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REJOINDER

Hypermnesia: The Importance of Recall Time and Asymptotic Level of Recall

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The points raised by Erdelyi are briefly discussed. He argues that some experiments failing to find level of recall on a first test related to gains across tests provide exceptions to our claims. Most of these alleged exceptions are unrelated to our proposal, since our assertion that level of recall and hypermnesia were correlated specified that recall level referred to asymptotic recall, not that on a first test. The importance of considering recall time as well as recall level in accounting for gains across tests is discussed. The second point, the difficulty in distinguishing between imaginal and other coding factors in accounts of hypermnesia, is not inconsistent with our proposal, as we did not favor a levels of processing account. Consideration of coding factors without regard to retrieval factors will not provide an adequate account of hypermnesia.

Erdelyi's (1982) comment on our work makes two points. The first is that existing evidence discredits the notion that hypermnesia is related to level of recall; the second emphasizes the difficulty in deciding between level of processing and imagery accounts of hypermnesia. I agree with the second—though, of course, we did not argue for a levels of processing account—but think that the first is premature.

Erdelyi (1982) argues that there are numerous exceptions to the generalization that hypermnesia is related to level of recall. Unfortunately, none of Erdelyi's remarks directly addresses the ideas we put forward, since we specifically refer to level of recall as the asymptote of the cumulative recall function and he chooses to refer to level of recall as performance on the first test in a multiple test situation. Thus we find most of the alleged exceptions irrelevant to our proposal, for reasons indicated below.

First the main points of our reasoning must be briefly reiterated. (a) Hypermnesia—increased recall across repeated tests—is equivalent in terms of the total number of items recalled to performance during a single long test of the same duration. (b) Since hypermnesia is equivalent to cumulative recall, properties of cumulative recall curves are critical for understanding the phenomenon. (c) These cumulative recall curves typically exhibit the property of a negative correlation between the asymptote, $n(\infty)$, and the rate of approaching that asymptote, λ. (d) Since the rate of approaching the asymptote is greater with lower levels of asymptotic recall, if recall is stopped after a fixed period of time performance will be nearer the asymptote in cases of lower than higher recall. Thus further potential gains in recall (hypermnesia) will be greater in cases of higher asymptotic recall. To take a concrete example, examine Figure 10 in the Roediger, Payne, Gillespie, and Lean (1982) article and imagine recall stopped (as it was) after the first 10 minutes. Obviously, only in the case of *birds* and *sports* is there much room for improvement thereafter. (e) Therefore, hypermnesia (recall growth on repeated tests) will tend to be correlated with recall level, $n(\infty)$. The reason for the greater level of recall, $n(\infty)$, in one condition over another should not matter.

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Putting the matter simply, if the first recall test lasts so long as to exhaust a person's knowledge under the set of retrieval conditions used (typically noncued recall), then no improvement can be expected on later tests. If recall is not exhausted by the first test, hypermnesia may be expected and should occur in direct proportion to the eventual level of recall. Thus hypermnesia can be predicted under certain conditions whenever some variable acts to increase asymptotic levels of recall. (The "certain conditions" referred to have to do chiefly with recall time, as illustrated below.) This conclusion thus becomes almost inescapable, so long as the critical assumption (a) above is made. (The finding that recall in a single long test is equivalent to that from several shorter ones of equal total time has now been shown in four experiments: Roediger and Thorpe (1978, Experiments 1 and 2); Roediger et al. (1982, Experiments 1 and 2).)

Erdelyi's (1982) proposed exceptions to the generalization that recall level and hypermnesia are correlated are based, as *noted above, on recall level defined as* performance on a first test rather than as asymptotic recall. Properly considered, our proposal can provide a tentative account of all the cases mentioned except one. The exceptions can be divided into three classes, which we treat separately.

The first class, which can probably be dismissed out of hand, involves cross experiment comparisons in which recall levels vary, but are confounded with numerous other variables. For example, Erdelyi (1982) compares recall of 50 nonsense syllables presented three times at a 5-second rate in our Experiment 2 with recall of 20 words presented once with a semantic orienting task (among 40 other words) at a 10-second rate in our Experiment 1. Given the number of confounded variables in such a comparison, the finding that absolute level of recall on a first test and improvements across tests are not correlated in this instance hardly seems relevant. Since the scales differ, one would somehow have to convert performance to a common scale before cumulative recall curves could even be usefully compared. These problems also exist in the comparisons made between Yarmey's (1976) and Madigan's (1976) experiments, as well as between the two experiments in the latter paper.

A second class of exception takes the form of some variable X not having an effect on a first recall test, but exerting its effect on later tests. The variables seeming to produce such a pattern include generation of words versus reading them (Erdelyi, Buschke, & Finkelstein, 1977) and studying words versus pictures (Erdelyi & Becker, 1974; Erdelyi & Kleinbard, 1978). One problem in establishing these exceptions hinges on the reliability of the observation of no difference on the first test. Numerous studies have shown reliable effects of generating versus reading words on a single test (e.g., Slamecka & Graf, 1978; McElroy & Slamecka, 1982), as well as a difference between recall of words presented by themselves or when generated in response to pictures (e.g., Paivio & Csapo, 1973). Thus we can question the reliability of studies failing to find such differences on a first test. Even if such reliability is established, it has no critical bearing on the ideas we put forward, since they are concerned with asymptotic recall. It could be, for example, that recall of words and pictures is equal after a first recall test, but diverges after that because cumulative recall of words has reached the asymptote while that of pictures continues to increase. Such analysis of cumulative recall functions may also provide an accounting of the unpublished picture–word study described by Erdelyi (1982). The general point is that in absence of the cumulative recall functions one cannot properly evaluate the notions put forth.

The same problem bedevils the third sort of exception claimed by Erdelyi (1982). In these cases differences in recall on a first test exist, but in some conditions hypermnesia does not occur when recall is

increased relative to some other condition. For example, Yarmey (1976) reported reliable differences in initial recall levels between pictures, high imagery words, and low imagery words, but only found hypermnesia in the picture condition. Despite the advantage in recall of concrete to abstract words, no hypermnesia was found in the case of concrete words. Madigan and Lawrence (1980) reported a similar pattern with colored pictures showing hypermnesia, but not with line drawings or concrete words, despite superiority in recall on the first test of line drawings to the words. By our account, such a pattern might occur if recall has reached the asymptote at the end of the first test for the conditions showing low and intermediate recall, but not the highest levels of recall. Of course, such a possibility cannot be evaluated without cumulative recall curves, which were not presented in the studies mentioned.

By our account it is quite possible to find large differences in recall but no hypermnesia when the first recall test lasts so long as to permit subjects to reach asymptote. Let us assume that two groups of subjects are presented material under different conditions that have a large impact on recall. Assume that the group recalling fewest items reaches asymptote after 5 minutes and the other group, recalling more, after 10. If a researcher tested for hypermnesia by giving subjects in these conditions three 10-minute tests, he or she would find a large difference in overall recall, but no hypermnesia in either condition. Whether or not hypermnesia will be found in a multiple test situation will depend on considerations of recall time as well as recall level, and such considerations can only be assessed with measures of cumulative recall.

A true exception to our view would be the finding of equivalent amounts of hypermnesia in two conditions differing in recall level. That is, if reliable hypermnesia is found in both conditions, it should be greater in the condition with higher recall, as in Experiments 1 and 3 of Roediger et al. (1982). An exception to this predicted interaction between recall level and hypermnesia is represented in Madigan's (1976) research. He reported roughly equivalent and reliable increases in recall across two tests for pictures presented once or twice, despite an advantage in overall recall of twice-presented pictures. This outcome may represent the only important exception to our claims, and even here in the relevant cumulative recall curves are not available.

The pattern of data reported by Madigan (1976) is quite different from that in the three experiments we reported, as well as in many others reviewed in Roediger et al. (1982). Only further research examining the relation between asymptotic level of recall and growth of recall across tests can settle this issue, but the cumulative recall data in hand argue strongly for the important role of recall level and recall time in determining hypermnesia. How can recall improve across tests if a first test lasts so long as to exhaust knowledge under the particular set of retrieval conditions employed?

Turning to the role of imagery in producing hypermnesia, the remarks of the Roediger et al. (1982) article stand. The research strategy we chose was to manipulate recall in ways not usually thought to involve imaginal coding. Finding hypermnesia correlated with level of recall under these conditions, we concluded that imaginal coding was not an important determinant, but that level of recall was. Erdelyi (1982) faults us for not including conditions with picture presentations, but such were not needed to demonstrate the points we wanted to make. Almost all studies show hypermnesia with pictures, hence our interest in examining other situations.

Interestingly, some of the studies Erdelyi (1982) cites to show that recall level is not correlated with hypermnesia do more to discredit the imagery hypothesis than our

own proposal. For example, Madigan and Lawrence (1980) failed to find hypermnesia with line drawings, whose coding presumably involved imagery. Similarly, Yarmey (1976) failed to find hypermnesia with concrete words, though finding an advantage of concrete to abstract words in recall. The latter is usually attributed to greater imaginal coding of concrete words (Paivio, 1969). In addition, Madigan (1976, Experiment I) did not find greater hypermnesia with twice-presented than with once-presented pictures, though a reasonable assumption would be that the imaginal trace was stronger in the former condition. Of course, these findings should produce little difficulty for an imagery hypothesis that is flexible enough to permit imaginal coding for words processed with phonetic and semantic orienting tasks, nonsense syllables presented three times, and birds and sports (but not presidents) retrieved from semantic memory.

To reiterate a point made in our article, an explanation for hypermnesia based strictly on coding factors will certainly be inadequate, as retrieval factors have been shown to be most important (e.g., Roediger & Payne, 1982). Thus we would agree that any debate over the coding basis of the effect (e.g., whether imagery or depth of processing is responsible) that ignores retrieval considerations will be unproductive and certainly we did not favor a depth of processing interpretation of our results.

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