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ABSTRACT

Research has demonstrated that subjects are sensitive to both thematic and non-thematic information in pictorial stimuli. Three experiments were conducted to investigate memory for pictures under conditions of difficult foil discriminability and lengthy retention intervals. The foils differed from the studied persons in the number and quality of non-thematic details that were added or deleted. In each experiment, college students viewed colored photographs, black and white photographs, elaborated line drawings, and unelaborated line drawings. Subjects (N=81) in Experiment 1 were given an old/new test either immediately, 1 day, 1 week, or 1 month after viewing the pictures. Subjects (N=92) in Experiment 2 were given a 4-alternative forced-choice test at the same time intervals. Subjects (N=40) in Experiment 3 were given the old/new test 3 months after viewing the pictures. The results revealed that, with a yes/no procedure, performance was best on colored photographs, with performance on each stimulus type additive across the retention interval. For the forced-choice test, performance on colored photographs and unelaborated line drawings was best, with performance again additive across delay. A confusion analysis indicated errors were based on physical similarity even after 3 months. These results refute the hypothesis that the memorial representations for pictorial variations converge to a common, thematic code after lengthy delays; rather, non-thematic, analogue information is encoded and preserved for lengthy time periods. (Author/NB)

Title: Long-Term Memory for Pictures under Conditions of Difficult Foil Discriminability

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Abstract

Memory for pictures 'as investigated under conditions of difficult foil discriminability and lengthy retention intervals. The foils differed from the studied versions in the number and quality of non-thematic details that were added or deleted. In each experiment, subjects viewed colored photographs, black and white photographs, elaborated line drawings, and unelaborated line drawings, followed by an old/new (Experiment ') or 4-alternative forced-choice (Experiment 2) test given either immediately, 1 day, 1 week, or 1 month later; Experiment 3 replicated Experiment 1 but with a 3 month delay. With a yes/no procedure, performance was best on colored photographs, with performance on each stimulus type additive across the retention interval. For the forced-choice test, performance on colored photographs and unelaborated line drawings was best, with performance again additive across delay. A confusion analysis indicated errors were based on physical similarity, even after 3 months. These results refute the hypothesis that the memorial representations for pictorial variations converge to a common, thematic code after lengthy delays; rather, non-thematic, analogue information is encoded and preserved for lengthy time periods.

Results from a variety of studies have demonstrated that subjects are sensitive to both thematic and non-thematic information in pictorial stimuli. When permitted to freely inspect a painting, Yarbus (1967) found that subjects fixated 5-6 locations. With additional viewing time, the majority of fixations were not distributed to novel locations but involved refixating the same 5-6 locations, often in the same order. Interestingly, the subject's scan path was markedly altered when the prior set was changed. From these results, Yarbus concluded that the scan path reflected ongoing thought and was the subject's attempt to extract thematic information. In a somewhat different vein, Biederman and his coworkers (Biederman, 1972; Biederman, Glass, & Stacy, 1973; Biederman, Rabinowitz, Glass, & Stacy, 1974) found that jumbling of a photograph differentially affected the subject's ability to identify thematic and object information. More recently, Biederman (1981) has argued that schematic (thematic) information is derived from both objects and the relations among those objects, where the latter may be characterized as involving either physical constraints (e.g., interposition) or referential meaning (e.g., probability). The deleterious effects of jumbling on thematic identification occur because object relations are violated.

What is interesting about picture memory is the potential role thematic and non-thematic information might play in explaining the high levels of accuracy frequently found (e.g., Shepard, 1967; Standing, 1973). Advocates of dual-code theory (e.g., Bower, 1972; Paivio, 1971) explain picture memory by proposing that pictures are encoded in two distinct formats, a sensory-spatial-analogue code, as well as in a semantic-thematic-abstract code. The rich visual details of a picture are stored at a sensory level, and the meaning of a picture is stored semantically. Opponents of dual-code theory have argued that subjects do not, in fact, remember the exact visual details and their spatial relations; rather, subjects remember a more abstract representation that captures the meaning of the picture (Anderson, 1985; Pylyshyn, 1984). In fact, Anderson (1978) has demonstrated that dual code and propositional theory can be framed such that their predictions are equivalent; that is, if neither theory is constrained, propositional explanations of picture memory cannot be distinguished from a dual-code interpretation.

Nonetheless, there is surprisingly little empirical data on the long-term retention of pictorial information, at least under conditions of difficult foil discriminability. In an experiment that closely mirrored some of the manipulations of the present study, Nelson, Metzler, and Reed (1974) had subjects first view black and white photographs, elaborated line drawings of these photographs, unelaborated line drawings of these photographs, or appropriate verbal descriptions of these photographs, followed by a 2-alternative forced choice test given immediately and 7 weeks later. On the immediate test, recognition performance was equivalent for the four stimulus types. However, on the test given 7 weeks later, performance was significantly worse on the verbal descriptions and equal for the three picture versions. Had subjects stored the visual details available in the picture types, then performance might have been expected to covary with stimulus detail; that is, best on the photographs, next on the elaborated line drawings, and worst on the unelaborated line drawings. Since performance on the three picture versions was equal, and since these versions differed in available visual detial but shared a common theme, support for a nonsensory, propositional explanation seemed clear.

However, there are at least 3 reasons why this interpretation should be questioned: (a) each subject worked with only one of the stimulus types; (b) the foils were semantically unrelated to the studied photographs; and (c) the immediate results were not replicated in a study that employed the same stimuli (Loftus & Bell, 1975). For the purposes of the present study, the first two criticisms are especially important. First, because the degree of discriminability required to distinguish old and new stimuli may not have been equivalent for the different stimulus types, potential performance differences among the three picture formats may have been masked by differences in foil discriminability. In addition, by using only unrelated foils, it is impossible to determine whether performance was mediated by correct retrieval of thematic or non-thematic information. In particular, Nelson et al. could not test a strong prediction of a semantic-only hypothesis: if subjects store only the meaning of a stimulus, can they later discriminate that stimulus from a foil that is theme-preserving but differing in detail? The failure to replicate the immediate results by Loftus and Bell may be due to a number of factors, including the fact that performance was at ceiling (95-100%) in the Nelson et al. study. Unfortunately, Loftus and Bell did not include a delayed test.

Results from recent studies have failed to clarify how pictures are represented in memory. Intraub and Nicklos (1985) found that memory for detailed colored photographs was better if attention was drawn to physical details rather than to meaning details, an outcome opposite to that obtained with verbal materials. Similarly, the picture superiority effect (greater memory for pictures than verbal equivalents) is reduced when a conceptually dissimilar study set is drawn to be schematically similar (Nelson, Reed, & McEvoy, 1977). These studies also employed an immediate test only.

What is needed is an assessment of picture memory over lengthy time periods, where the foils are thematically-similar but differ in detail. Under such conditions, three general predictions can be assessed. If only meaning-preserving information is stored, then performance should be equivalent on picture types that differ only in non-thematic detail, both immediately as well as after lengthy delays (performance should also be quite poor, since originals and theme-preserving foils should be nearly impossible to discriminate). If both thematic and non-thematic information are stored, then performance should be monotonic with the amount and quality of detail contained in the picture. Finally, if both thematic and non-thematic detail are initially encoded but the non-thematic detail is rapidly forgotten (or forgotten at a faster rate than thematic information), then the initial performance advantage for stimuli high in detail should vanish with sufficiently long retention intervals; that is, it should be possible to demonstrate an interaction between pictorial detail and length of the retention interval.

These predictions were assessed in the present study using four types of pictorial stimuli; colored photographs, black and white versions of the colored photographs, elaborated line drawings of the colored photographs, and unelaborated line drawings of the colored photographs. At the time of study, the subject saw different pictures in each of four formats. At the time of test, the subject had to discriminate studied items from foils that were thematically similar, differing only in the number and quality of details from the original. For example, the subject might initially see an elaborated line drawing of a stimulus and later be tested on the black and white version of the same stimulus. To the extent that thematic detail was held constant in the two versions, correct discrimination would reflect preservation of non-thematic detail. These predictions were evaluated both immediately as well as for delays as long as 1 (Experiment 1 and 2) and 3 (Experiment 3) months.

One other manipulation was used. Recognition performance on the stimulus variations might vary, depending upon how recognition was tested. In particular, the processes or subject strategies evoked by a yes/no and a forced-choice test might not be equivalent. On a 4-alternative forced-choice test, the studied item is included among three foils that differ only in detail. Correct selection of the studied item may involve comparing each alternative with the available memorial representation of the stimulus. However, only the available versions need be considered; that is, the subject need not consider whether a colored stimulus, different from the one in the array, was the correct one. In effect, the full set of potential foils was available to the subject. In contrast, a yes/no test places a greater (and different) burden on memory. In order to reject a foil in a yes/no task, the subject must retrieve information sufficient to reject the stimulus. This could involve either retrieving details not included in the presented foil or deleting details from the presented foil. Importantly, the subject must generate alternatives from memory rather than evaluating available alternatives (as is the case in a forced-choice test). For example, if the subject is presented with a black and white foil of an earlier-presented colored photograph, correct rejection may hinge upon retrieval of the appropriate colored details. This potential difference in strategy was tested by using both kinds of tests following an identical study session; in experiments 1 and 3, a yes/no procedure was used, whereas a 4-alternative forced-choice test was used in experiment 2. Potential differences in strategy for these two types of test are discussed in more detail in the General Discussion.

Experiment 1

Method

Subjects. A total of 81 introductory psychology students served as subjects to complete the course requirements. Twenty subjects were randomly assigned to one of four different delay groups; immediate, 1 day, 7 days, and 28 days. One subject in the immediate delay group was replaced as an outlier because her scores were 3.94 standard deviations below the group mean. Subjects were tested in groups of five.

Stimuli. The stimuli consisted of 96 color photographs depicting a salient theme and non-essential detail, and three sets of variations. For each colored photograph, three versions were prepared, a black and white copy, a detailed line drawing, and a sparsely detailed line drawing. The detailed line drawing was generated by tracing over the color photograph and included the non-essential detail but not the shading or fine-grained detail. The undetailed line drawing was generated by tracing over the detailed line drawing so as to preserve the salient theme of the original color photograph but eliminating all non-essential detail. The four sets of 96 items were made into 35 mm slides and presented on a Kodak carousel projector. An example of the four versions is shown in Figure 1.

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insert Figure 1 about here

Items were counterbalanced across subjects using a 4 X 4 Latin square, so that each item was presented for study in each of the four formats in all four delays. Four different presentation orders were randomly generated so that five subjects at each delay received the same presentation order during study. Additionally, four different presetnation orders were randomly generated and used in a similar manner for the test presentations.

Design and procedure. A 4 (delay) X 4 (stimulus type) mixed design was used, with the delay factor as a between-subject variable and stimulus type as a within-subject variable.

During study, all subjects were shown all 96 themes, 24 in each of the four formats, for 5 sec. Subjects were seated in a semi-circle approximately 6 feet from a white projection screen suspended from the wall. Those subjects in the immeidate condition were given an intervening arithmetic task for approximately 12-15 min immediately following the study session while the test slides were being arranged. The testing procedure for the four delays was otherwise identical.

At test, subjects were again shown all 96 items, 50% in the same format as during study, and the remainder as foils, equally distributed among the three remaining formats. Thus, of the 24 items originally viewed as color slides, 12 appeared again as color slides during the test session. Of the remaining 12, four appeared as black and white slides, four as detailed line drawings, and four as sparsely detailed line drawings. This procedure was replicated for all four formats.

Subjects were informed prior to the test that 50% of the stimuli would appear in the exact format as during study and that the remaining 50% were equally likely to appear in any of the other three formats. Subjects were told to answer "old" for only those items that appeared in exactly the same format as during study, and to respond "new" otherwise. Pre-test instructions included admonitions that theymust answer all trials, guessing when necessary. Further, subjects were required to give a confidence rating for each answer using a scale of 1-3, where 1 = uncertain, 2 = moderately certain, and 3 = very certain. The test items were presented at the rate of 5 sec per slide.

Results

Performance measures based on hit rates, a d' analysis (Green & Swets, 1966), and an accuracy measure combining correct recognitions and correct rejections (with and without the confidence judgments) all resulted in identical statistical outcomes. Analyses based on d' are reported.

Figure 2 shows the mean d' score for each stimulus type as a function of the four delays.

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insert Figure 2 about here

In general, performance decreased across the month delay by 50-70%, with overall d' scores highest for the color photograph (2.08), relative to the other stimulus types (black and white = 1.42; unembellished = 1.34; embellished = 1.07). The main effects of delay and stimulus type were both significant, $F(3, 76) = 24.00$ and $F(3, 228) = 32.46$, respectively, each $p < .001$. The interaction between delay and stimulus type was not significant, $p > .10$. Post-hoc Tukey tests revealed that performance on the color format exceeded performance on the remaining stimulus types ($p < .01$), with both black and white and unembellished better than embellished ($p < .05$). A simple analysis on the immediate test only showed that the superiority of the color format was evident on this test, $p < .001$.

The decrease in performance across delay was characterized by comparable changes in both hits and false alarms; overall, hits decreased by .150 (immediate = .778; 1 month = .628), and false alarms increased by .153 (immediate = .157; 1 month = .310). Even after a month delay, performance on each stimulus type was better than chance ($p < .01$ in each case).

Confusion Analysis. A confusion analysis was done to determine if the tendency to false alarm was a function of the study/test format, and whether these rates changed over time. For example, 24 colored photographs were presented in the study phase, and 12 appeared as old items in the test phase. The other 12 studied photographs appeared equally often as foils in the other three formats (BW = black and white; E = embellished; U = unembellished). Table 1 shows the false alarm rates for each study and test format at each delay, conditionalized upon an error; the chance confusion rate is .33.

insert Table 1 about here

A number of interesting results are apparent. First, confusions are not random but are related to the similarity of the study format. For example, on the immediate test, colored photographs and black and white photographs are frequently confused, as are elaborated and unelaborated line drawings. Second, when colored photographs and unelaborated line drawings were studied, the best foil type remained the same across the four delays (for colored photographs, the best foil throughout was the black and white photographs; for the unelaborated line drawings, the best foil throughout was the elaborated line drawings). In contrast, the best foil for black and white photographs and elaborated drawings changed over time. For example, the best foil on an immediate test for the black and white photographs was a colored photograph, but after one month, the best foil was an elaborated line drawing. Finally, confusion rates are disproportionate for each stimulus type even after one month, except for the elaborated line drawing stimuli.

Discussion

Recognition accuracy was significantly better for colored photographs, relative to the other formats, regardless of time of test. Furthermore, there was no evidence of an interaction between stimulus type and delay, which suggests that the codes representing each stimulus type were stable; that is, initial representations did not converge into a common format, at least not after a month's delay. Further support for the stability of each format across delay was found in the confusion analyses: even after one month, confusion rates were non-uniform across format.

In Experiment 2, a 4-alternative forced-choice test replaced the yes/no task used in Experiment 1. This task should maximize discriminability difficulty, since the correct choice was always paired with its three variations. To the extent that irrelevant detail is rapidly forgotten over time, then performance should rapidly decline to a common level at near-chance levels. Should stimulus type again be above chance at each delay, and should performance on stimulus type be additive with delay of test, then evidence for a stable representation based on distinguishing visual detail would again be found.

Experiment 2

Method

Subjects. A different group of 92 introductory psychology students served as subjects in Experiment 2. A total of 12 subjects were replaced as follows: In the immediate delay group, one subject was replaced for his failure to answer all trials and one subject for his failure to maintain the correct numerical response sequence. In the 1-da/ delay group, three subjects in one testing session were replaced for their inability to follow instructions; additionally, one subject failed to answer all trials, another failed to maintain the correct numerical response sequence, and an entire group of five was replaced due to the interruption of the testing session by one of the subjects who was ill and wished to discontinue the session. Subject assignment was identical to Experriment 1.

Stimuli. The same four stimulus sets from Experiment was used in the same manner during the study session. A fifth set of slides consisting of 95 of the original 96 themes was prepared in the form of a four-item array containing the four different stimuli versions (the absence of one theme from the test set was due to the inadevertent failure to photograph the test array for that theme). For all 95 test slides, the array format was as follows: the color version was shown in the upper left quadrant, the black and white version was shown in the upper right quadrant, the detailed line drawing in the lower left quadrant, and the sparsely detailed line drawing in the lower right quadrant.

Design and Procedure. The design and study procedure were identical to Experiment 1. At test, subjects were shown all 95 test arrays and were instructed to identiy the stimulus they had viewed during the study session. They were informed that during the study session, approximately 25% of the stimuli had appeared in each of the four formats, and that, for each test array, a color photograph would appear in the upper left quadrant, a black and white photograph would appear in the upper left quadrant, a detailed line drawing in the lower left quadrant, and a sparsely detailed line drawing in the lower right quadrant.

Subjects were instructed to carefully inspect each test array and to indicate which of the four stimuli had been viewed at study by recording their choice on a prepared scoresheet. They were then told to indicate their confidence, for their first choice only, by using the 1-3 confidence scale described in Experiment 1. After deciding their first choice and assessing their confidence, subject were then told to rank-order the remaining formats from most likely to least likely. If subjects were unable to rank-order their remaining choices, they could ignore them. However, they were instructed that for each trial they must always indicate their first choice and their confidence rating for that choice.

Subjects were told they would have about 10 seconds on each trial, and that, prior to the end of the trial, they would hear the word "respond". If they had not made a response by that time, they were then to write down their choices, guessing if necessary. Care was taken to insure that all subjects understood the instructions prior to commencing the test session. The test items were presented at the rate of about 11-12 seconds per item. Periodically during the test session, subjects were given the current trial number to insure that their responses were being notated in correct numerical sequence.

Results

Performance measures based on hit rates, a d' analysis, and an accuracy measure combining correct recognition and correct rejections all resulted in identical statistical outcomes. Analyses based on d' are reported.

Figure 3 shows the mean d' score for each stimulus type as a function of the four delays. In general, performance decreased

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insert Figure 3 about here

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across the month delay by about 60%, with overall d' scores highest on the color photographs (1.56) and unembellished drawings (1.56), relative to the other two stimulus types (black and white = 1.04; embellished = 1.32). The main effects of delay and stimulus type were both significant, $F(3, 76) = 21.35$ and $F(3, 228) = 35.91$, respectively, each $p < .001$. The interaction between delay and stimulus type was not significant, $p > .10$. Post-hoc tests revealed that performance on the color format and unbellished format did not differ, $p > .10$, but both exceeded performance on the remaining stimulus types ($p < .01$), with embellished better than unembellished, $p < .01$.

The hit rate decreased by about 30% for each stimulus type across the month delay (immediate = .716; 1 month = .430). Nonetheless, performance on each stimulus type was better than chance even after 1 month ($p < .01$). For example, poorest performance was obtained on the black and white photographs after one month, yet all 20 subjects provided a positive d' value for this stimulus type after 1 month.

<u>Confusion Analysis.</u> Table 2 shows the confusion rate for each study and test format, as a function of delay

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insert Table 2 about here

(conditionalized upon an error). As was the case in Experiment 1, confusion rates appear to be systematically related to the original study format, even after 1 month. The confusion rate for the best foil does show some decline across the retention interval (immediate = .504; 1 day = .539; 1 week = .460; 1 month = .432), but these rates are still above chance, even for the 1 month condition, $p < .01$.

Discussion

The results of Experiment 2 were similar to those obtained in Experiment 1, with one major exception: performance on colored photographs was again best, but the ordering on the other stimulus types failed to match that obtained in Experiment 1. In particular, performance on the unelaborated drawings was now equal to that of the colored photographs, and performance on the black and white photographs was the poorest. Otherwise, no evidence for convergence among the four types across the delays was obtained, which again argues against a convergence to a common code for the stimulus types. This conclusion is supported by the confusion data, in that confusions are not uniformly distributed among the formats.

Experiment 3

Experiment 3 attempted to replicate the results of Experiment 1 (especially the ordering of stimulus types), and investigated the potential for convergence among stimulus codes for a far greater delay (3 months rather than 1 month). In addition, a within-subject manipulation of delay was used, with different sets of stimuli used on the immediate and delayed test.

Method

<u>Subjects.</u> A total of 40 introductory psychology students served as subjects, none of whom had served in the previous two experiments.

<u>Stimuli.</u> The same stimulus assignment used in Experiment 1

was used in Experiment 3, with half of the stimulus set (48 items) used in the immediate test and the remaining 48 used in the 3 month delayed condition. The four stimulus types were counterbalanced across subjects over the two delays, using a 4 X 4 Latin square design similar to Experiment 1. Eight different presentation orders were randomly generated and used during the study sessions and an additional set of eight different presentation orders were randomly generated and used during the test session.

Design and procedure. A 2 (delay) X 4 (stimulus type) within-subject design was used. Study and test procedures were identical to Experiment 1, with the exception that no confidence ratings were collected in Experiment 3.

Results

Performance measures based on hit rates, d', and recognition accuracy all resulted in identical statistical outcomes. Analyses based on d' are reported.

Figure 4 shows the mean d' score for each stimulus type as a function of delay. In general, performance decreased by about 80% at the 3 month test, with overall d' scores highest on the color photographs (2.02), relative to the other stimulus types (black and white = 1.33; embellished = 1.01; unembellished = 1.12). The main effects of delay and stimulus type were both significant, $F(1, 78) = 146.57$ and $F(3, 156) = 16.98$, respectively, each $p < .001$. The interaction between delay and stimulus type was not significant, $p > .10$. Post hoc tests revealed that performance on the color format exceeded performance on the remaining stimulus types ($p < .01$), with performance on the remaining formats not differing from each other ($p > .10$).

Hit rates decreased by about 30% across the 3 month delay (immediate = .780; 3 month = .492), and false alarms increased by about 16% over the same period (immediate = .184; 3 month = .348). Although the performance drop was considerable across the 3 month delay, performance was still above chance, with 34 of the 40 subjects having positive d' values ($p < .01$). Of the four stimulus types, only the elaborated drawings functioned at a chance level after 3 months ($d' = 0.10$, $p > .10$).

Confusion Analysis. Table 3 shows the rates of false alarms for each stimulus type as a function of the format originally studied, shown separately for immediate and delayed tests.

insert Table 3 about here

As was the case in the previous experiments, false alarms on the immediate test are strongly related to the visual similarity between original and test format; on the test 3 months later, false alarm rates are a bit erratic but, overall, are still disproportionately related to visual similarity. The major difference on the delayed test is the reduced false alarms to black and white photographs when the studied item was a colored photograph, and the reduced rates to unembellished drawings when the original was an embellished drawing. However, colored photographs are false alarmed at high rates to studied black and white photographs, and unembellished drawings are frequently called old when embellished stimuli were studied. Overall, it would appear that the rate of false alarming to visually similar items is reduced after 3 months, relative to an immediate test, but that the rate is still greater than chance.

Discussion

The results of Experiment 3 largely replicated those found in Experiment 1. Therefore, the performance ordering on a yes/no test appears to be reliable one, and one that is unchanged across delayes as long as 3 months after study. Furthermore, no evidence for a convergence to a common code was apparent after 3 months.

General Discussion

Three major results emerged from the present study: (a) subjects encode sufficient pictorial detail in a single 5 second viewing period to reject thematically-related foils over time periods as long as 3 months later; (b) the memorial representation of thematically-related stimuli does not converge to a common code after lengthy delays; and (c) the type of test strongly influences performance on stimulus types.

In each experiment, performance on the four stimulus types was above chance, with the sole exception of the elaborated line drawings in Experiment 3 at the 3 month delay. These results are all the more remarkable, given that subjects observed each of 96 stimuli for only 5 seconds and were later required to discriminate the studied stimuli from theme-preserving foils after substantial delays. At a minimum, subjects clearly store more than core or thematic information; some degree of irrelevant and/or idiosyncratic detail is also encoded and retained. The additivity of stimulus format and retention interval suggests that information does not decay into a common, thematic code, with non-thematic detail decaying at a faster rate than thematic information. Rather, the pictorial code decays uniformly for all types of detail. An alternative hypothesis is that the non-thematic detail decays at a faster rate, but this decay rate is compensated for by the encoding of a vast amount of non-thematic detail. Further support for the durability of distinctive codes comes from the kinds of false alarms made by subjects. Even after 3 months, errors occur disproportionately to visually similar foils. There is a suggestion that the rate of visually-based confusions is slowly declining with time; only large-scale parametric tests (varying study time and using longer delays such as 6 months) would verify whether this trend is specious or real. Regardless, the stability of confusions and the obtained additivity of stimulus type with retention interval seem at variance with studies using verbal materials; for example, the convergence of performance on verbatim and gist recall after brief delays (less than 1 hour) has been obtained frequently in studies of sentence memory (e.g., Reder, 1982). These studies typically use short sentences with little detail, in which subjects are asked to discriminate tense change and/or changes in which foils contain the subjects or verbs from other studied sentences. We are currently investigating memory for short passages that have substantial embellishment of detail. Under these conditions, retention for detail might better mimic that found for pictures.

It is tempting to conclude that these results favor a dual-code interpretation to a propositional one. However, Anderson's (1978) argument is a compelling rejoinder to such an interpretation. Nonetheless, these results place severe constraints on the kind of propositional theory needed to explain these findings. A propositional theory which states that only core information is either initially stored or available after a short duration (e.g., 1 hour) is clearly incorrect. Anderson (1985) has contended that: "...subjects are not likely to remember the exact visual details or spatial relations in a picture. Instead, they are remembering some rather abstraction representation that captures the picture's meaning" (pg. 107). The results of the present study suggest that this contention is misleading and, perhaps, incorrect. Rather, the propositonal code must be sufficiently complex to accommodate both thematic and non-thematic detail for time periods as long as 1-3 months after brief inspection.

The results obtained with the two paradigms (yes/no and forced-choice) did not produce the same ordering for the various stimulus types. This outcome, although unexpected, appears to be stable, since the ordering obtained in Experiment 1 was replicated in Experiment 3. In Experiments 1 and 3, a yes/no procedure resulted in an ordering that was generally consistent with the number of details available at study:

colored photographs were recognized more accurately than black and white photographs, which enjoyed a slight (non-significant) advantage over the line drawings (both elaborated and unelaborated). In Experiment 2, a 4-alternative forced-choice test favored colored photographs and unelaborated line drawings, followed by elaborated drawings and black and white photographs. Since the experiments were otherwise identical, an explanation based on differences in strategy or processing seems likely.

In a yes/no task (Experiments 1 and 3), the subject must evaluate the match between the current stimulus and its memorial represenation. Except for cases when the subject either failed to encode the study item and/or failed to retrieve its representation at test, the match between a test probe and its representation must always be positive, since all foils were variations on studied stimuli. To evaluate the goodness of the current match, the subject must generate, from memory, variations of the current stimulus probe by adding or deleting details. If any of the generated matches exceed the match of the current probe, then the subject is likely to respond that the stimulus is "new". Importantly, the generated matches are likely to exceed the match of the current stimulus only if the subject adds/deletes the correct detail. For example, the subject presented with an elaborated line drawing at the time of test might first match this stimulus with its memorial trace. If the original (study) item was a colored photograph of the same theme, successful rejection of the current probe requires that the subject retrieve the appropriate coloration of the stimulus. The successful addition of detail is required whenever the test probe is less complex than its studied variation. When the test probe is more complex than its studied variation, correct rejection requires the proper deletion of detail. Thus, a test probe that appears as a colored photograph can be rejected as "new" only if the subject correctly deletes the proper detail (e.g., removing color if the original probe was a black and white photograph). A number of subjects wrote comments reflecting the addition/deletion of details, e.g., "I remember that the dress was a deep blue" (addition of detail). Since accuracy in the yes/no procedure favored performance on the more detailed stimuli, and sicne this advantage was uniformly maintained across a month's delay, it must be concluded that the additional detail inherent in the more complex stimuli was encoded and faithfully preserved over time.

In contrast, the forced-choice test (Experiment 2) precludes the generation, from memory, of alternatives, since the choices available to the subject are prsented in the test array. On a forced-choice test, the subject may compute similarity matches for each test variation, identifying as "old" the one version receiving the highest score. What needs explanation is the ordering of performance of the variations, especially in light of the different ordering on the yes/no task. One possibility is that the colored photographs and unelaborated line drawings, which occupy extreme positions on an assumed scale of complexity, were subject to less interference/competition than the two intermediate variations. For example, colored photographs differ from black and white photographs only in the absence of color; from elaborated line drawings in terms of color and precision of detail; and from unelaborated line drawings in terms of color, precision of detail, and number of details. In effect, the colored photographs contained features that differed from the foils in one, two, or three ways (color, precision, number). A similar argument may be made for the unelaborated line drawings; its foils also vary in one, two, or three ways. However, both the black and white photographs and the elaborated line drawings have two foils that differ in only one way. For example, an elaborated line drawing differs from black and white photographs in terms of precision of detail, and from unelaborated line drawings in terms of number of details. The existence of two highly-similar foils for the elaborated line drawings and the black and white drawings, versus the existence of one highly-similar foil for the colored photographs and unelaborated line drawings, may be the basis for the performance ordering. Note that this rationale, which predicts the obtained ordering on the forced-choice test (Experiment 2) is inappropriate as an explanation for the yes/no task, since, in the latter, the addition/deletion of details must be generated from memory. If the full complement of alternatives is not generated, and/or the accuracy of retrieved details is imperfect, then the number of close foils in the yes/no task may be functionally smaller than in the forced-choice task.

Although neither paradigm produced evidence of convergence to a common, thematic code after 1-3 months, it may be argued that the distinction between thematic and non-thematic detail is not as sharp as supposed. This argument might suggest that the full complement of visual details are not incidental attributes but part of the intrinsic core meaning of a stimulus. Thus, coloration may produce moods that modify the core meaning or theme of a stimulus, as might the very angularity/curvilinearity/texture of details. A propositional code, that is sensitive to all details and their remarkable preservation over time, could accommodate the present results. This interpretation, however, is inconsistent with both the scanning literature and its emphasis on thematic encoding (e.g., Yarbus, 1967), as well as any assertion that only core meaning is maintained (e.g., Anderson, 1985). At a minimum, these results provide an empirical foundation which any theory of pictorial encoding must explain: after 5 sec of inspection, most subjects (85%) can discriminate theme-preserving variations from each other 3 months later. What is needed is an analytical technique which captures the full complement of detail encoded by the subject. Asking subjects to report detail may vastly underestimate what has been stored, since subjects may be unable or unwillilng to report the visual nuances available to them. At a more theoretical level, the results of the present study are not necessarily inconsistent with a propositional explanation; however, these results place severe constraints on the form such a theory must take. Core information is clearly not the sole product of encoding, and the resulting memory trace clearly preserves fine visual detail over lengthy delays. The adequacy of any theory of visual representation, including propositional accounts, must ultimately satisfy a generation test: the information supposedly extracted and maintained in memory must lend itself to a generation process that produces a visual copy that the subject cannot dis riminate from recollection of the studied version. The present results suggest that the development of such a model would be a formidable task, since the number and quality of preserved details and their relations are vast.

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Author Identification Notes

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Footnotes

1. This is an implicit assumption of most forced-choice tests, and one that was made explicit in the present study. In fact, one could construct a forced-choice test that included some, but not all, alternatives, and presented foils differed from the original in both type (e.g., black and white) and distortion of type (e.g., a colored foil of an originally studied colored stimulus). Manipulation of the latter type of foil would provide a fine-grained test of the amount and quality of preserved detail.

2. Having subjects rank order the remaining alternatives after they had made their first selection resulted in many blank or undecipherable responses for the rank order data. For that reason, that data are not reported here. The confidence data for the first selection did not suffer from these scoring problems, but the analysis of confidence data produced statistical outcomes identical to that reported in the results section.

Table 1

False Recognition Confusions, Conditional Upon an Error

Test Stimulus

	Imm				1 Day				1 Week				1 Month		
P	BW	E	U	P	BW	E	U	P	BW	E	U	P	BW	E	U
---	.434	.247	.319	---	.492	.297	.261	---	.471	.279	.250	---	.462	.231	.308
.525	---	.250	.225	.361	---	.347	.292	.354	---	.369	.277	.284	---	.500	.216
.156	.221	---	.624	.250	.280	---	.470	.217	.317	---	.467	.254	.373	---	.373
.118	.176	.706	---	.246	.261	.493	---	.235	.235	.529	---	.183	.338	.479	---

Table 2

False Recognition Confusions, Conditional Upon an Error, Experiment 2

Test Stimulus

Study		Imm				1 Day				1 Week				1 Mo		
		P	BW	E	U	P	BW	E	U	P	BW	E	U	P	BW	E
Study	P	---	.487	.313	.201	---	.530	.232	.238	---	.556	.204	.240	---	.430	.321
	BW	.500	---	.300	.200	.520	---	.259	.239	.372	---	.376	.252	.430	---	.300
	E	.103	.369	---	.528	.193	.284	---	.572	.205	.336	---	.459	.212	.342	---
	U	.152	.345	.502	---	.104	.361	.535	---	.154	.392	.454	---	.225	.389	.386

Table 3

False Recognition Confusions, Conditional Upon an Error,

Experiment 3

Test Stimulus

	Immediate				3 Months			
	P	BW	E	U	P	BW	E	U
P	----	.742	.194	.065	----	.302	.245	.453
BW	.367	----	.429	.204	.462	----	.280	.258
E	.229	.208	----	.562	.196	.370	----	.435
U	.255	.191	.553	----	.449	.202	.348	----

Figure Captions

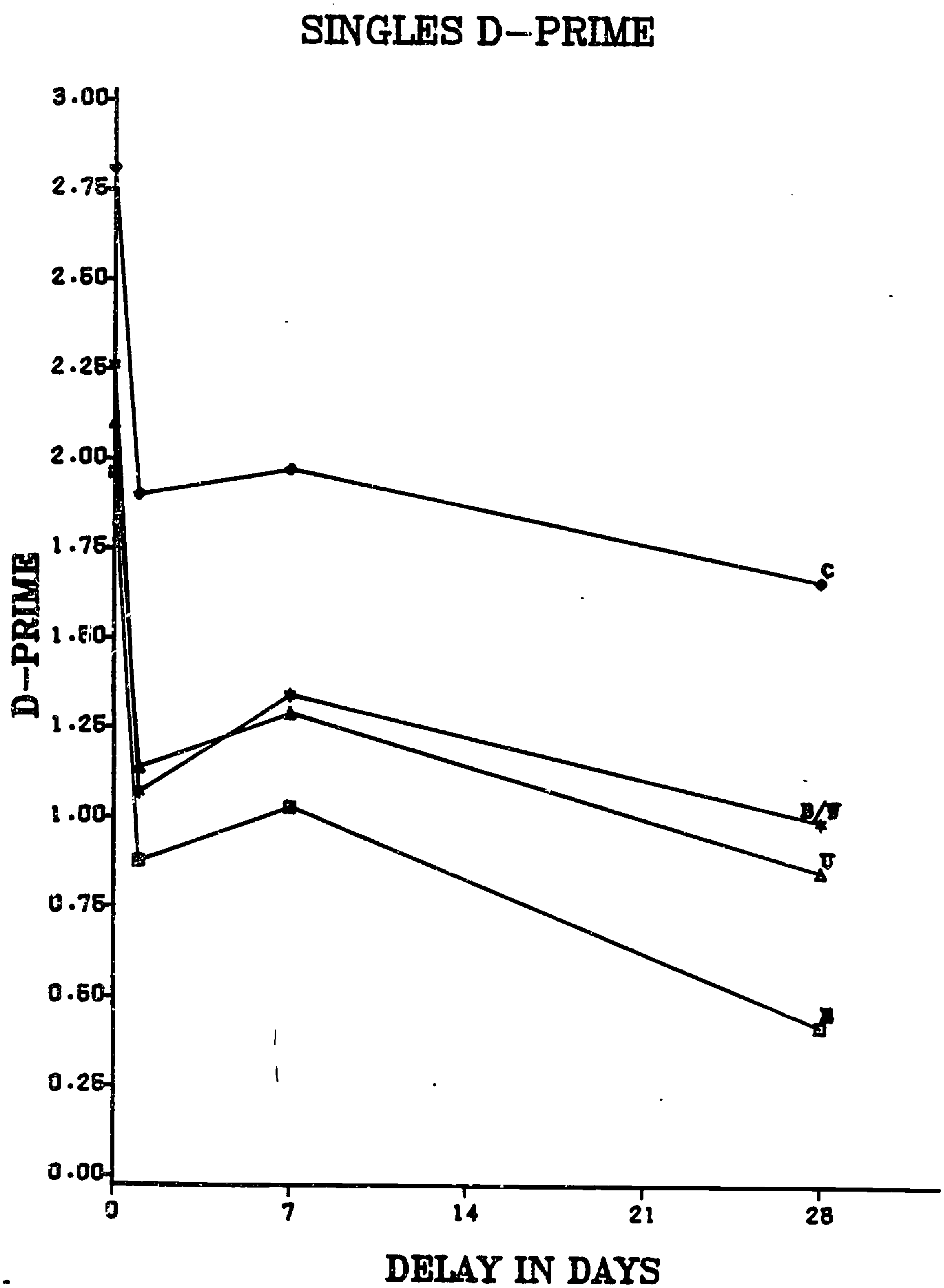
Figure 1. An example of the four stimulus versions

Figure 2. Mean d' for each stimulus type, as a function of retention interval (C = colored photographs; BW = black and white photographs; E = elaborated line drawings; U = unelaborated line drawings), Experiment 1.

Figure 3. Mean d' for each stimulus type, as a function of retention interval (C = colored photographs; BW = black and white photographs; E = elaborated line drawings; U = unelaborated line drawings), Experiment 2.

Figure 4. Mean d' for each stimulus type, as a function of retention interval (C = colored photographs; BW = black and white photographs; E = elaborated line drawings; U = unelaborated line drawings), Experiment 3.



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D-PRIME
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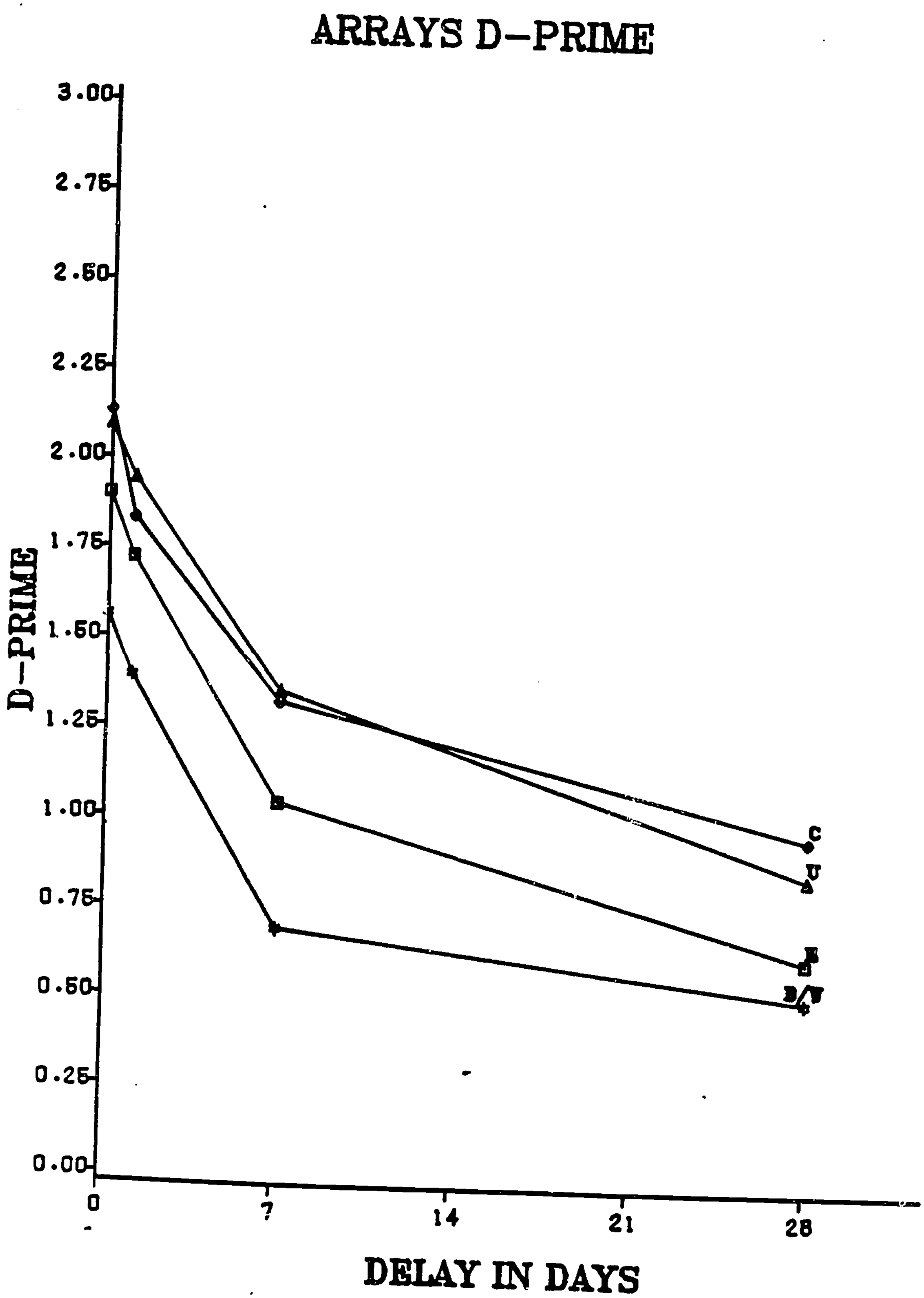
2.75
2.50
2.25
2.00
1.75
1.50
1.25
1.00
0.75
0.50
0.25
0.00
C
B/U
U
B
0
7
14
21
28
DELAY IN DAYS



ARRAYS D-PRIME
D-PRIME
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2.50
2.25
2.00
1.75
1.50
1.25
1.00
0.75
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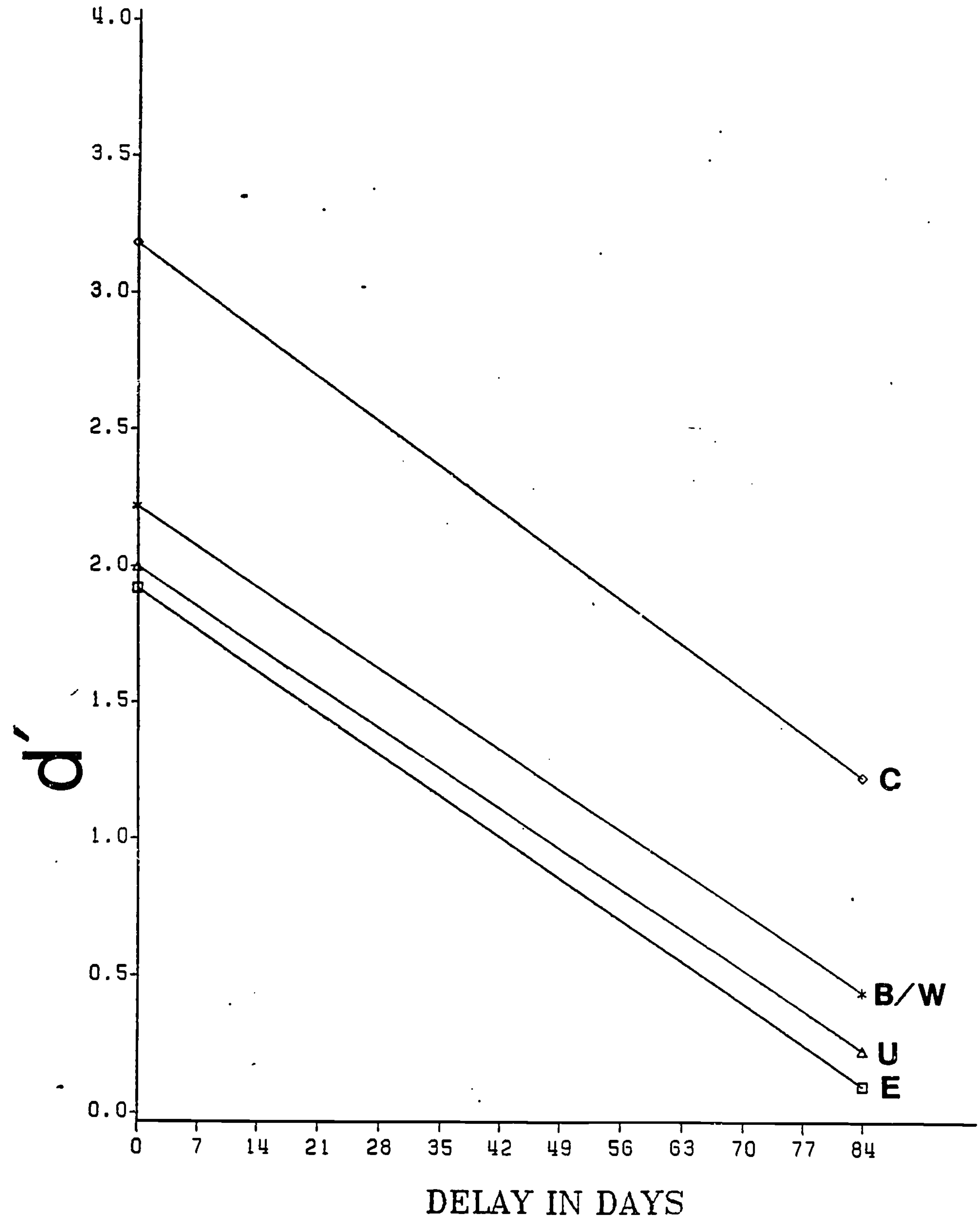
0.00
0
7
14
21
28
C
U
E
B/W
DELAY IN DAYS



4.0
3.5
3.0
2.5
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1.5
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0.5
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d′
C
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7
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21
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35
42
49
56
63
70
77
84
DELAY IN DAYS