977)		type of word pairs: noun-adjective	fo	288	.61	.66	.64	.73	-.09	-1.14
77			type of word pairs: noun-noun	fo	288	.70	.47	.82	.81	.01	.13
78			type of word pairs: adjective-adjective	fo	288	.76	.31	.92	.85	.07	.89
79			type of word pairs: adjective-noun	fo	288	.79	.44	.96	.87	.09	1.14
80	Rabinowitz et al. (1977)	1	Rn old/new	fr	96	.87	.58	.98	.93	.05	.63
81			Rn old only	fr	96	.77	.79	.85	.86	-.01	-.13
82		2	list A, repl of Watkins & Tulving (1975), Exp 5	fr	192	.49	.51	.62	.61	.01	.13
83			list B, repl of Watkins & Tulving (1975), Exp 5	fr	192	.49	.59	.61	.61	.00	.00
84		3	list A, repl of Exp 2	fr	216	.52	.53	.71	.64	.07	.89
85			list B, repl of Exp 2	fr	216	.56	.73	.64	.68	-.04	-.51
86		4	list A, repl of Exp 3, backw Rc betw Rn and Rc	fr	192	.63	.57	.75	.75	.00	.00
87			list B, repl of Exp 3, backw Rc betw Rn and Rc	fr	192	.51	.56	.64	.64	.00	.00

APPENDIX (continued)

88	5	1st Rn test, repl of Exp 4	fr	384	.60	.67	.68	.72	-.04	-.51
89		both Rn tests, repl of Exp 4	fr	384	.67	.67	.75	.78	-.03	-.38
90	6	unrel pairs, 12 sessions of Rn, forw Rc, backw Rc	fr	1728	.72	.65	.85	.82	.03	.38
91	7	1st Rn test, same subj as in Exp 6	fr	284	.80	.75	.88	.88	.00	.00
92	Tajika (1977)	high frequency assoc, subj generated Rn test	fo	300	.17	.35	.26	.24	.02	.25
93		low frequency assoc, subj generated Rn test	fo	300	.24	.37	.41	.33	.08	1.02
94		high frequency assoc, exp generated Rn test	fo	300	.98	.44	1.00	.99	.01	.13
95		low frequency assoc, exp generated Rn test	fo	300	.96	.58	.98	.98	.00	.00
96		high frequency assoc, Rn test item gen by other subj	fo	300	.77	.52	.83	.86	-.03	-.38
97		low frequency assoc, Rn test item gen by other subj	fo	300	.80	.56	.80	.88	-.08	-1.02
98	Tulving & Watkins (1977)	cue-target relation, immediate test	fr	576	.98	.95	.99	.99	.00	.00
99		cue-target relation, delayed test: 7 days	fr	576	.51	.60	.65	.64	.02	.13
100		cue-target relation: weak	fr	768	.78	.59	.87	.86	.01	.13
101	Humphreys (1978)	no study, Rn of fame names, descr phrase as cue for Rc	fr	864	.30	.42	.46	.41	.05	.63
102	Muter (1978)	free assoc, high frequency assoc, same context	fo	240	.88	.91	.93	.93	.00	.00
103	Tajika (1978a)	free assoc, high frequency assoc, diff context	fo	240	.39	.54	.37	.51	-.14	-1.78*
104		low frequency assoc, same context	fo	240	.90	.94	.95	.95	.00	.00
105		low frequency assoc, diff context	fo	240	.26	.65	.35	.36	-.01	-.13
106		nonverbal task, high frequency assoc, same context	fo	240	.79	.95	.82	.87	-.05	-.63
107		nonverbal task, high frequency assoc, diff context	fo	240	.68	.53	.75	.79	-.04	-.51
108		low frequency assoc, same context	fo	240	.83	.92	.90	.90	.00	.00
109		low frequency assoc, diff context	fo	240	.56	.53	.62	.68	-.06	-.76
110	Tajika (1978b)	free assoc task	fo	330	.34	.44	.43	.45	-.02	-.25
111		nonverbal task	fo	330	.64	.46	.72	.76	-.04	-.51
112		free assoc task	fo	600	.19	.37	.30	.27	.03	.38
113		nonverbal task	fo	270	.52	.42	.64	.64	.00	.00
114		free assoc task	fo	330	.21	.27	.37	.29	.08	1.01
115		nonverbal task	fo	360	.52	.36	.69	.64	.05	.63
116	Wallace (1978)	1 weak cue target pairs, Rn, cued Rc	fr	384	.59	.59	.68	.71	-.03	-.38
117		2 weak cue target pairs, Rn, cued Rc	fr	384	.48	.58	.67	.60	.07	.89
118		3 weak cue target pairs, Rn, cued Rc, no lures in Rn	fr	384	.60	.61	.74	.72	.02	.25
119	Begg (1979)	1 meaningful instructions	fr	800	.76	.58	.79	.85	-.06	-.76
120		rote learning instructions	fr	800	.61	.23	.84	.73	.11	1.40
121		2 meaningful instr, freq-varied pairs, common resp	fr	90	.79	.62	.87	.87	.00	.00
122		meaningful instr, freq-varied pairs, rare resp	fr	90	.91	.37	.94	.95	-.01	-.13
123		meaningful instr, concret-varied pairs, abstract resp	fr	120	.69	.38	.78	.80	-.02	-.25
124		meaningful instr, concret-varied pairs, concrete resp	fr	120	.86	.32	.92	.92	.00	.00
125		meaningful instr, freq-concrt-var pairs abstr-common resp	fr	120	.77	.49	.81	.86	-.05	-.63
126		meaningful instr, freq-concrt-var pairs concret-rare resp	fr	120	.94	.28	.97	.97	.00	.00
127		root learn instr, freq-varied pairs, common resp	fr	90	.69	.23	.95	.80	.15	1.90*
128		root learn instr, freq-varied pairs, rare resp	fr	90	.89	.04	1.00	.94	.06	.76
129		root learn instr, concret-varied pairs, abstract resp	fr	120	.58	.05	1.00	.70	.30	3.81*
130		root learn instr, concret-varied pairs, concret resp	fr	120	.68	.03	1.00	.79	.21	2.66*
131		root learn instr, freq-concrt-var pairs, common resp	fr	120	.58	.13	.81	.70	.11	1.40
132		root learn instr, freq-concrt-var pairs, concret-rare resp	fr	120	.73	.07	.88	.83	.05	.63

APPENDIX (continued)

133	3	list 1, separate processing of pairs	fr 520	.56	.02	.28	.68	-.40	-5.08*
134		list 1, joint processing of pairs	fr 520	.43	.08	.59	.54	.05	.63
135		list 2, separate processing of pairs	fr 520	.69	.04	.86	.80	.06	.76
136		list 2, joint processing of pairs	fr 520	.49	.17	.58	.61	-.03	-.38
137		repeated, separate processing of pairs	fr 520	.88	.04	.88	.93	-.05	-.63
138		repeated, mixed: separate, joint	fr 1040	.78	.27	.81	.87	-.06	-.76
139		repeated, joint processing of pairs	fr 520	.64	.42	.64	.76	-.12	-1.52
140	Bowyer & Humphreys (1979)	1 weak cue target pairs, priming between subjects	fr 1152	.71	.68	.77	.81	-.04	-.51
141		2 weak cue target pairs, priming within subjects	fr 720	.63	.64	.73	.75	-.02	-.25
142	Fisher (1979)	2 repetition rehearsal, low-low cue target assoc	fr 144	.62	.24	.91	.74	.17	2.16*
143		repetition rehearsal, low-high cue target assoc	fr 144	.64	.31	.89	.76	.13	1.65
144		repetition rehearsal, high-low cue target assoc	fr 144	.46	.63	.62	.58	.04	.51
145		repetition rehearsal, high-high cue target assoc	fr 144	.63	.65	.74	.75	-.01	-.13
146		meaningful rehearsal, low-low cue target assoc	fr 144	.78	.63	.86	.87	-.01	-.13
147		meaningful rehearsal, low-high cue target assoc	fr 144	.92	.65	.96	.96	.00	.00
148		meaningful rehearsal, high-low cue target assoc	fr 144	.60	.86	.65	.72	-.07	-.89
149		meaningful rehearsal, high-high cue target assoc	fr 144	.81	.84	.88	.89	-.01	-.13
150	Lieury (1979)	1 weak pairs, free assoc, strong extra-list cue to target	fr 361	.67	.50	.84	.78	.06	.76
151		2 weak pairs, free assoc, strong extra-list cue to cue	fr 108	.82	.64	.95	.89	.06	.76
152	Tajika (1979)	1 free assoc, different context	fo 300	.52	.51	.53	.64	-.11	-1.40
153		nonverbal task, different context	fo 300	.67	.51	.69	.78	-.09	-1.14
154		2 free association, same context	fo 300	.76	.59	.86	.85	.01	.13
155		nonverbal task, same context	fo 300	.88	.67	.91	.93	-.02	-.25
156	Vining & Nelson (1979)	1 strong cue target pairs	fo 520	.81	.91	.84	.89	-.05	-.63
157		weak cue target pairs	fo 560	.84	.70	.90	.91	-.01	-.13
158		unrelated cue target pairs	fo 540	.84	.52	.91	.91	.00	.00
159	Gardiner & Tulving (1980)	1 standard group, abstract lists	fr 320	.58	.14	.82	.70	.12	1.52
160		standard group, digit lists	fr 320	.51	.18	.93	.64	.30	3.68*
161		special group, abstract lists	fr 320	.68	.28	.84	.79	.05	.63
162		special group, digit lists	fr 320	.69	.37	.89	.80	.09	1.14
163		standard group, abstract lists	fr 320	.58	.11	.82	.70	.12	1.52
164		standard group, digit lists	fr 320	.53	.13	.85	.66	.20	2.41*
165		special group, abstract lists	fr 320	.69	.48	.84	.80	.04	.51
166		special group, digit lists	fr 320	.74	.52	.87	.84	.03	.38
167	Nilsson & Shaps (1980)	1 cat name cat instance pair, cat name as Rc cue	fo 480	.88	.56	.99	.93	.06	.76
168		2 study of cat instance only, cat name as Rc cue	fo 480	.70	.41	.99	.81	.19	2.28*
169		3 same as Exp 1, immediate test	fo 480	.94	.81	.97	.97	.00	.00
170		same as Exp 1, delayed test	fo 480	.81	.81	.95	.89	.06	.76
171	Shaps & Nilsson (1980)	1 weak cue-target pairs, young subj	fo 240	.83	.69	.93	.90	.03	.38
172		weak cue-target pairs, old subj	fo 240	.85	.43	.98	.91	.07	.89
173		strong cue-target pairs, young subj	fo 240	.90	.88	.94	.95	-.01	-.13
174		strong cue-target pairs, old subj	fo 240	.84	.79	.87	.91	-.04	-.51
175		weak cue-target pairs, young subj	fo 240	.81	.66	.88	.89	-.01	-.13
176		weak cue-target pairs, old subj	fo 240	.75	.43	.91	.84	.07	.89
177		strong cue target pairs, young subj	fo 240	.66	.84	.75	.77	-.02	-.25

APPENDIX (continued)

178		strong cue target pairs, old subj	fo	240	.81	.83	.83	.89	-.06	-.76
179	Nilsson & Shaps (1981)	1 type of pair: category name-instance (high frequency)	fo	560	.88	.68	.98	.93	.05	.63
180		type of pair: category name-instance (low frequency)	fo	560	.94	.61	.98	.97	.01	.13
181		2 type of pair: category name-instance (high frequency)	fo	480	.86	.67	.99	.92	.07	.89
182		type of pairs: category name-instance (medium frequency)	fo	480	.88	.62	1.00	.93	.07	.89
183		type of pairs: category name-instance (low frequency)	fo	480	.90	.56	1.00	.94	.06	.76
184		3 type of pairs: category name-high instance 4-AFC	fo	156	.84	.81	.98	.91	.07	.89
185	Neely & Payne (1983)	type of pairs: category name-high instance 6-AFC	fo	156	.88	.85	.98	.93	.05	.63
186		famous names from study, semantic group	fr	585	.69	.67	.81	.80	.01	.13
187		famous names not from study, semantic group	fr	580	.43	.52	.59	.56	.04	.38
188		famous names from study, episodic group	fr	559	.77	.60	.85	.86	-.01	-.13
189		nonfamous names from study, episodic group	fr	557	.71	.12	.96	.81	.15	1.90*
190		related word pairs, semantic group	fr	585	.81	.67	.87	.89	-.02	-.25
191		related word pairs, semantic group (replication)	fr	456	.79	.58	.88	.87	.01	.13
192		related word pairs, episodic group	fr	563	.75	.52	.90	.84	.06	.76
193		related word pairs, episodic group (replication)	fr	561	.80	.66	.85	.88	-.03	-.38
194		unrelated word pairs, semantic group	fr	584	.79	.48	.90	.87	.03	.38
195		unrelated word pairs, semantic group (replication)	fr	455	.78	.40	.88	.87	.01	.13
196		unrelated word pairs, episodic group	fr	561	.72	.32	.90	.82	.08	1.02
197	Payne & Neely (1983)	unrelated word pairs, episodic group (replication)	fr	562	.75	.39	.82	.84	-.02	-.25
198		semantic Rn, episodic Rn	fr	455	.71	.57	.87	.81	.06	.76
199		episodic Rn, semantic Rn	fr	527	.78	.66	.81	.87	-.06	-.76
200	Muter (1984)	type of targets: common names	fr	576	.46	.44	.65	.58	.07	.89
201		type of targets: unique names	fr	576	.47	.26	.99	.59	.40	5.08*
202	Rabinowitz (1984)	weak cue target pairs, young subj	fr	576	.61	.62	.71	.73	-.02	-.25
203		weak cue target pairs, old subj	fr	576	.49	.38	.57	.61	-.04	-.51
204	Nilsson et al. (1987)	1 cat name hi-inst pairs, no Rn lures, cat name cue in Rc	fr	180	.77	.68	.82	.86	-.04	-.51
205		cat name lo-inst pairs, no Rn lures, cat name cue in Rc	fr	180	.80	.55	.87	.88	-.01	-.13
206		cat inst hi-inst pairs, no Rn lures, cat name cue in Rc	fr	180	.71	.63	.75	.81	-.06	-.76
207		cat inst lo-inst pairs, no Rn lures, cat name cue in Rc	fr	180	.79	.44	.86	.87	-.01	-.13
208		assoc hi-inst pairs, no Rn lures, cat name cue in Rc	fr	180	.73	.59	.85	.83	.02	.25
209		assoc lo-inst pairs, no Rn lures, cat name cue in Rc	fr	180	.77	.44	.84	.86	-.02	-.25
210		cat name hi-inst pairs, no Rn lures, cat name cue in Rc	fr	144	.80	.84	.86	.88	-.02	-.25
211		cat name lo-inst pairs, no Rn lures, cat name cue in Rc	fr	144	.82	.66	.88	.89	-.01	-.13
212		cat inst hi-inst pairs, no Rn lures, cat inst cue in Rc	fr	144	.70	.74	.81	.81	.00	.00
213		cat inst lo-inst pairs, no Rn lures, cat inst cue in Rc	fr	144	.81	.59	.95	.89	.06	.76
214		assoc hi-inst pairs, no Rn lures, assoc cue in Rc	fr	144	.71	.65	.80	.81	-.01	-.13
215		assoc lo-inst pairs, no Rn lures, assoc cue in Rc	fr	144	.73	.52	.87	.83	.04	.51
216		cat name hi-inst pairs, cat name cue in Rc	fr	144	.71	.69	.83	.81	.02	.25
217		cat name lo-inst pairs, cat name cue in Rc	fr	144	.82	.51	.96	.89	.07	.89
218		cat inst hi-inst pairs, cat name cue in Rc	fr	144	.70	.49	.82	.81	.01	.13
219		cat inst lo-inst pairs, cat name cue in Rc	fr	144	.75	.35	.91	.84	.07	.89
220		assoc hi-inst pairs, cat name cue in Rc	fr	144	.66	.44	.80	.77	.03	.38
221		assoc lo-inst pairs, cat name cue in Rc	fr	144	.73	.25	.88	.83	.05	.63
222	Donnelly (1988)	1 phrase word pairs, immediate test	fr	216	.95	.90	.98	.97	.01	.13

APPENDIX (continued)

223			phrase word pairs, delayed test: 3 days	fr	216	.43	.49	.57	.55	.02	.25
224			phrase word pairs, delayed test: 2 weeks	fr	216	.31	.39	.49	.42	.07	.89
225		2	phrase word pairs, immediate test	fr	576	.92	.84	.94	.96	-.02	-.25
226			phrase word pairs, delayed test: 1 week	fr	576	.38	.42	.50	.50	.00	.00
227			phrase word pairs, delayed test: 4 weeks	fr	576	.34	.32	.44	.45	-.01	-.13
228	Gardiner (1988)	1	cued recall overall	fr	384	.73	.66	.84	.83	.01	.13
229			free recall failures	fr	250	.62	.54	.72	.74	-.02	-.25
230		2	cued recall (control), strict	fr	288	.52	.57	.68	.65	.03	.38
231			cued recall overall, strict	fr	288	.56	.62	.67	.69	-.02	-.25
232			free recall failures, strict	fr	200	.46	.54	.56	.59	-.03	-.38
233			cued recall (control), lenient	fr	288	.68	.65	.82	.79	.03	.38
234			cued recall overall, lenient	fr	288	.72	.64	.80	.82	-.02	-.25
235			free recall failures, lenient	fr	200	.60	.56	.69	.72	-.03	-.38
236	Nilsson, Law & Tulving (1988)		phrase pers name pairs, lo meaningful	fr	412	.25	.16	.38	.34	.04	.51
237			phrase pers name pairs, med meaningful	fr	543	.36	.36	.52	.48	.04	.51
238			phrase pers name pairs, hi meaningful	fr	738	.45	.55	.53	.57	-.04	-.51
239			phrase geography name pairs, low meaningful	fr	832	.11	.05	.31	.16	.15	1.90*
240			phrase geography name pairs, med meaningful	fr	504	.16	.12	.28	.23	.05	.63
241			phrase geography name pairs, hi meaningful	fr	355	.21	.26	.34	.29	.05	.63
242	Sandberg (1988)		weak cue target pairs, Rn instruction	fr	528	.60	.33	.73	.74	-.01	-.13
243			weak cue target pairs, cued Rc instruction	fr	528	.65	.37	.81	.76	.05	.63
244			weak cue target pairs, free Rc instruction	fr	528	.61	.25	.74	.73	.01	.13
245	Svensson & Nilsson (1989)		enactment of verbal commands	fr	324	.94	.77	.94	.97	-.03	-.38
246			nonenactment of verbal commands	fr	324	.84	.45	.97	.91	.06	.76
247	Jones & Gardiner (1990)	1	congruous cue, mixed cue target relation, Rc lures	fr	192	.54	.63	.60	.67	-.07	-.89
248			incongruous cue, mixed cue target relation, Rc lures	fr	192	.50	.59	.59	.63	-.04	-.51
249			identical cue, mixed cue target relation, Rc lures	fr	192	.39	.39	.77	.51	.26	3.30*
250			congruous cue, mixed cue target relation, no Rc lures	fr	96	.50	.55	.62	.63	-.01	-.13
251			incongruous cue, mixed cue target relation, no Rc lures	fr	96	.38	.60	.52	.50	.02	.25
252			identical cue, mixed cue target relation, no Rc lures	fr	96	.21	.22	.67	.29	.38	4.82*
253			incongruous cue, pure cue target relation, no Rc lures	fr	96	.39	.52	.52	.51	.01	.13
254			identical cue, pure cue target relation, no Rc lures	fr	96	.57	.41	.87	.69	.18	2.28*
255			congruous cue, mixed cue target relation, Rc lures	fo	192	.86	.71	.88	.92	-.04	-.51
256			incongruous cue, mixed cue target relation, Rc lures	fo	192	.77	.63	.82	.86	-.04	-.51
257			identical cue, mixed cue target relation, Rc lures	fo	192	.72	.56	.85	.82	.03	.38
258			congruous cue, mixed cue target relation, no Rc lures	fo	96	.81	.64	.89	.89	.00	.00
259			incongruous cue, mixed cue target relation, no Rc lures	fo	96	.76	.63	.80	.85	-.05	-.63
260			identical cue, mixed cue target relation, no Rc lures	fo	96	.53	.54	.60	.66	-.06	-.76
261			incongruous cue, pure cue target relation, no Rc lures	fo	96	.76	.56	.84	.85	-.01	-.13
262			identical cue, pure cue target relation, no Rc lures	fo	96	.82	.57	.95	.90	.05	.63
263	Gardiner et al. (1990)	1	Rn, Rc of music: folksongs	fr	324	.77	.75	.82	.86	-.04	-.51
264		2	Rn, Rc of music: classical	fr	270	.52	.75	.59	.64	-.05	-.63
265	Sandberg (1990)		word-word forming word, 1 pres., Rc instruction	fr	200	.45	.47	.57	.57	.00	.00
266			word-word forming word, 5 pres., Rc instruction	fr	200	.79	.83	.82	.87	-.05	-.63
267			nonword-nonword forming word, 1 pres., Rc instruction	fr	200	.52	.57	.61	.65	-.04	-.51

APPENDIX (continued)

268	nonword-nonword forming word, 5 pres., Rc instruction	fr	200	.65	.77	.68	.76	-.08	-1.02
269	word-word forming nonword, 1 pres., Rc instruction	fr	200	.52	.11	.91	.65	.26	3.30*
270	word-word forming nonword, 5 pres., Rc instruction	fr	200	.80	.45	.98	.88	.10	1.27
271	nonword-nonword forming nonword, 1 pres., Rn instruction	fr	200	.38	.03	.67	.50	.17	2.16*
272	nonword-nonword forming nonword, 5 pres., Rn instruction	fr	200	.74	.32	.88	.84	.04	.51
273	word-word forming word, 1 pres., Rn-Rc instruction	fr	200	.53	.60	.58	.66	-.08	-1.02
274	word-word forming word, 5 pres., Rn-Rc instruction	fr	200	.81	.88	.81	.89	-.08	-1.02
275	nonword-nonword forming word, 1 pres., Rn-Rc instruction	fr	200	.63	.63	.70	.75	-.05	-.63
276	nonword-nonword forming word, 5 pres., Rn-Rc instruction	fr	200	.74	.88	.76	.84	-.08	-1.02
277	word-word forming nonword, 1 pres., Rn-Rc instruction	fr	200	.61	.20	.85	.73	.12	1.52
278	word-word forming nonword, 5 pres., Rn-Rc instruction	fr	200	.80	.45	.95	.89	.06	.76
279	nonword-nonword forming nonword, 1 pres., Rn-Rc instr.	fr	200	.55	.03	.67	.67	.00	.00
280	nonword-nonword forming nonword, 5 pres., Rn-Rc instr.	fr	200	.69	.23	.96	.80	.16	2.03*
281 Bryant (1991)	1 structural encoding	fr	168	.56	.28	.85	.68	.17	2.16*
282	phonetic encoding	fr	168	.69	.38	.93	.80	.13	1.65*
283	semantic encoding	fr	168	.84	.55	.92	.91	.01	.13
284	no cue-target association	fr	360	.53	.06	.95	.65	.30	3.81*
285	weak cue-target association	fr	360	.63	.35	.97	.75	.22	2.79*
286	strong cue-target association	fr	360	.65	.60	.85	.76	.09	1.14
287 Rönnerberg et al. (1991)	6 Rn, Rc of prose, 3 trials, 4 h delay	fr	252	.57	.68	.66	.69	-.03	-.38
288	Rn, Rc of prose, 6 trials, 4 h delay	fr	252	.45	.66	.55	.57	-.02	-.25
289	Rn, Rc of prose, 3 trials, 24 h delay	fr	252	.43	.64	.54	.55	-.01	-.13
290	Rn, Rc of prose, 6 trials, 24 h delay	fr	252	.57	.77	.60	.69	-.09	-1.14
291	Rn, Rc of prose, 3 trials, 4 h delay, thematic target	fr	480	.40	.70	.46	.52	-.06	-.76
292	Rn, Rc of prose, 3 trials, 4 h delay, non-thematic target	fr	480	.25	.51	.34	.34	.00	.00
293	Rn, Rc of prose, 3 trials, 24h delay, thematic target	fr	480	.42	.77	.49	.54	-.05	-.63
294	Rn, Rc of prose, 3 trials, 24h delay, non-thematic target	fr	480	.35	.60	.43	.46	-.03	-.38
295 Arleman & Nilsson (1992)	noun-adjective pairs, 5 presentations, Rc instruction	fo	480	.59	.60	.76	.71	.05	.63
296	adjective-noun pairs, 5 presentations, Rc instruction	fo	480	.80	.46	.91	.88	.03	.38
297	noun-adjective pairs, 1 presentation, Rc instruction	fo	480	.30	.28	.57	.41	.16	2.03*
298	adjective-noun pairs, 1 presentation, Rc instruction	fo	480	.49	.16	.85	.62	.23	2.92*
299	noun-adjective pairs, 5 presentations, Rn-Rc instruction	fo	480	.52	.48	.65	.65	.00	.00
300	adjective-noun pairs, 5 presentations, Rn-Rc instruction	fo	480	.67	.38	.86	.78	.08	1.02
301	noun-adjective pairs, 1 presentation, Rn-Rc instruction	fo	480	.20	.22	.47	.29	.18	2.28*
302	adjective-noun pairs, 1 presentation, Rn-Rc instruction	fo	480	.34	.10	.83	.45	.38	4.82*

Note—Rn-t, type of recognition test, free (fr) or forced (fo) choice recognition; N, number of observations, items × subjects; Rn, recognition performance; Rc, recall performance; Obs, observed probability of recognition given recall; Pred, predicted probability of recognition given recall on the basis of Equation 1; Diff, difference between Obs and Pred; Cr, critical ratio. Rounding errors may occur in the column showing differences between Obs and Pred (Diff). Free versus forced choice recognition was a within-subject variable in Watkins and Tulving (1975), and in Wiseman and Tulving (1976). *Conditions that exceed the 90% confidence level (see text).