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Proportional Manipulation of Produced Words Tests the Distinctiveness and Strength Accounts
of the Production Effect

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Abstract

The production effect occurs when producing items enhances memory relative to reading items silently. Although the most common mode of production used in research has been “reading aloud”, singing, mouthing, whispering, writing, typing, and spelling out also produce a memory advantage. Distinctiveness and strength of encoding have both been offered as explanations for the memory enhancement. Production, relative to silent reading, makes items distinctive and therefore, memorable. Production increases memory traces at encoding (strength). Two experiments ($N = 272$) tested the distinctiveness and strength accounts by manipulating the proportion of words produced at study. Experiment 1 involved the production method of reading aloud in a classroom setting. Experiment 2 involved the production method of writing, tested in a classroom setting, small groups, and individuals. Our results were consistent with both accounts; however, neither account can explain our full data pattern.

Keywords: production effect, memory, distinctiveness, strength, proportions

Proportional Manipulation of Produced Words Tests the Distinctiveness and Strength Accounts
of the Production Effect

The production effect, although studied for decades (Conway & Gathercole, 1987; Gathercole & Conway, 1988; Hopkins & Edwards, 1972), was only defined and named in recent years (MacLeod, Gopie, Hourihan, Neary, & Ozubko, 2010). The production effect appears as a memory advantage for words that are produced, over words that are read silently. Words may be produced in various ways such as reading aloud normally, reading aloud loudly, singing, mouthing, whispering, writing, and typing (Conway & Gathercole, 1987; Forrin, MacLeod, & Ozubko, 2012; Gathercole & Conway, 1988; Hopkins & Edwards, 1972; MacLeod et al., 2010; Ozubko, Gopie, & MacLeod, 2012; Ozubko & MacLeod, 2010; Quinlan & Taylor, 2013).

There has been ongoing debate about what underlies the production effect. The two explanations providing the strongest evidence are the distinctiveness account (Bodner & Taikh, 2012; Conway & Gathercole, 1987; Dodson & Schacter, 2001; Forrin et al., 2012; MacLeod et al., 2010; Ozubko et al., 2012; Ozubko & MacLeod, 2010; Ozubko, Major, & MacLeod, in press) and the strength account (Bodner & Taikh, 2012; Bodner, Taikh, & Fawcett, 2014; Fawcett, 2013; MacLeod et al., 2010; Ozubko & MacLeod, 2010).

The distinctiveness account suggests that production provides an additional mode of encoding to make the produced item stand out from the unproduced items (Bodner & Taikh, 2012, Castel, Rhodes, & Friedman, 2013; Forrin et al., 2012; MacLeod et al., 2010; Ozubko et al., 2012; Ozubko & MacLeod, 2010). The modes would be articulatory, in the case of mouthing and reading aloud, and motor, in the case of writing or typing. The strength account posits that the production of items creates stronger memory traces, thereby making the items easier to recollect

later (Bodner & Taikh, 2012; Bodner et al., 2014; Fawcett, 2013; MacLeod et al., 2010; Ozubko & MacLeod, 2010).

Research in this area has found that the memory performance increase due to the production effect appears almost exclusively in mixed-list within-subject designs, where the participant studies lists composed of items that are to be both produced and unproduced (Conway & Gathercole, 1987; Forrin, et al., 2012; Hopkins & Edwards, 1972; MacLeod et al., 2010; Ozubko et al., 2012; Ozubko & MacLeod, 2010). As an example of a mixed-list within-subject design, participants read some items silently and some words aloud normally, experiencing both the produced and unproduced conditions. This memory performance increase has not been shown in a pure-list between-subjects design. Pure lists consist of only one condition. That is, participants either produce all of the items on the study list or they read all of the items silently. It appears that for items to seem unique or distinctive, it is necessary to have other items with which to compare them. The between-subjects design does not provide participants with a manner of comparison, thereby removing the opportunity to use distinctiveness.

Much of the research conducted thus far suggests that the most prominent feature of distinctiveness is that it is relative (Bodner et al., 2014; Conway & Gathercole, 1987; Lin & MacLeod, 2012). Participants must be able to determine at the time of retrieval that the produced word was different from the word that was not produced. The assessment of whether the word had been seen before could be determined by using a distinctiveness heuristic (Dodson & Schacter, 2001; Forrin, MacLeod, & Ozubko, 2012; MacLeod, 2011; Ozubko & MacLeod, 2010; Ozubko et al., in press). Curiously, participants seem to have also used this heuristic in reverse, determining that the item could not have been studied if it was not distinctive (Bodner & Taikh, 2012; Dodson & Schacter, 2001).

When groups of younger adults with an age range of 17 to 25 years and older adults with an age range of 67 to 88 years were tested, both groups benefited from production in their memory retrieval, but older adults showed a smaller advantage (Lin & MacLeod, 2012). These results were interpreted as evidence for distinctiveness as an explanation for the production effect. Lin and MacLeod (2012) stated that older adults experienced more difficulty in retrieving distinctive information than younger adults.

There may be more than one explanation for the production effect, with more than one process contributing to the memory benefits. A meta-analysis of production effect experiments using a between-subjects design prompted Fawcett (2013) to suggest that strength at encoding may only be a small aspect of the production effect, with other factors as contributors. The between-subjects experiments showed a trend toward a production effect. If strength only plays a small part in remembering, then it follows that there would be only a small effect when strength is the only contributing factor to the production effect (Bodner & Taikh, 2012; Fawcett, 2013).

The experiments in this study tested the distinctiveness and strength accounts by manipulating the proportion of produced words to unproduced words in the study phase. If the memory benefit found in the production effect is attributable to distinctiveness, then the fewer the words in the study list that are produced, the more those words would be remembered by participants (e.g. if 80% of the words are produced and 20% of the words are silent, the silent words would be more distinctive, and in turn, better remembered). If the memory benefit is due to strength, then regardless of the proportion of words produced at study, participants would remember a greater number of produced words. Production results in stronger memory traces at encoding, allowing the produced words to be more easily remembered than non-produced words (Bodner

& Taikh, 2012; Bodner et al., 2014; Fawcett, 2013; MacLeod et al., 2010; Ozubko & MacLeod, 2010). The benefits of production were also tested in a between-subjects design, where participants either read all of the words silently (unproduced condition) or produced all of the words.

When there are fewer words produced or unproduced, those words are more distinctive, relative to the other words in the list. Since distinctiveness has been predominant in explanations of the production effect in mixed-list, within-subjects designs, I predicted that when a proportional manipulation of produced words was applied, there would be a memory advantage for produced words in the 20% produced condition and unproduced words in the 80% produced condition (Bodner & Taikh, 2012, Castel, Rhodes, & Friedman, 2013; Forrin et al., 2012; MacLeod et al., 2010; Ozubko et al., 2012; Ozubko & MacLeod, 2010). I anticipated that in the typical production effect paradigm where 50% of the words were produced, that produced words would have a memory advantage over unproduced words. I also expected that there would be either a small or no production effect in the between-subjects design, as evidenced in previous experiments (Fawcett, 2013; Hopkins & Edwards, 1972). (See Table 1 for production conditions and predictions).



Experiment 1

Method

Participants

Undergraduate students from Kwantlen Polytechnic University (KPU) Psychology classes were recruited to participate in this experiment ($N = 120$). All five classes that participated were first year Psychology classes. Participants received course credit as compensation for taking part in the experiment.

Materials

The study and test words were drawn from the pool of 120 words that were listed in the appendix of MacDonald and MacLeod (1998) (see Appendix 1). This word list was used in other experiments on the production effect with consistent results, reflecting its reliability (Bodner & Taikh, 2012; Forrin et al., 2012; MacDonald & MacLeod, 1998; MacLeod et al., 2010; Ozubko et al., 2012). The stimuli in the study phase consisted of 60 words randomly selected from the item pool. The 60 words were randomly assigned to lists that varied in the proportion of produced to unproduced words according to each of the five conditions as follows: 0 percent produced (0% produced words to 100% unproduced words), 20 percent produced (20% produced words to 80% unproduced words), 50 percent produced (50% produced words to 50% unproduced words), 80 percent produced (80% produced words to 20% unproduced words), and 100 percent produced (100% produced words to 0% unproduced words). Each list had the words arranged in the same random fixed order. An icon accompanied each word to show the participant how to read the word. The “speech bubble” icon () indicated that the participant was to read the word aloud in a normal manner (produced condition). The “eyeglasses” icon () indicated that the participant was to read the word silently (unproduced condition). The words were projected onto a classroom screen using Microsoft PowerPoint, presented in black 55 Calibri lowercase font against a white background. Each stimulus item during the study phase stayed on the screen for 3000 ms and was offset from the next word by a 1000 ms blank screen. Each word and its accompanying icon was presented in the middle of the screen.

Participants wrote the words for the free recall test on a blank piece of 8.5” by 11” paper. The recognition test was composed of 120 words, with each word presented in black letters on a piece of 8.5” by 11” piece of paper (Appendix 1). Sixty of the words were “old” and seen by the

participants in the study phase, and 60 of the words were “new”, and had not been seen by the participants during the experiment.

Procedure

Five groups of participants from first year Psychology classes completed the experiment in classroom settings. Each class formed a separate group to study a different proportion of produced to unproduced words. The groups were as follows: 0% produced words to 100% unproduced words ($n = 20$); 20% produced words to 80% unproduced words ($n = 25$); 50% produced words to 50% unproduced words ($n = 19$); 80% produced words to 20% unproduced words ($n = 27$); 100% produced words to 0% unproduced words ($n = 29$).

Participants received verbal and written instructions to describe the procedure of the experiment. The participants completed a practise phase of five slides that demonstrated the study phase. The actual experiment commenced after it was determined that all the participants understood the procedure. The study phase consisted of 60 words presented in a PowerPoint presentation on a classroom screen. Each word in the 20% produced, 50% produced, and 80% produced conditions was accompanied by an icon (either eyeglasses or speech bubble) that indicated how the word was to be read (read silently or produced by reading aloud).

The study phase was followed by a free recall test and then a recognition test. For the recall test, the participants were directed to write down all of the words that they remembered from the study phase. The recognition test immediately followed the recall test. The recognition test consisted of 120 words. Sixty words were “old” and had been seen by participants in the study phase, and 60 were “new” and had not been seen by the participants in the study phase. The participants were told that some of the words were “old” and had been presented during the study phase and that some of the words were new. Participants were not told that the test contained all

of the 60 study words. Participants were directed to circle all words that they remembered from the study phase.

Results

The proportional means of produced words remembered compared to unproduced words remembered in each proportional condition were evaluated by conducting *t*-tests, calculating average difference scores and 95% confidence intervals (CI) for each. The number of items recalled or recognized by each participant was converted into proportions by dividing the number recalled by the total number of items in that condition (e.g. In the 20% produced group, the number of produced items recalled were divided by 12, the unproduced items were divided by 48, and the errors were divided by 60.) The results from the recall test will be reported first, followed by the results of the recognition test.

The data from the recall tests showed no differences in memory between produced and unproduced words except in the 20% production condition (see Table 2). The 20% produced group recalled more unproduced words than produced words, $t(24) = -2.29$, with a difference score of $M = -0.04$, 95% CI $[-0.08, 0.00]$. The 50% produced group recalled the same proportion of produced words and unproduced words, $t(32) = 1.41$, with a difference score of $M = 0.02$, 95% CI $[-0.01, 0.05]$. The 80% group recalled the same proportion of produced words as unproduced words, $t(26) = 1.39$, with a difference score of $M = 0.03$, 95% CI $[-0.01, 0.07]$. The 100% produced group and the 0% produced group had unequal sample sizes, with the 100% produced group having nine more participants. Only the data from 20 participants in the 100% produced group were included in the analysis. These were the first 20 participants in the data set. The 100% produced group recalled the same proportion of words as the 0% produced group, $t(38) = 2.33$, with a difference score of $M = 0.05$, 95% CI $[0.00, 0.11]$ (see Table 4).

The recognition tests showed differences in the memory for produced words and unproduced words across all proportional manipulations (see Table 3). As with the recall test, the 20% produced group recognized fewer produced words than unproduced words $t(24) = -3.74$, with a difference score of $M = -0.11$, 95% CI $[-0.17, -0.05]$. The 50% produced group recognized more produced words than unproduced words, $t(32) = 7.13$, with a difference score of $M = 0.16$, 95% CI $[0.12, 0.21]$. The 80% group recognized more produced words and unproduced words, $t(26) = 5.74$, with a difference score of $M = 0.14$, 95% CI $[0.09, 0.19]$. As with the recall results, the 0% produced group and the 100% produced group had unequal sample sizes, with the 100% produced group having nine more participants. Only the data from 20 participants in the 100% produced group were included in the analysis. The 100% produced group recognized significantly more words than the 0% produced group, $t(38) = 3.83$, with a difference score of $M = 0.195$, 95% CI $[0.07, 0.31]$ (see Table 4).

Discussion

Experiment 1 tested the production effect paradigm in a classroom setting. All published production effect experiments have tested participants individually rather than in groups, except in MacLeod (2011), where each participant was paired with one other individual. In MacLeod's experiment, similar to the typical production effect paradigm, there were items to be read silently and items to be produced by reading aloud. The items were produced by either one individual or the other, or by both participants. MacLeod (2011) found that participants remembered the items that they had produced themselves best. However, there was still a memory advantage for items produced at the same time as the other participant, and for items produced solely by the other participant. The benefit was less in the latter two cases, but the production effect was still robust (MacLeod, 2011). MacLeod's experiment demonstrated that it was possible to generate a

production effect by testing more than one individual at a time. Experiment 1 of the two experiments described in this paper, investigated whether testing the production effect in a classroom setting was a viable option. The mean proportion of words recognized in the 50% production condition (the typical proportion produced in production effect studies) in the recognition test was comparable to results found in other production effect studies, although the proportion recalled was lower than what might normally be found (Forrin, Jonker, & MacLeod, 2013; MacLeod et al., 2010).

There were some questions about the findings of Experiment 1, particularly in the 20% produced condition, where participants recalled more silent words than produced words. These findings support neither the distinctiveness account nor the strength account. Distinctiveness would predict that more produced words would be remembered, as fewer produced words would stand out compared to the unproduced words. The strength account would have predicted that producing the words would strengthen the memory traces at encoding, allowing more produced words to be remembered. There may be another unknown variable contributing to the effect that was found, or it may be a Type I error. Since all of the participants tested were in first year Psychology classes, it is unlikely that this particular class of students was different from the other classes that were tested. However, to ensure that there were no appreciable differences, it would be necessary to replicate this condition.

The results of this experiment indicated that there were no significant differences in recall between the silently read words and the produced (read aloud) words, except when 20% of the words were produced and 80% were silent (see Table 2). Based on these results, distinctiveness would not appear to explain the production effect. If distinctiveness accounted for the memory advantage, then having fewer produced words would make them more, not less, memorable.

They would be distinctive relative to the unproduced words, and would stand out in memory (Bodner & Taikh, 2012; Conway & Gathercole, 1987; Dodson & Schacter, 2001; Forrin et al., 2013; Forrin et al., 2012; MacLeod, 2011; MacLeod et al., 2010; Ozubko et al., 2012; Ozubko & MacLeod, 2010; Ozubko et al., in press). Strength does not provide an explanation either. According to the strength account, producing words provides an additional memory trace at encoding (Bodner & Taikh, 2012; Bodner et al., 2014; Fawcett, 2013; MacLeod et al., 2010; Ozubko & MacLeod, 2010). Therefore, produced words would be more easily recalled than unproduced words, regardless of the proportion of produced words presented at study. If strength at encoding allowed for enhanced memory, then the 20% produced group would show a production effect, but this is not the case.

Analysis of the recognition data for Experiment 1 displayed significant differences between produced and unproduced words in all the groups (see Table 3). Production of words provided enhanced memory, except in the group where 20% of the words were produced. For the reasons outlined above, neither distinctiveness nor strength appears to explain the results. The recognition test data were confounded by the recall test that was administered immediately prior to the recognition test. Therefore, it is important to evaluate the recognition results in light of this confound.

When compared to reading silently, production by reading aloud provides an additional auditory modality to provide distinctiveness (Conway & Gathercole, 1987; Forrin et al., 2012; Hopkins & Edwards, 1972; Ozubko et al., in press). Writing also offers the additional mode of orthographic processing to add distinctiveness (Conway & Gathercole, 1990; Forrin et al., 2012). MacLeod (2011) noted that when both participants produced words by reading aloud at the same time, the decreased benefit over solo reading could be due to a disruption in the distinctiveness at

encoding. It is possible that the disruption described by MacLeod was amplified in the classroom setting used in Experiment 1. Experiment 2 was designed as a replication of Experiment 1 to address the problem of disruption, by changing the mode of production from reading aloud to writing.

Experiment 2

Method

Participants


Undergraduate students from Kwantlen Polytechnic University (KPU) Psychology classes and the Psychology Research Pool were recruited to participate in this experiment ($N = 152$). The participants that comprised the 0% ($n = 22$), 50% ($n = 34$), and 100% ($n = 28$) produced conditions were tested in a classroom setting, small groups, and individually. All but three of the participants in the 100% produced condition were tested in a classroom setting. Participants in the 20% ($n = 34$) and 80% ($n = 34$) produced conditions were tested in small groups or individually. All of the classes used were first year Psychology classes, except those in the 0% production condition, whose class was a second year Psychology class. To ensure that there were no appreciable differences between participant classes, additional participants from a second year Psychology class were tested in the 100% production condition. Participants received course credit as compensation for taking part in the experiment.

Materials

The apparatus was identical to that used in Experiment 1 aside from three exceptions. The stimuli were the same as Experiment 1 except that the assignment of “produced” or “unproduced” words was counterbalanced to eliminate the potential confound of order effects (Frensch, 1994). Writing was the mode of production rather than the reading aloud mode of

production used in Experiment 1. Each participant was provided with pieces of paper measuring 4.75" by 5.25" on which to write each of the produced words. Each stimulus item during the study phase stayed on the screen for 5000 ms and was offset from the next word by a 2000 ms blank screen to allow participants sufficient time in which to write each word.

Procedure

The procedure was identical to that of Experiment 1, except that participants wrote the produced words rather than read the produced words aloud. A pencil icon () indicated that the participants were to write the word. Participants wrote each word to be produced on the paper provided, immediately turning the paper over in front of them (see Conway and Gathercole, 1990; Forrin et al., 2012). Each paper used in the study phase was checked by the researcher to ensure that each participant had sufficient time to write each word completely.

Results

The proportional means of produced words remembered compared to unproduced words remembered in each proportional condition were evaluated by conducting *t*-tests, calculating average difference scores and 95% confidence intervals (CI) for each. As in Experiment 1, the number of items recalled or recognized by each participant was converted into proportions by dividing the number recalled by the total number of items in that condition. The results from the recall test will be reported first, followed by the results of the recognition test.

The data from the recall tests showed no differences in memory between produced and unproduced words except in the 20% production condition (see Table 2). The 20% produced group recalled more produced words than unproduced words, $t(32) = 4.77$, with a difference score of $M = 0.13$, 95% CI [0.08, 0.19]. The 50% produced group recalled the same amount of produced words and unproduced words, $t(32) = 2.35$, with a difference score of $M = 0.07$, 95%

CI [0.01, 0.12]. The 80% group recalled the same amount of produced words as unproduced words, $t(32) = -1.61$, with a difference score of $M = -0.35$, 95% CI [-0.09, 0.02]. The 100% produced group and the 0% produced group had unequal sample sizes, with the 100% produced group having nine more participants. Only the data from the first 22 participants in the data set from the 100% produced group were included in the analysis. The 100% produced group recalled the same amount of words as the 0% produced group, $t(41) = -2.65$, with a difference score of $M = -0.09$, 95% CI [-0.16, -0.02] (see Table 4).

The recognition tests showed significant differences in the memory for produced words and unproduced words across all proportional manipulations in the within-subjects groups (see Tables 3 and 4). The 20% produced group recognized more produced words than unproduced words $t(33) = 4.81$ with a difference score of $M = 0.13$, 95% CI [-0.16, -0.02]. The 50% produced group recognized more produced words than unproduced words $t(33) = 3.32$, with a difference score of $M = 0.12$, 95% CI [0.05, 0.19]. The 80% produced group recognized more produced words than unproduced words $t(33) = 3.32$, with a difference score of $M = 0.09$, 95% CI [0.04, 0.15]. The 100% produced group was essentially the same as the 0% produced group in recognition of produced versus unproduced words $t(38) = 0.95$, with a difference score of $M = -0.05$, 95% CI [-0.15, 0.06].

Discussion

A production effect was observed in all the within-subject groups, with significant differences between the produced words and unproduced words recalled. The only exception was the 80% produced group in the recall test, where there was essentially no difference between the proportional mean of the produced words recalled and the unproduced words recalled.

The between-subjects group that produced all of the words by writing recalled proportionally fewer produced words than the group that read all of the words silently (unproduced words). This result, where more unproduced words were recalled than produced words in a recall test, to our knowledge, has not been reported previously. It may be a feature that arises when testing written production with recall tests. In previous studies, written production was tested with recognition tests only (Conway and Gathercole, 1990; Forrin et al., 2012).

There was a possible confound in the between-subjects groups. Twenty-five of the 28 participants in the 100% produced condition were from a first year Psychology course while 14 of the 22 participants in the 0% produced condition were from a second year Psychology course. To address this possible confound, another second year Psychology class ($n = 19$) was tested in the 100% produced condition. Their data was essentially the same as the original group. Thus, the finding that more unproduced words were recalled than produced words in our between-subjects comparison is not due to year 1 versus year 2 students comprising the 100% and 0% produced conditions, respectively.

General Discussion

This experiment set out to test the distinctiveness account and the strength account as explanations for the production effect, by manipulating the proportion of produced words relative to unproduced words. The data from the recall tests in Experiment 1 provided no evidence to support the distinctiveness account in any of the production conditions. In fact, Experiment 1 did not provide evidence for either distinctiveness or strength in any of the production conditions. Only in the between-subjects design, where a group that studied all produced words was compared to a group that studied all unproduced words, was there support for either of the accounts. In this comparison, participants recalled more produced words than

unproduced words, supporting the strength account, which posits that production will result in a memory advantage.

Experiment 1 used reading aloud as the mode of production, the same paradigm as a majority of other production effect experiments (for example, MacLeod et al., 2010; Ozubko & MacLeod, 2010). Other production effect experiments used individual testing, whereas a classroom setting was used in Experiment 1. It is possible that self-consciousness or embarrassment moderated the responses of some of the participants. In addition, it was difficult to monitor whether participants were actually reading aloud.

Experiment 2 provided evidence to support distinctiveness in the 20% produced and 50% produced conditions, with more produced words recalled than unproduced words. Distinctiveness could explain the production effect in the 20% produced and 50% production conditions, since production has made the words in those conditions stand out, relative to the unproduced words (Bodner et al., 2014; Conway & Gathercole, 1987; Lin & MacLeod, 2012). If distinctiveness provided the explanation for this effect, then the 80% produced condition should have yielded more unproduced words recalled and recognized than produced words, since the smaller proportion of unproduced words made them more distinctive. However, this was not the case. Because more produced words were recalled than unproduced words, evidence for the strength account surfaces. The strength account posits that production increases the memory traces at encoding, aiding memory (Bodner & Taikh, 2012; Bodner et al., 2014; Fawcett, 2013; MacLeod et al., 2010; Ozubko & MacLeod, 2010). Strength could also be offered as an explanation for the results found in the 20% produced and 50% produced conditions in Experiment 2, since strength posits that production increases the memory traces at encoding to provide a memory advantage.

Transfer-appropriate processing might explain the production effect when writing is the mode of production. This theory suggests that there is a memory advantage when the study and test modalities match (Graf & Ryan, 1990). In Experiment 2, the match of production by writing and the subsequent written recall test might explain the production effect when production conditions were proportionally manipulated. However, transfer-appropriate processing does not explain why more unproduced words were recalled by the 0% produced condition than produced words recalled by the 100% produced condition, in Experiment 2. According to this theory, the match of study and test modality should result in more produced words recalled in the 100% produced condition.

False alarms in Experiment 2 were consistently higher than in Experiment 1 across all production conditions. Production by writing may lead participants to feel more confident in their recognition judgments than those participants who produce by reading aloud. A follow-up study might include confidence judgments by participants to test this assumption.

The between-subjects design in Experiment 2 yielded results that have not yet been seen in the published literature. More unproduced than produced words were recalled when comparing the groups of 100% produced versus 0% produced. It is possible that the 0% produced group used the time given to them to view the words, to employ study strategies that provided a memory advantage over the group that produced all the words (G. E. Bodner, personal communication, March 26, 2014). Some participants may have grouped words that had a common theme (e.g. vacation, resort, ticket, travel). The 100% produced group participants were busy writing each word and turning over each paper, so did not have the same amount of time to visually encode the words, putting this group at a disadvantage. This effect may not have been seen in the proportionally produced conditions because the produced words would interrupt

the study strategies. The mixture of produced and unproduced words would make it difficult to consciously adopt a strategy that could persist throughout the entire study phase.

Replications of these experiments will be necessary. It may be found that both the distinctiveness and strength accounts contribute to the production effect, with an additional contribution from another, yet unknown source. Understanding the underlying mechanisms of the production effect could result in more effective strategies for studying (Ozubko, Hourihan, & MacLeod, 2012) and memory improvement in older adults (Lin & MacLeod, 2012).

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Table 1.

Production Proportion Conditions and Predictions for Distinctiveness and Strength Accounts

Production Condition	Experimental Design	Prediction if Distinctiveness Account	Prediction if Strength Account
20% produced	Within-subjects	Produced words > unproduced words	Produced words > unproduced words
50% produced	Within-subjects	Produced words > unproduced words	Produced words > unproduced words
80% produced	Within-subjects	Produced words > unproduced words	Produced words > unproduced words
100% produced versus 0% produced	Between-subjects	Produced words = unproduced words	Produced words > unproduced words

Table 2.

Experiments 1 and 2: Mean Proportions of Words Remembered in Recall Test

Proportion	Produced	Unproduced	Errors
Exp 1. 20% produced	0.07 (0.02)	0.11 (0.01)	0.01 (0.00)
Exp 1. 50% produced	0.14 (0.01)	0.12 (0.01)	0.02 (0.00)
Exp 1. 80% produced	0.13 (0.01)	0.10 (0.02)	0.02 (0.00)
Exp 2. 20% produced	0.26 (0.02)	0.13 (0.01)	0.02 (0.00)
Exp 2. 50% produced	0.16 (0.02)	0.09 (0.02)	0.02 (0.00)
Exp 2. 80% produced	0.14 (0.02)	0.17 (0.03)	0.03 (0.00)

Note. Standard errors are shown in parentheses below each corresponding mean.

Table 3.

Experiments 1 and 2: Mean Proportions of Words Remembered in Recognition Test

Proportion	Produced	Unproduced	False Alarms
Exp 1. 20% produced	0.23 (0.04)	0.34 (0.05)	0.03 (0.01)
Exp 1. 50% produced	0.52 (0.03)	0.35 (0.03)	0.03 (0.01)
Exp 1. 80% produced	0.40 (0.04)	0.26 (0.03)	0.04 (0.01)
Exp 2. 20% produced	0.54 (0.03)	0.41 (0.02)	0.07 (0.01)
Exp 2. 50% produced	0.48 (0.04)	0.36 (0.04)	0.12 (0.02)
Exp 2. 80% produced	0.52 (0.04)	0.43 (0.03)	0.07 (0.01)

Note. Standard errors are shown in parentheses below each corresponding mean.

Table 4

Experiment 1 and 2: Mean Proportions of Words Remembered in Between-Subjects Conditions

Experiment/Test	Produced	Errors/False Alarms	Unproduced	Errors/False Alarms
Exp 1/Recall	0.17 (0.02)	0.04 (0.01)	0.12 (0.01)	0.02 (0.01)
Exp 1/Recognition	0.53 (0.03)	0.06 (0.01)	0.33 (0.04)	0.04 (0.01)
Exp 2/Recall	0.19 (0.02)	0.02 (0.00)	0.28 (0.03)	0.03 (0.01)
Exp 2/Recognition	0.58 (0.04)	0.05 (0.01)	0.63 (0.03)	0.10 (0.02)

Note. Standard errors are shown in parentheses below each corresponding mean

Appendix 1: Words to be read silently or produced

forest	pocket	traffic	machine	leather	lesson
branch	invention	station	education	history	village
theatre	wagon	minute	factory	direction	century
amount	record	debate	furniture	wheel	address
judge	ticket	account	powder	uniform	teacher
answer	package	quarrel	victory	captain	trousers
shoulder	afternoon	election	ocean	resort	laugh
market	capital	industry	entrance	school	dinner
vacation	clothes	partner	merchant	foundation	stream
garden	kettle	winter	glass	beauty	queen
avenue	evening	language	painting	gravity	friend
engine	basket	treasure	office	plate	campaign
pebble	speech	battery	thread	distance	summer
knock	valley	invitation	guardian	attitude	wheat
whisper	reward	handle	daughter	building	steam
neighbor	travel	attention	peace	harbor	author
kingdom	river	uncle	meadow	nephew	message
arrow	holiday	fashion	turnip	department	island
journey	ladder	sailor	shadow	porch	castle
kitchen	orchard	border	quarter	justice	envelope