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The Production Effect in Memory

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Abstract
Producing items by means as simple as saying, writing, or typing them can yield substantial memory improvements relative to silent reading. We review the research on this *production effect* and outline some important extensions and boundary conditions. We also evaluate the evidence that production enhances the distinctiveness of items in memory during encoding, thereby facilitating their later retrieval. There are issues to resolve and areas to explore, but production offers a practical means of enhancing some forms of long-term, explicit memory.

Keywords
memory, encoding, retrieval, production, distinctiveness

The "production effect" was named by MacLeod, Gopie, Hourihan, Neary, and Ozubko (2010) in a series of experiments in which the mere act of reading words aloud resulted in substantially better memory than reading them silently. Though recently coined, the production effect was not newly minted. Hopkins and Edwards (1972) initially reported the effect, but with a few exceptions (e.g., Conway & Gathercole, 1987; MacDonald & MacLeod, 1998), it largely escaped attention over the intervening years. By contrast, the memorial benefits of other encoding strategies have been continuously and extensively researched since the 1970s, including the level of processing effect (Craik & Lockhart, 1972) and the generation effect (Slamecka & Graf, 1978). How did we overlook such a simple, intuitive encoding strategy? Perhaps the effect merely needed a name to make a name for itself. Since the delineation of the effect by MacLeod et al., at least 40 articles have appeared, including a special issue of the *Canadian Journal of Experimental Psychology* (see Bodner & MacLeod, 2016). Our goals here are to briefly review what we have learned about the production effect from this recent research and to invite readers to pursue the unanswered questions.

Extensions and Boundaries

As is common for research on encoding strategies, much of what we know about the production effect comes from studies of memory for word lists. In a typical experiment, people study a list of words shown one at a time with print color dictating whether a word is to be produced or read silently (e.g., blue = aloud; white = silent), and a memory test follows. Most studies have used intentional learning, but the effect also occurs with incidental learning (e.g., MacDonald & MacLeod, 1998). Figure 1 presents some illustrative data from MacLeod et al. (2010), who identified several conditions that yielded a production effect, including (a) saying words aloud, (b) silently mouthing words, and even (c) saying nonwords aloud. In terms of boundaries, they found no advantage from making nonunique productions for all produce-cued words, such as (d) saying "yes" to all of them. The effect was also absent when implicit memory was assessed using a speeded reading test.

The production effect was initially thought to be absent when the two conditions were assigned between lists (usually to separate groups) rather than within list, as reported both by Hopkins and Edwards (1972) and by MacLeod et al. (2010). However, meta-analysis including these early studies by Fawcett (2013) in addition to more recent experiments beginning with Bodner, Taikh, and Fawcett (2014) have confirmed a between-lists production effect in recognition—although it is markedly smaller than the within-list effect (compare panels A and B in the hypothetical data presented in Fig. 2).

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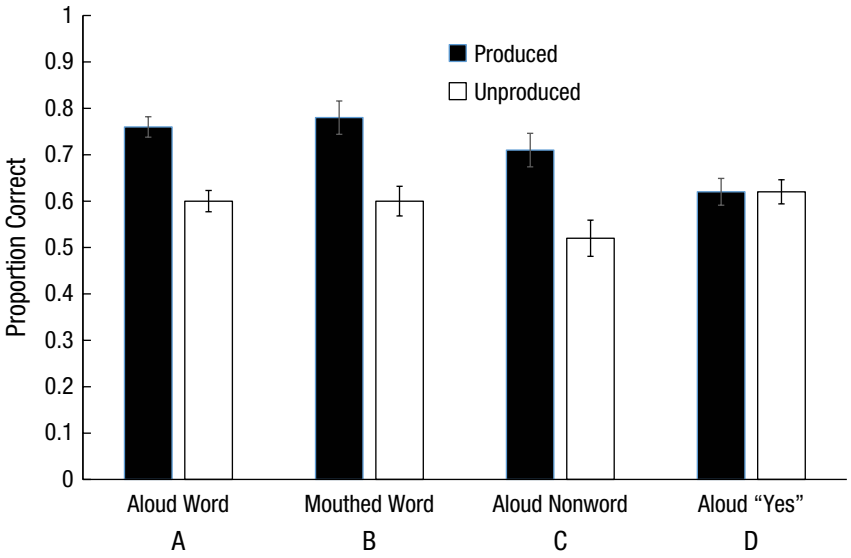

Fig. 1. Recognition memory data (hit rates) from several of the within-list experiments in MacLeod et al. (2010). The production effect is evident for (A) saying words aloud, (B) mouthing words, and (C) saying nonwords aloud, but not for (D) saying the same word ("yes") repeatedly. In each case, the comparison is to silent reading.

When the memory test is free recall, on the other hand, a within-list effect is consistently found, whereas a between-lists effect is consistently absent (see Forrin & MacLeod, 2016). These patterns provide valuable clues about the mechanisms driving the production effect.

Many varieties of production can enhance memory. There is a production advantage for handwriting, for typing, and even for spelling, although none of these is as large as for speaking (Forrin, MacLeod, & Ozubko, 2012). In contrast, there is some indication that singing words may enhance memory more than speaking them (Quinlan & Taylor, 2013). Production helps even when you hear someone else do it, though not as much as when you do it yourself (MacLeod, 2011). And imagining typing a word results in better memory than simply seeing it, but actually typing the word is better still (Jamieson & Spear, 2014).

Many varieties of materials also can yield production effects. Fawcett, Quinlan, and Taylor (2012) reported that the production advantage was somewhat larger for mouthing the names of line-drawing pictures than for mouthing words. Ozubko, Hourihan, and MacLeod (2012) extended the effect to word pairs and sentences. Putnam, Ozubko, MacLeod, and Roediger (2014) found that production benefits both item memory and associative memory for pairs of items (e.g., *approach-record*), but the benefit for associative information was eliminated when a semantic judgment followed the study of each pair. Interestingly, Hourihan and Smith (2016) found no evidence of a production advantage when people were asked to say aloud (vs. read silently) first names paired with unfamiliar faces, so it appears that there are more boundary conditions when production is applied to associations.

In the realm of "real-world" learning and memory, Ozubko et al. (2012) showed that the production advantage endures over longer retention intervals: A week later, produced words were still better recognized. Importantly, they also found a lasting production effect for textbook passages: Memory on a cued recall (fill-in-the-blank) test was better for paragraphs that had been read aloud a day previously than for paragraphs that had been read silently. In another extension, Knutsen and Le Bigot (2014) found that production enhances memory for dialogue: People were more likely to reuse a reference that they had personally spoken earlier, relative to a reference spoken by someone else.

Costs and Benefits

In most published studies, production has been varied within list, and memory has been better for produced items than for unproduced items. Using hypothetical data, Figure 2 illustrates possible data patterns. Relative to the production effect in a between-lists design (A), a larger within-list effect could be due to a memory benefit for produced items (B), or it could solely or partially reflect a memory cost for unproduced items (C or D). Extending the "lazy reading" account of the generation effect (e.g., Begg & Snider, 1987), Bodner et al. (2014) suggested that the unproduced items in a within-list condition might receive less processing than they would in a pure list of unproduced items. Essentially, in a mixed list, the produced items may be judged

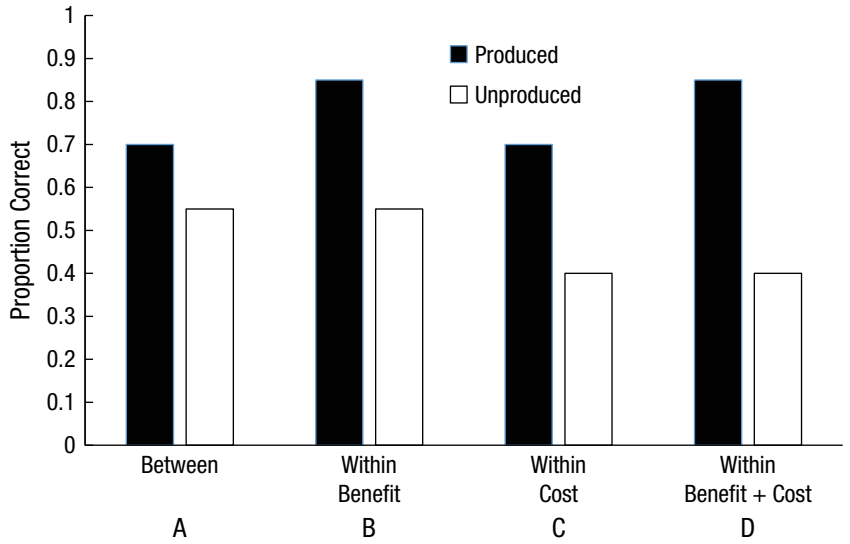

Fig. 2. Hypothetical recognition memory data to illustrate possible cost/benefit patterns. A production effect is shown for both between-lists and within-list designs, but a larger effect is shown for the within-list design. Relative to (A) the between-lists effect, the larger within-list effect could be driven by (B) a benefit for produced items, (C) a cost for unproduced items, or (D) both a benefit and a cost. At present, the within-list data are most consistent with there being a benefit and a cost for recognition but only a cost for recall.

to be more important, resulting in less attention being devoted to the unproduced items than they would ordinarily receive.

When the test is recognition, the occurrence of a between-lists production effect mitigates the possibility that within-list production effects are solely due to a cost to unproduced items. In addition, MacLeod et al. (2010) found a reliable within-list production effect even when elaborative processing was initially required for both produced and unproduced words—accomplished either by a level of processing or a generation task prior to production (see also Forrin, Jonker, & MacLeod, 2014). Yet there is also evidence that part of the within-list production effect in recognition reflects a cost (e.g., Forrin, Groot, & MacLeod, 2016), suggesting a possible influence of "lazy reading." As mentioned earlier, in free recall the between-lists effect is absent and the within-list effect appears to be almost exclusively due to a cost (Forrin & MacLeod, 2016; Jones & Pyc, 2014; Jonker, Levene, & MacLeod, 2014; Lambert, Bodner, & Taikh, 2016). This difference across recognition and recall is surprising given current accounts of the production effect, to which we now turn.

Distinctiveness and Strength

Performing production tasks is simple, but accounting for their effects on memory has proven to be less straightforward. MacLeod et al. (2010) interpreted the within-list production effect as evidence for a *distinctiveness account* (for a cogent case for distinctiveness as a general explanatory mechanism in memory, see Hunt, 2006, 2013). The idea is that producing items increases their distinctiveness in memory *relative to unproduced items*. The processing operations applied during a production task constitute part of the encoding for items (Conway & Gathercole, 1987), and at the time of test, the distinctiveness of these operations can facilitate access to produced items relative to unproduced items. Similarly, Conway and Gathercole (1990) characterized the translation of items between different modalities (e.g., from visual to auditory) as enhancing distinctiveness (see also Forrin et al., 2012). In accord with this view, Richler, Palmeri, and Gauthier (2013) reported that production failed to enhance memory (and sometimes made it worse) when participants named pictures of exemplars from only two categories ("chair" vs. "lamp"), which added little distinctiveness during encoding. Other evidence supports a role for distinctiveness, including the finding that older people, known to benefit less from distinctive processing in other situations, show a smaller production effect than younger people (Lin & MacLeod, 2012). Moreover, Jamieson, Mewhort, and Hockley (2016) successfully simulated production effects in a formal memory model (MINERVA 2) by modeling distinctiveness as increased sensory feedback.

Although relative distinctiveness has been the dominant explanation of the production effect to date, it has

its limitations. For one, there is the between-lists production effect to contend with. By an alternative *strength account*, production might enhance the strength of items in memory (more specifically, their *familiarity*), which would occur in both within-list and between-lists designs (e.g., Bodner & Taikh, 2012). Alternatively, people might benefit from distinctiveness, regardless of design, by using a *distinctiveness heuristic* (i.e., strategy) at test, in which they attempt to recollect the production task and only endorse items when their attempt succeeds (i.e., "if I recall saying it aloud, then it must have been studied"; e.g., Dodson & Schacter, 2001; see Taikh & Bodner, 2016). Recent evidence from Fawcett and Ozubko (2016) is consistent with the idea that production enhances both recollection (i.e., enhanced distinctiveness) and familiarity (i.e., greater strength) in a within-list design but enhances only familiarity in the between-lists design.

Returning to the within-list case, Ozubko, Major, and MacLeod (2014) pitted the predictions of distinctiveness and strength accounts against each other. At test, participants judged whether each recognized item had been studied aloud or silently. Critically, Ozubko et al. (2014) had repeated some of the silent words during study, thereby bringing their recognition performance to the same level as that of the aloud words. People nevertheless correctly attributed these repeated silent items to the silent condition, whereas by a strength account they should have attributed them to the aloud condition given their equivalent recognition. Thus, consistent with a distinctiveness account, people were able to use their memory for having performed a production task to enhance their source accuracy.

However, other production effects have a locus other than enhanced distinctiveness or strength. For example, Icht, Mama, and Algom (2014) showed that when produced items are rarer than unproduced items on the study list, memory can sometimes be better for unproduced items (i.e., a reverse production effect)—even though the memory records for the unproduced items would not include the distinctive information studied aloud and/or would be weaker. Thus, distinctiveness in a statistical sense can also influence memory.

Finally, as described earlier, the cost-based pattern of production effects in free recall does not fit with either distinctiveness or strength accounts. Instead, work beginning with Jonker et al. (2014) has supported an item-order account of the production effect in recall (Nairne, Riegler, & Serra, 1991). In brief, production not only enhances item-specific processing; it also impairs item-order processing. In a within-list design, the presence of the produced items disrupts order information for the unproduced items, resulting in a cost for the within-list unproduced items relative to their between-lists counterparts. Indeed, there is even another possibility, raised by Lambert et al. (2016): In a within-list design, a task-switching cost for both produced and unproduced items might be offset for produced items by their enhanced relative distinctiveness, resulting in a cost for the within-list unproduced items in recall.

In sum, a variety of mechanisms may contribute to production effects, depending on factors such as how production is manipulated and how memory is tested. Much of the evidence currently in hand is, however, consistent with the idea that producing material at the time of encoding makes that material distinctive, which in turn enhances memory.

Unresolved Issues and Opportunities

Despite the recent progress in research, we still have much to learn about the production effect. One important unresolved issue is why production improves recognition and cued recall but not free recall. If production enhances the distinctiveness or strength of items in memory, why does that not render those items easier to free recall at test? One possibility is that free recall leads participants to emphasize a strategy of retrieving relational/order information rather than a strategy of applying a production-based distinctiveness heuristic.

Related to this last point, the claim that participants adopt an intentional strategy of trying to recall the production task warrants further scrutiny (see Taikh & Bodner, 2016). On this issue of metamemory for production, Castel, Rhodes, and Friedman (2013) used judgments of learning to examine whether people know the value of production. At study, people correctly judged themselves to be more likely to later recognize words read aloud than words read silently. Interestingly, though, they overgeneralized, incorrectly thinking that they would also better remember words to which they always made the same vocal "yes" response, which they did not. People's awareness of how distinctiveness affects memory may not be very precise. It may also be that, under some yet-to-be-clarified circumstances, they abandon the use of the distinctive production information in memory.

The metamemory observation raises another issue: If production effects are not closely tied to awareness or strategy use, then should they not also occur on implicit memory tests? Although MacLeod et al. (2010) did not obtain production effects using an implicit speeded reading task, Bodner and Taikh (2012) suggested that people might not evaluate item familiarity on such a test. Therefore, future research should examine whether production effects might occur on other implicit memory tasks. For example, the act of producing (and therefore hearing) items at study might confer

a benefit on an auditory test such as identifying words in noise (e.g., Pilotti, Bergman, Gallo, Sommers, & Roediger, 2000).

Another informative direction will be to investigate the neural basis of production effects, using techniques such as fMRI and ERP. For example, given that within-list and between-lists production effects appear to rely differentially on recollection and familiarity processes (Fawcett & Ozubko, 2016), then the pattern of production effects should match the activation of brain regions associated with each process. Moreover, brain regions associated with a given mode of production should be more active at both study and test for produced items and should be less active for unproduced items.

It is also reasonable to anticipate more work on the applied value of production now that there is a firm experimental base upon which to build. Which everyday types of memory will benefit from using a production-based encoding strategy and under what conditions? Ozubko et al. (2012) found better memory for text paragraphs read aloud relative to those read silently. But this difference could reflect a benefit and/or a cost. We also do not know whether reading all of a text aloud will result in a memory advantage. Finally, whether production can enhance other cognitive processes, such as text comprehension or decision making, remains an open avenue to explore.

Conclusion

Language developed for oral communication long before there was any form of written communication. Production accentuates the oral element. Production also translates information into other modalities, making that information stand out precisely because it has been produced. Despite having been largely overlooked until recently, production is a simple way to influence encoding, allying it with other long-studied encoding tasks as a tool for exploring the fundamental operation of memory.

Recommended Reading

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