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The level of processing affects the magnitude of induced retrograde amnesia

Vencislav Popov (vencislav.popov@gmail.com)
Georgi Petkov (gpetkov@cogs.nbu.bg)
Central and East European Center for Cognitive Science,
Department of Cognitive Science and Psychology,
New Bulgarian University, 21 Montevideo Street
Sofia 1618, Bulgaria

Abstract

If a distinctive event is amid other, non-distinctive events, often the memory for the item that immediately precedes the distinctive one is severely impaired. One explanation is that memory for the preceding items is reduced because when the priority item is detected all attentional resources are directed to it and the encoding of the preceding item is prematurely disrupted. Because perceptually defined priority is detected earlier in time, compared to semantically defined priority, the encoding of the preceding item should be disrupted at an earlier stage, and the impairment should be greater. An experiment confirmed this prediction by showing that retrograde amnesia was present when participants had to preferentially remember the word written in capital letters (RABBIT), but not when the priority item was defined by being a kind of animal (rabbit). These results can explain the reason behind recent failed replications and they provide evidence for the encoding hypothesis.

Keywords: induced retrograde amnesia, short-term memory, levels of processing, priority detection, encoding

Introduction

People have to remember a lot of lists throughout their daily lives – groceries, tasks, plans, and even names of people to invite to a party. Some items within those lists are deemed more important than others, and they are treated with priority. For example, it is much more pressing to invite your mother to a family gathering than a distant cousin, and when you are planning a trip, packing often takes priority over brushing your teeth. However, the preferential processing of such distinctive events is not without cost - memory for the item that precedes them in a list is often impaired (Tulving, 1969).

This impairment, called by Tulving "retrograde amnesia in free recall", is an adaptive constructive process that distorts memory as a byproduct of its otherwise efficient functioning (Schacter, 2012). The process is efficient because it directs additional attentional resources to important for memory items, but it is not yet clear why it impairs memory for the preceding item. Two major explanations have been put forward to explain induced retrograde amnesia. First, when the priority item is detected, all attentional resources could be directed to it, and as a result the rehearsal or the consolidation of the preceding item could be disrupted during its *encoding* (Tulving, 1969). An alternative explanation is that its retrieval could be inhibited by the *retrieval* of the priority item (Epstein, Ruggieri, & Schermerhorn, 1980).

Encoding disruption vs retrieval failures

Retrograde amnesia in free recall was discovered by Tulving (1969), who asked participants to memorize lists of 15 words presented individually. One was a famous name (Aristotle, Columbus, etc.), while the rest were common nouns. Participants had to remember all words, but they had to remember the famous name with priority and to recall it first in the beginning of the retention test. When each word was presented for 0.5 or 1 sec., memory for the item that immediately preceded the famous name was significantly impaired. When the presentation rate was increased to 2 sec. per word, the effect disappeared. Because of this rate-sensitivity Tulving (1969) argued that encoding continues even after the item is physically removed, and that it is disrupted by the detection of the priority item to which all available attentional resources are directed.

Support for the encoding hypothesis comes from several converging lines of research: (1) the effect is present only when each word is presented for less than 1 second (Tulving, 1969); (2) it was reproduced even when subjects did not begin recall with the famous name (Saufley Jr & Winograd, 1970); (3) memory for the preceding item was impaired even in forced-choice recognition tests (Schulz, 1971; Schulz & Straub, 1972); (4) but it was not impaired when participants evaluated the pleasantness of the items during memorization (Fisk & Wickens, 1979). If inhibited retrieval impairs memory, the impairment should have been present regardless of the presentation rate; it should have disappeared when the famous name was not recalled first; it should have disappeared on recognition tests, since retrieval cues were provided; it should have remained regardless of the type of task performed during encoding.

The retrieval hypothesis is also supported by evidence which, supposedly, encoding-based mechanisms cannot explain. For example, some later studies argued that retrograde amnesia was, in fact, not rate-sensitive. They showed that critical for the effect was not the rate of item presentation, but the exposure time for the priority item (Detterman & Ellis, 1972). When stimuli were object drawings, and the priority item was a nude photo, retrograde amnesia appeared only for large exposure times for the nude photo (3 s), but not for small exposure times (0.5s), regardless of the presentation rate for the other items. The authors concluded that disruption cannot be due to encoding because attention was drawn away at the same time in both cases. Furthermore, instructions to limit rehearsal had no effect on the magnitude of retrograde amnesia, as is expected by the rehearsal variant of the encoding hypothesis. Although those two pieces of evidence are claimed to be in conflict with an encoding-based explanation, they do not lend direct support to the retrieval hypothesis.

Later, Detterman (1976) provided such support by presenting words auditorily, where the priority items had a much higher intensity (115dB) than the regular items (75dB). Retrograde amnesia was present only in free recall, and not in cued-recall (the first two letters of each word were given). Since providing retrieval cues removed the impairment, they concluded that the item was encoded successfully, but it was inhibited during retrieval. Finally, retrograde amnesia appears even when the priority item is defined after the presentation of the list (Epstein et al, 1980). When participants were told *after* the memorization phase to recall first an item from a specific taxonomic category, the item that preceded it in the original list was less well remembered. However, Epstein et al, (1980) also replicated Fisk & Wickens's (1979) effect and showed that instructions to evaluate the pleasantness of words removed the impairment. For that reason the authors concluded that both encoding and retrieval failures operate together in retrograde amnesia and that each one is sufficient, but not necessary, for the effect to appear.

Endogenous vs exogenous control of attention

Although this conclusion seems reasonable, there are some procedural issues with the studies presented in the preceding section. While on a functional level they seem to describe the same effect, this may not necessarily be so. The studies that support the encoding and retrieval hypotheses use essentially different tasks, and this difference can be related to the distinction between endogenous and exogenous attention (Posner, 1980; Yantis, 2000). Endogenous attention (goal-driven attention) is voluntarily directed towards a stimulus or its search, while exogenous attention (stimulus-driven attention) is reflexive – it is drawn by the inherent salience of stimuli.

Similarly, the studies that support the encoding hypothesis usually use a task that requires endogenous attention – the priority of an item is defined by instructions, not its salience. In those tasks participants have to manually search for the priority item and test each item against the predefined criterion. When the priority item is detected and classified as such, the attentional resources are voluntarily directed to it. On the other hand, priority in Detterman and Ellis' (1972) and Detterman's (1976) studies was not defined beforehand, but their stimuli had high perceptual salience (nude photos amid object drawings and higher intensity sounds amid lower intensity ones). These tasks required exogenous attention – it was driven to the items by their salience. Finally, Epstein et al's (1980) task conceptually differs from all others – no priority existed during encoding at all, and no preferential attention was given to any items.

While the effect is superficially similar, there is no reason to suppose that the same mechanisms are responsible for the impairment given that different attentional ones are involved. Further support for this idea comes from the fact that anterograde amnesia, i.e., impairment in recall for the *following* item, is usually present only in studies that require exogenous attention (the one exception is Schultz, 1971,but there it is much smaller than retrograde amnesia, and the authors say it could be attributable to masking). Since endogenous and exogenous direction of attention have different effects on variety of parameters in other tasks such as detection time of visual stimuli (Posner, 1980; Yantis, 2000), the conflict between the results we discussed is possibly no conflict at all, but it could merely reflect the essential underlying differences of the paradigms.

The motivation for the present research was twofold: First, it further tests the hypothesis that retrograde amnesia in tasks involving endogenous control of attention is the result of encoding failures. Second, it stems from the desire to determine the reason behind more recent attempts that failed to replicate Tulving's (1969) original results (Guynn & Roediger, 1995) (see the next section). To our knowledge this is the last published study on induced retrograde amnesia, and this drop of interest in the phenomenon could possibly be due either to the inability to replicate the results or to the inability to resolve the debate about the underlying cause. We suggest that by using the concepts of endogenous and exogenous attention to differentiate the experimental tasks we could delineate the effects of encoding and retrieval failures, and we offer an explanation for the failed replication.

Failed replication and current experiment

Tulving (1969) initially developed the laboratory variant of retrograde amnesia to study real amnesic patients. Because clinically amnesic patients show intact implicit memory (Schacter, Chiu, & Ochsner, 1993), Guynn and Roediger (1995) wanted to test whether laboratory induced retrograde amnesia will be absent on implicit memory tests as well. They followed Tulving's (1969) paradigm but used animals as priority items, not famous names. They first tried to replicate his results in explicit memory tests. Memory for the preceding item was not impaired on explicit tests when the presentation rate was 1 sec. per item, and it was modestly impaired when presentation rate was decreased to 0.5 sec. per item; no effect was present in the cued-stem recall tests. Contrary to their results, presentation of 1 sec. per item is usually enough for the effect to appear (Tulving, 1969; Saufley Jr & Winograd, 1970; Schulz, 1971; Schulz & Straub, 1972), it is much higher in the 0.5 sec. condition, and in some cases it was obtained even during presentation rate of 2 sec. per item (Epstein et al., 1980).

So what could be the reason for this discrepancy? The main difference between Guynn and Roediger's (1995) task and those used by previous studies is the type of category that defined the priority item - animals vs famous names. Although this may seem trivial at first, we suggest that it caused the lack of effect.

Consider the following. Attentional resources can be directed for preferential processing of the priority item only when it is classified as such – only when the priority criterion is detected. When that happens would depend on the type of the priority criterion – on what stage of processing is one able to detect it. For example, if perceptual criteria define the priority of a word (such as "The most important word is written in red"), then it can be detected and classified as the priority word just as soon as one detects its color. On the other hand, if semantic criteria define the priority of a word (such as "The most important word is a type of animal"), one must first encode its orthographic features, access its meaning from semantic memory, and recognize that it belongs to the category animal, before they direct attentional resources to it. Therefore, priority defined by perceptual criteria will be detected much earlier in time, relative to priority defined by semantic criteria.

The encoding hypothesis predicts that the impairment is time-sensitive (Tulving, 1969), and that the sooner encoding is disrupted the greater the impairment will be. Then, if priority is perceptually defined, it will be detected earlier in time, and it should impair memory for the previous item to a greater degree compared to if it is semantically defined.

Now, the priority of both famous names and animals seems to be semantically defined, but famous names in all studies were always perceptually distinct from other items - they began with a capital letter. In that way, the priority of famous names could have been detected perceptually as well. Thus, the priority of famous names can be detected earlier in time compared to the priority of animals, and the encoding hypothesis predicts that the effect will be greater in the first case. This would explain the discrepancy between Guynn and Roedinger's (1995) data and that previously gathered (Tulving, 1969; Saufley Jr & Winograd, 1970; Schulz, 1971; Schulz & Straub, 1972).

The present experiment tests this prediction by having people study different lists of words in which the same priority words were either perceptually defined (written in capital letter: RABBIT), or semantically defined (the priority word is an animal: rabbit). If the encoding of an item is disrupted when a priority item is detected, recall will be impaired to a larger degree in the perceptual condition, because participants will detect its priority earlier in time, and the preceding item will be less processed. However, if the effect is due to retrieval failures, no difference should be found.

Methods

Participants and design

Eighty-seven undergraduates (58 women) at New Bulgarian University participated for partial fulfillment of course credit. All were native Bulgarian speakers, whose age ranged from 18 to 51 years (*M* = 22.74, *SD* = 4.98).

We used a 3 (type of instruction: control vs semantically defined priority vs perceptually defined priority) by 5 (position of the priority item: 2/5/8/11/14) mixed design. We randomly assigned participants to one of the three levels of the between-subject variable (type of instruction), and they were tested in each condition of the priority position variable. The dependent measure was whether the participant recalled correctly the item immediately preceding the priority item in each list (positions 1/4/7/10/13 respectively). The experiment was double-blind.

Materials

We constructed 15 lists of words; each consisted of 15 words – 14 common nouns from different taxonomic categories and one additional word depicting an animal, which was the priority item in each list. The non-animal categories differed between lists. The priority item appeared three times in the five priority positions across lists. All 225 words differed from one another. Items were controlled and balanced for written frequency, length in syllables and imageability, and the same lists were used in all between-subject conditions with the following difference: the words depicting animals were written in capital letters in the perceptually defined priority condition.

Procedure

Participants were tested individually in a sound-proof booth. We used E-prime 2.0 software to present items on a computer screen. Participants had to remember and recall as many words from each list as they could. Additionally, in the semantically defined priority condition they were told that the most important word to remember depicted an animal and that they should write it first during recall. In the perceptually defined priority condition they were instructed that the most important word to remember was written with capital letters and to begin recall by writing it first. Words appeared individually in the middle of the screen for 500 ms with a 100 ms blank screen interval between every two words (SOA = 600 ms). Free recall followed after the presentation of each list - participants had 60 seconds to write all words that they could recall from the preceding list. If they were uncertain whether a word had appeared on the list or not, they had to write it down with the rest. After the time for recall had passed, the next list of words was presented in the same way. A fixation cross appeared for 1000 ms before the presentation of the first word from each list. All lists were presented in the same order for all participants.

Results

All mean values presented in this section represent ratio of correctly recalled items from their respective pool of presented items. The traditional ANOVA analysis has known problems for dealing with aggregated percentages data, so all data were analyzed by binary logistic regressions over the raw results, which, due to the categorical dependent measure, is based on the Wald χ^2 statistic. The dependent measure was whether the particular item was remembered (1) or not (0). Because the ANOVAs results were identical to the binary logistic regressions', only the latter is presented.

Analyses of overall recall and recall for the HP (high-priority) item

First, we analyzed memory performance for the priority item (HP) to see if the instructions were successful, and whether there was any difference in memory for the priority items between the experimental groups. An overall model with type of instruction was highly significant, Wald $\chi^2(2)$ = 306.93, p < .001. People remembered more animals in the semantic (M = .87, SE = .019) and perceptual (M = .89, SE = .016) conditions compared to the control condition (M =.42, SE = .025), Wald $\chi^2(1)$ = 167.82, p < .001 and Wald $\chi^2(1)$ = 180.13, p < .001, respectively. The semantic and perceptual conditions did not differ from each other, Wald $\chi^2(1)$ = 1.09, p = .297. A separate analysis revealed that all three groups of participants had similar levels of overall recall for the lists, Wald $\chi^2(2)$ = 3.39, p < .183 (M = .32, SE = .011; M = .31, SE = .007; M = .33, SE = .011, respectively for the control, semantic and perceptual conditions). Thus, participants in the different groups did not differ on memorizing skills, and both priority instructions for memorizing were equally successful. Therefore the results presented in the next section cannot be due to sampling differences.

Analyses on the immediately preceding item

Model 1 included the type of instruction, position of the HP item, and their interaction, entered in that order, as predictors for the memory of the item immediately preceding the HP item. It was overall significant Wald $\chi^2(6)$ = 191.45, p < .001. The analysis revealed a significant effect of the position of the HP item, Wald $\chi^2(4)$ = 51.38, p < .001, which is the well-known serial position effect. The effect of instruction was not significant Wald $\chi^2(2)$ = 0.03, p = .985, although it was in the expected direction - control condition (M = 0.313, SE = 0.023), semantic condition (M = 0.306, SE = 0.023) and perceptual condition (M = 0.264, SE = 0.023). The interaction was not significant as well, Wald $\chi^2(8)$ = 3.837, p = .872. When the interaction was excluded from the model, the effect of instruction was still not significant, Wald $\chi^2(2)$ = 3.303, p = .192, although the difference of 4.9% between the control and the perceptual condition was marginally significant, Wald $\chi^2(1)$ = 2.851, p = .09 (overall for model 2, Wald $\chi^2(6)$ = 187.63, p < .001).

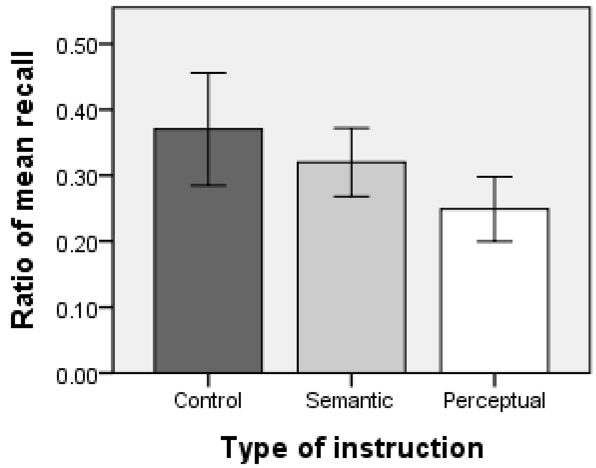

Figure 1. Mean recall ratio of the item immediately preceding the priority item (all lists). Only trials on which the priority item was successfully recalled are shown. Error bars represent 95% CI

During debriefing, participants in the experimental conditions uniformly reported that they failed to recall some of the priority items, because they simply missed them during list presentation (13% and 11% of the cases in the semantic and perceptual conditions). Since our main hypothesis was that successful detection of the priority item disrupts the encoding of the immediately preceding item, it was theoretically justified to exclude from the analysis all cases in which the HP item was not recalled correctly. Model 3 was based only on trials in which the HP item was correctly recalled, with position of the HP item and type of instruction, entered in that order, as categorical predictors. It was overall significant, Wald $\chi^2(6)$ = 153.001, p < .001. Type of instruction did have a significant effect overall, Wald $\chi^2(2)$ = 8.562, p < .05 (figure 1). When only trials with correct recall of the HP item were considered, people in the perceptual condition recalled significantly less items that preceded the HP item (M = .25, SD = .024) than people in the semantic condition (M = .32, SD = .026), Wald $\chi^2(1)$ = 4.199, p < .05, and than people in the control group (M = .37, SD = .043), Wald $\chi^2(1)$ = 7.69, p < .001. The semantic instruction group did not differ significantly from the control condition, Wald $\chi^2(1)$ = 1.175, p = .278. The effect of position was still significant Wald $\chi^2(4)$ = 121.467, p < .001.

Analyses on the immediately following item

We further tested whether there was any anterograde amnesia for the item that immediately followed the HP item. We repeated the models described in the previous section on the immediately following item. None of them revealed a significant effect of type of instruction. All models were run with the same parameters as in the previous section, but we report only the results about the instructions predictor – all position predictors were significant, as in the previous section. When all trials were analyzed there was no significant difference in memory for the following item between control (M = 0.354, SE = 0.023), semantic (M = 0.361, SE = 0.022) and perceptual (M = 0.414, SE = 0.022) conditions, overall Wald $\chi^2(2) = 4.894$, p = .087, although there was a tendency for the following item to be better remembered in the perceptual group, Wald $\chi^2(1) = 4.054$, p = .044.

When we included only trials in which the HP item was correctly recalled, there was still no significant effect of instruction on memory for the following item(M = .47, SE = .028; M = .40, SE = .023; M = .43, SE = .023, respectively for the control, semantic and perceptual conditions).

Comparisons of the first and last five lists

One concern with the procedure we used might be that participants in the control and perceptual conditions noticed that one word was always an animal. It may have become a priority word over trials in the control condition, or it may have added semantic processing to the perceptual group. If that happened it would attenuate the effect. If that was the case the effect should decrease as the list number increases. For this reason we compared performance on the first five and the last five lists (because there are five different HP positions this was the only equal split with relation to that variable). The reported results are only for trials in which the HP item was correctly recalled and are shown on figure 2. The list numbers were recoded as a categorical predictor (0 – first five lists, 1 for the last five lists) and the interaction between this variable and the instruction variable was added to model 3. This did not improve the model and there was no significant interaction, Wald $\chi^2(2) = 0.119$, p = .942. As can be seen from figure 2, memory performance in the two list groups was nearly identical (M = .36, SE = .058; M = .29, SE = .033; M = .22, SE = .039, respectively for the control, semantic and perceptual conditions in the first five lists and M = .39, SE = .078; M = .29, SE = .045; M = .24, SE = .037, respectively for the control, semantic and perceptual conditions in the last five lists).

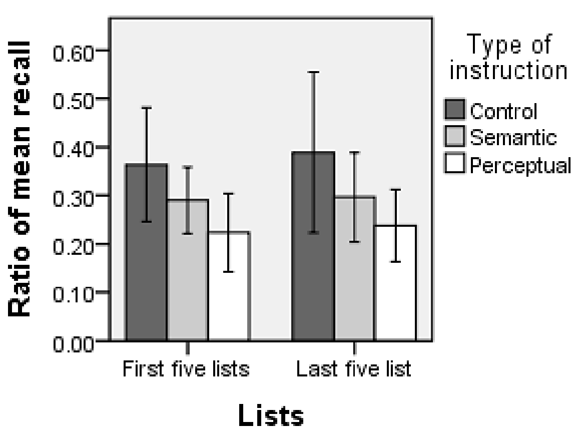

Figure 2. Mean recall ratio of the item immediately preceding the priority item for the first and last five lists. Only trials on which the priority item was recalled correctly are shown. Error bars represent 95CI.

Discussion

We identified a new factor that affects retrograde amnesia in free recall – the level of processing on which the priority of an item is detected. People's memory for the items that immediately preceded a priority item was impaired only when the priority of that item could be detected on a perceptual level (i.e., when the priority item was written in capital letters, "RABBIT"). In contrast, memory was not impaired when the criterion for priority was semantic (i.e., when the priority item was defined as an animal, "rabbit"). Overall memory for the lists was the same, regardless of the instructions and memory for the priority item in the two experimental conditions did not differ, therefore the effect cannot be attributed to individual differences, distraction or other non-controlled factors between groups.

Our results support the encoding hypothesis, which states that when a priority item is detected all attentional resources are directed to it, and as a result the encoding of the preceding item is disrupted. When the distinctiveness of an item is defined not by intrinsic salience, but by task-relevant instructions, one must first detect the feature of that item that corresponds to the predefined criterion of priority, before they direct preferential attention to it. Because perceptual criteria, (such as when the world is written in capital letters) are detected earlier in time, compared to semantic criteria (such as the taxonomic category an item belongs to), the encoding of the preceding item is disrupted at an earlier stage, and hence, to a greater degree, which is precisely what we found.

One disadvantage is that it was possible for participants in the control and perceptual condition to have noticed that one word was always an animal. Semantic processing may have interfered with lack of priority or with perceptual processing of the priority item in those conditions. Comparison of the first and the last five lists revealed no difference in memory for the preceding items. Maybe the control group did not notice that one word was always an animal or they did not attach it priority if they did. Besides, people in the perceptual condition could not have benefited from semantic processing, since perceptual criteria are detected earlier in time.

Another limitation of our experiment is that it cannot distinguish between two distinct versions of the encoding hypothesis. One states that retrograde amnesia is due to disruption of consolidation into working memory (Tulving, 1969), while the other suggests that it is the result of prematurely interrupted rehearsal (Jenkins & Postman, 1948). Our results are compatible with both possibilities and further work is required to distinguish between the two.

The task we used required endogenous (goal-driven) control of attention and as we reasoned in the beginning, retrieval-based explanations fail to account for the results in those types of tasks (Tulving, 1969; Saufley Jr & Winograd, 1970; Schulz, 1971; Schulz & Straub, 1972; Fisk & Wickens, 1979; Epstein et al., 1980). There was no anterograde amnesia in our experiment, which is the case for most tasks that use endogenous attention, just as we discussed in the introduction. The other prediction that results in tasks which require exogenous control of attention would be better explained by retrieval failures, or a combination of both, was not directly assessed here, and is subject for further work.

The pattern of results also suggests that Gyunn and Roediger (1995) failed to replicate Tulving's (1969) original results because their criterion for priority was semantic (people had to remember the animals with priority), while Tulving's (1969) criterion could have been detected perceptually (a famous name, starting with a capital letter). Besides from resolving this discrepancy, our study would allow researchers to use this knowledge to better plan their procedure, stimuli and design, so that they are able to study retrograde amnesia in free recall with greater confidence and ease.

Conclusion

Our data suggests that the stage of processing at which the priority of an item is detected affects the degree to which the encoding of the preceding item is impaired. In tasks that require endogenous control of attention, induced retrograde amnesia does not result from inhibition during retrieval, but from failure to encode the preceding item, because attention is directed prematurely away from it.

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