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Directed Forgetting Meets the Production Effect: Distinctive Processing is Resistant to Intentional Forgetting

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The production effect refers to the fact that, relative to reading a word silently, reading a word aloud during study improves explicit memory. The authors tested the distinctiveness account of this effect using the item method directed forgetting procedure. If saying words aloud makes them more distinctive, then they should be more difficult to forget on cue than should words read silently. Participants studied a list of words by reading half aloud and half silently; half of the words in each of these subsets were followed by a Remember instruction and half were followed by a Forget instruction. There was a robust production effect for both Remember and Forget words on an explicit recognition test. Critically, however, a directed forgetting effect was observed only for words read silently; words read aloud at study were unaffected by memory instruction. An implicit speeded reading test showed equal priming for all studied items. This pattern supports a distinctiveness account of the production effect: Words processed distinctively during production are not influenced by subsequent rehearsal differences.

Keywords: directed forgetting, distinctiveness, recognition, memory

Cognitive psychologists have numerous techniques at their disposal for improving their participants' memories for some studied material over other studied material. Level of processing (Craik & Lockhart, 1972) has been widely used to bring about better memory for semantically over nonsemantically processed words. Likewise, the generation effect (Slamecka & Graf, 1978) has repeatedly produced better memory for words generated from a cue than for words simply read at the time of study. The most recent addition to this family of encoding manipulations that improve explicit memory is the *production effect*: Words read aloud (produced) at the time of study are later better recognised than are words read silently at the time of study (MacLeod, Gopie, Hourihan, & Neary, 2008). All of these represent robust, effective ways to improve memory.

The production effect is thoroughly delineated by MacLeod et al. (2008) in a series of experiments. This robust effect is consistently observed when manipulated within subjects, but not when manipulated between subjects. Production benefits memory even for nonwords, indicating that an item need not have a preexisting lexical entry to benefit from production. Intriguingly, words do not even have to be read aloud per se to show a production benefit: Mouthing words without vocalizing results in the same benefit in explicit memory. Despite the benefit in explicit memory being consistent, production never increased priming on an implicit test in any of the six experiments conducted by MacLeod et al.

Like the generation effect, the production effect seems to arise from the distinctiveness of the produced words relative to the read words (MacLeod et al., 2008). Produced or generated words stand out at the time of test, either because they are stronger—a one-process account—or because the extra information about having been generated or produced is useful in recollection—a two-process account (see Yonelinas, 2002). Because neither generation nor production results in a memory advantage in between-subjects manipulations, the memory benefit is only *relative* to the other study condition (reading silently in production experiments; reading aloud in generation experiments). This fact is more consistent with a two-process account, given that a one-process account would seem to predict strengthening by generation or production regardless of design.

For theory development, it is important to understand the boundary conditions on such phenomena. In the case of generation, one intriguing observation comes from the directed forgetting literature. In item-method directed forgetting,[1] participants study words that are randomly followed by an instruction either to Remember or to Forget that word. When memory for all studied words is tested, typically more Remember words are recalled or recognised than Forget words—the directed forgetting effect. This effect is widely attributed to Remember words selectively receiving additional rehearsal not given to Forget words (see MacLeod, 1998, for a review). MacLeod and Daniels (2000) cued participants to Remember or Forget words that they either had read or had generated from a definition. In free recall, the standard directed forgetting effect was observed for Read

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[1] The alternative to the item method directed forgetting paradigm is the list method, in which participants are given only one memory instruction mid-list to Forget the first half of the list. List method directed forgetting effects are typically observed in free recall, but not in recognition (see MacLeod, 1998, for a review), and have been commonly attributed to context change (e.g., Sahakyan & Kelley, 2002) or inhibition (e.g., Basden et al., 1993).

items but it disappeared for Generated items. These results imply that generation is such a powerful encoding mechanism that explicit memory for generated words does not benefit substantially from additional selective rehearsal favouring Remember words, and that the item distinctiveness afforded by generation is sufficient to overcome directed forgetting.

The goal of the present experiment was therefore to explore the robustness of the production effect in the context of an item-method directed forgetting paradigm. If the benefits of both generation and production rely on an increment in distinctiveness, an increment sufficient to overcome typical rehearsal effects, then the same pattern should be observed for production and generation: Directed forgetting should occur only for words that are read and not for those that are produced.

Participants studied a list of words by reading half of the words aloud and half silently, with each word followed by either a Remember or Forget instruction. A directed forgetting effect is predicted on the recognition test for the words read silently, consistent with the bulk of the literature on item-method directed forgetting. Given the distinctiveness associated with producing a word at study, however, no directed forgetting effect is predicted for the words read aloud at study. That is, if it relies on the same mechanism, production is expected to be as powerful an encoding mechanism as generation on a direct, explicit test of memory. Due to their enhanced distinctiveness, produced words should be better remembered overall than read words, but should not benefit from the subsequent rehearsal ordinarily allocated selectively to Remember words. Selective rehearsal should, however, operate for the read words, so a directed forgetting effect should be observed there.

MacLeod and Daniels (2000) also had their participants perform an indirect, implicit test of memory—speeded reading (also known as "naming"). They found equivalent priming for read Remember and Forget words, although latencies were slower for generated Forget than Remember words. As none of the six experiments in MacLeod et al. (2008) showed any production effects on speeded reading, however, no production effect was predicted here for speeded reading, nor was any directed forgetting effect predicted, paralleling the results for the read words in MacLeod and Daniels (2000). The critical results, then, will be those from the explicit recognition test.

Method

Participants

Fifty-five students at the University of Waterloo received either course credit or payment for participating in the experiment. The data of two participants were removed because their false alarm rates were greater than 70% (statistical outliers in the distribution of false alarm rates), resulting in 53 participants contributing to the final analyses.

Stimuli

The item pool consisted of the 120 words used by MacLeod et al. (2008). All stimuli were presented in 16-point lower case font against a black background.

A random 80 of the 120 words were selected for study, with 40 presented in blue and 40 in white, in random order. Half of the items presented in each colour were followed by a Remember instruction ("RRRRR"); the other half were followed by a Forget instruction ("FFFFF"). Memory instructions were randomly determined and were presented in yellow.

Twenty of the words presented in each colour (10 Remember and 10 Forget), together with 20 other words not shown at study, were assigned to the speeded reading test and presented in a new random order. The remaining 20 words presented in each colour (10 Remember and 10 Forget), plus the remaining 20 unused words from the pool, were assigned to the recognition test and presented in another new random order. Consequently, the two tests used entirely nonoverlapping sets of stimuli, preventing contamination. This follows the procedure of MacLeod et al. (submitted).

Apparatus

An IBM-compatible microcomputer with a 15-inch colour monitor was used for testing. The controlling programme was written in E-Prime (version 1.1, Schneider, Eschman, & Zuccolotto, 2002). In speeded reading, a voice key measured the time between stimulus presentation and oral response onset. The experimenter coded reading trials as acceptable or problematic (i.e., voice key misfired, reading error) online. The programme scored recognition accuracy.

Procedure

In the study phase, participants were instructed to read the words presented in blue aloud and to read the words presented in white silently.[2] They were informed that each word would be followed by an instruction indicating whether it would be tested; words followed by "RRRRR" were to be remembered for the test whereas words followed by "FFFFF" did not need to be remembered because they would not be tested.

Study trials began with a 250 ms blank preceding each word's appearance at the centre of the screen. Blue words were read aloud into a microphone; detection of a vocal response onset removed the word from the screen. White words stayed on the screen for 2000 ms. Following a 250-ms blank, the Remember or Forget instruction was presented for 3000 ms, followed by a final 2000-ms blank.

The implicit test immediately followed the study phase. The test presented 20 of the blue words (10 Remember and 10 Forget), 20 of the white words (10 Remember and 10 Forget), and 20 new

[2] Note that word colour and reading instruction were not counterbalanced: All participants read the blue words aloud and the white words silently. In their study list, Hopkins and Edwards (1972) did counterbalance, presenting half of the words underlined and the other half not underlined. Half of the participants were instructed to read the underlined words aloud; the other half of the participants read the non-underlined words aloud (both groups read the other half of the study list silently). In their two experiments, Hopkins and Edwards showed that words read aloud were remembered better than words read silently, regardless of underlining. Given that the usual function of underlining is to highlight or draw attention to the underlined word, if the word display condition itself (rather than the reading instruction) could produce a benefit in memory, then it should have occurred for underlined words. Thus, it is very unlikely that the colour blue—not reading aloud—would be responsible for any observed memory benefit in the present study.

Table 1
Proportions of "Yes" Responses and Correct Response Latencies in Recognition, and Latencies (in msec) in Speeded Reading as a Function of Study-Test Condition and Memory Instruction

Measure	Studied aloud		Studied silently		Unstudied
	Remember	Forget	Remember	Forget	new
Recognition, proportion (Yes)	.80 (.022)	.77 (.022)	.70 (.025)	.61 (.022)	.23 (.016)
Recognition (latency)	968 (52.87)	932 (34.71)	973 (47.72)	1085 (60.40)	1104 (50.82)
Speeded Reading (latency)	498 (8.97)	492 (8.67)	494 (8.20)	499 (8.50)	509 (9.01)

Note. Standard errors are shown in parentheses after the respective means.

words from the pool one at a time in random order. All were presented in yellow font to prevent colour overlap between study and test. Participants were to read each word aloud into the microphone as quickly as possible, avoiding errors. This test was represented as a "filler task" before the actual memory test. Following a 250-ms blank, the word appeared and remained on the screen until the participant responded. A 250-ms blank followed the response, and finally a plus sign ("+") appeared centred on the screen until the experimenter pressed a key to indicate trial acceptability.

The explicit recognition test followed the implicit test. Here, the remaining 20 blue words (10 Remember and 10 Forget), 20 white words (10 Remember and 10 Forget), and 20 unstudied new words were shown one at a time, and the participant responded Yes (the "c" key) or No (the "m" key). Participants were told to disregard the initial memory instructions, and to respond "yes" to any item presented during study, even if it had been followed by "FFFFF." Again, all test items were presented in yellow font. There was a 500 ms blank before each word, and the word disappeared upon the participant's key response. The next trial began immediately.

Results

Recognition

The first row of Table 1 presents the recognition data expressed as proportions of yes responses. For words that had been studied, these are hit rates; for unstudied words, this is the false alarm rate. False alarm rates ranged from 0.05 to 0.55, with a mean of 0.23.

A 2 (memory instruction: Remember, Forget) × 2 (production: Aloud, Silent) repeated measures analysis of variance (ANOVA) was conducted. This revealed a main effect of memory instruction, $F(1, 52) = 11.81$, $MSe = .017$, $p < .001$, with Remember words (.75) better recognized than Forget words (.69) overall. There was also a main effect of production, $F(1, 52) = 38.86$, $MSe = .022$, $p < .001$, with Aloud words (.79) better recognized than Silent words (.66) overall. The memory instruction x production interaction, $F(1, 52) = 3.32$, $MSe = .016$, $p = .07$, although marginally significant, provided the basis for theoretically motivated planned comparisons to be conducted. These comparisons revealed that there was no directed forgetting effect for words studied Aloud, $F(1, 52) = 1.42$, $p = .24$. This was in sharp contrast to words studied in the Silent condition, which showed a reliable directed forgetting effect, $F(1, 52) = 13.89$, $p < .001$.

Given the theoretical interest in the observed null difference, a power analysis of the comparison between Remember Aloud and Forget Aloud was conducted. The observed difference of 0.03 produced a δ value of 0.848. To obtain a power of 0.80, this small effect would require approximately 578 participants to reach statistical significance (at $p = .05$). Note that observed power for the 0.094 difference between Remember Silent and Forget Silent was 0.71. Directed forgetting occurred for the less distinctive read words but it did not occur for the more distinctive produced words.

The second row of Table 1 presents the recognition response latency data for correct recognition responses only (i.e., for unstudied words, correct rejection latencies are presented instead of false alarm latencies).

A one-way repeated measures ANOVA comparing Remember Aloud, Forget Aloud, Remember Silent, Forget Silent, and New showed a significant effect of study-test condition, $F(4, 208) = 4.50$, $MSE = .69541$, $p < .01$. A 2 × 2 ANOVA was also conducted on the recognition latencies of the studied items only. This analysis revealed no main effect of memory instruction, $F(1, 52) = 1.92$, $p = .17$, but a marginally significant main effect of production, $F(1, 52) = 3.66$, $p = .06$ and memory instruction x production interaction, $F(1, 52) = 3.70$, $p = .06$. Pairwise comparisons (using a Sidak correction for multiple comparisons) revealed that Forget Aloud words were recognised faster than Forget Silent words ($p < .05$), but that no other differences were significant.

Speeded Reading

The third row of Table 1 presents the speeded reading latency data. Trials discarded for voice key problems (or for rare reading errors; we did not differentiate between these) constituted 7% of the overall data.

A one-way repeated measures ANOVA comparing Remember Aloud, Forget Aloud, Remember Silent, Forget Silent, and New words showed a significant overall main effect, $F(4, 208) = 5.02$, $MSE = 475.08$, $p = .001$. Pairwise comparisons (using a Sidak correction for multiple comparisons) revealed that all studied words were read at least marginally faster than new words (all $ps \leq .09$), and that there were no differences in reading latencies amongst the four studied conditions (all $ps > .70$). A separate 2 × 2 ANOVA was conducted on the studied words only. This analysis produced no significant main effects (both $Fs < 1$), and a marginal memory instruction x production interaction, $F(1, 52) = 3.42$, $p = .07$; however, none of the pairwise comparisons (using a Sidak correction for multiple comparisons) revealed any significant differences (all $ps > .54$). Neither a directed forgetting effect nor a production effect was evident on the implicit test; put another way, priming was equivalent for all studied items.

Discussion

The strong production effect in the present experiment testifies to its robustness and replicability. The 13% advantage observed here for words produced at study over those simply read at study agrees with our prior work (MacLeod et al., 2008). Our account in that prior work was that producing words at study differentiated them, making them more distinctive than did simply reading them silently. We further suggested that this enhanced distinctiveness was useful at the time of test to assist recollection, and hence to improve recognition for produced words by making them more discriminable at test. Interesting to note, distinctiveness has also been used this way to explain the advantage of generation (e.g., Begg, Snider, Foley, & Goddard, 1989).

MacLeod and Daniels (2000) demonstrated that directed forgetting influenced memory for words that were read but not for words that were generated, and suggested that directed forgetting was limited to weaker memories. We reasoned that it might well be that directed forgetting cannot influence words that are encoded distinctively (cf. Golding, Long, & MacLeod, 1994). If so, then the same pattern of a directed forgetting influence on the less distinctive words but no influence on the more distinctive words should occur when distinctiveness was manipulated by production instead of generation. This is precisely what we found: Produced words were unaffected by instructions to Remember or Forget whereas read words showed better memory under Remember instructions than under Forget instructions.

This parallel pattern is consistent with the conclusion that directed forgetting influences explicit memory only when the information being retrieved is not highly distinctive. We suggest that both the generation effect and the production effect operate by heightening the distinctiveness of a subset of the studied material through the addition of contextual information at the time of encoding. The subset so heightened consequently becomes impervious to directed forgetting.

As further support for this argument, consider another technique for improving memory—the enactment effect (often called "subject-performed tasks"). Here, participants either read a short phrase describing an action to be performed on an object (e.g., "break the match") or they actually perform the action (e.g., Engelkamp & Dehn, 2000; Engelkamp & Jahn, 2003; see Engelkamp, 1998, for a review). This paradigm may also constitute a distinctiveness manipulation: It certainly shares the critical feature of only working in a within-subject design. For present purposes, the results of Earles and Kersten (2002), who applied directed forgetting to the enactment effect, are most instructive: Directed forgetting affected the read condition but not the enactment condition.

Although certainly less central to the present argument, the results of the indirect, implicit memory test—speeded reading—are also informative. Speeded reading did not show any influence of either memory instruction or production. The lack of a production effect corresponds well with all of the experiments in MacLeod et al. (2008), and also with most of the directed forgetting literature, which generally shows equivalent priming for Remember and Forget items (e.g., Basden, Basden, & Gargano, 1993; Marks & Dulaney, 2001; but see MacLeod, 1989; Paller, 1990). Interesting to note, with only rare exceptions, generation and enactment also typically express themselves strongly on explicit tests but not on implicit tests (for enactment, see Engelkamp, Zimmer, & Kurbjuweit, 1995; Nyberg & Nilsson, 1995; for generation, see Gardiner, 1988; Masson & MacLeod, 1992; Toth, Reingold, & Jacoby, 1994). So the "big picture" across tasks appears to be very consistent.

As MacLeod et al. (2008) discuss, it is somewhat counterintuitive that production does not influence performance on a speeded reading test. A transfer appropriate processing view (e.g., Morris, Bransford, & Franks, 1977) would certainly predict that reading words aloud at study should benefit performance on a test that requires reading words aloud. However, our claim is that production benefits memory by differentiating the items studied aloud from those studied silently; the words read aloud have the additional contextual information that they were read aloud, and this information is quite useful on an explicit test that requires discrimination of studied from unstudied items. Being an implicit memory test, speeded reading only requires that the participant read the word, and this process is faster for any words seen in the study phase (i.e., both aloud and silent words), relative to new words. Discrimination of old from new is not required for reading, and thus the distinctiveness of the aloud words has no effect on priming. This pattern of explicit test benefits in the absence of implicit test effects matches the pattern produced by other distinctiveness manipulations on explicit and implicit tests (see Geraci & Rajaram, 2006).

The results of the present study fit well with the distinctiveness account of the production effect. Production, like generation and enactment, only produces an advantage in explicit memory in within-subject manipulations. This indicates that production at study provides an additional basis for discrimination of old from new at the time of test—having said the word aloud makes it distinctive, and this distinctiveness is not available for the words read silently. Distinctiveness is also not useful on an indirect memory test, such as speeded reading, because discrimination of old from new is not required to perform such tasks.

The distinctive aspect of words produced at study appears to be powerful enough that subsequent rehearsal—whether viewed as rote rehearsal or more elaborative rehearsal—does little to influence memory beyond the initial encoding. The selective rehearsal account of item-method directed forgetting (see MacLeod, 1998, for a review) maintains that once the memory instruction is presented, only Remember words receive any subsequent rehearsal whereas Forget words are dropped from the rehearsal set. Yet produced Forget words were recognised as well as produced Remember words. This suggests that any subsequent rehearsal did not influence recognition of produced words, or that distinctive items are difficult to drop from the rehearsal set when Forget cued. Enhanced distinctiveness at encoding also explains the lack of a directed forgetting effect for generated items (MacLeod & Daniels, 2000) and for enacted items (Earles & Kersten, 2002). Sufficiently distinctive encoding would appear to result in a differentiated encoding that is not influenced by subsequent rehearsal.

Résumé

L'effet de production réfère au fait que, comparativement à la lecture d'un mot en silence, lire un mot à vois haute durant l'étude améliore la mémoire explicite (MacLeod, Gopie, Hourihan, & Neary, submitted). Nous avons testé l'explication du caractère distinctif pour rendre compte de cet effet, en utilisant la procédure d'oubli dirigé avec la méthode des items. Si le fait de mots à voix haute les rend plus distincts, ils devraient alors être plus difficules à oublier que les mots lus en silence. Les participants ont étudié une liste de mots en lisant une moitié à voix haute et l'autre moitié en silence; la moitié des mots dans chaque sous liste étaient suivis d'une instruction Rétention et l'autre, d'une instruction Oubli. Un effet de production robuste a été observé seulement pour les mots lus en silence ; les mots lus à voix haute ne furent pas affectés par les instructions. Un test de lecture implicite accéléré a montré un indiçage équivalent pour tous les items étudiés. Ces résultats appuient l'explication du caractère distinctif pour rendre compte de l'effet de production : les mots traités de façon distincte durant la production ne sont pas influencés par les différences dans la répétition subséquente.

Mots-clés : oubli dirigé, distinction, rappel, mémoire

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