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This time it's personal: the memory benefit of hearing oneself

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ABSTRACT

The production effect is the memory advantage of saying words aloud over simply reading them silently. It has been hypothesised that this advantage stems from production featuring distinctive information that stands out at study relative to reading silently. MacLeod (2011) (I said, you said: The production effect gets personal. *Psychonomic Bulletin & Review*, *18*, 1197–1202. doi:10.3758/s13423-011-0168-8) found superior memory for reading aloud oneself vs. hearing another person read aloud, which suggests that motor information (speaking), self-referential information (i.e., "*I* said it"), or both contribute to the production effect. In the present experiment, we dissociated the influence on memory of these two components by including a study condition in which participants heard themselves read words aloud (recorded earlier) – a first for production effect research – along with the more typical study conditions of reading aloud, hearing someone else speak, and reading silently. There was a gradient of memory across these four conditions, with hearing oneself lying between speaking and hearing someone else speak. These results imply that oral production is beneficial because it entails two distinctive components: a motor (speech) act and a unique, self-referential auditory input.

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Production effect; distinctiveness; recognition; self-referential memory

Production is a simple but versatile learning strategy. In their detailed investigation of the production effect, MacLeod, Gopie, Hourihan, Neary, and Ozubko (2010) demonstrated that words that are read aloud are better remembered than those that are read silently. Mouthing, writing, and typing words all have also been revealed to be memory-enhancing productions (Forrin, MacLeod, & Ozubko, 2012), and there is evidence that drawing pictures also helps (Wammes, Meade, & Fernandes, 2016). Production effects have been found in recognition and in free recall. There is now a substantial body of research on the phenomenon, as evidenced by the collection of articles in a recent special issue of the *Canadian Journal of Experimental Psychology* (see Bodner & MacLeod, 2016) and by a recent review (MacLeod & Bodner, 2017).

As MacLeod and Bodner (2017) summarise, although memory strength has been implicated (see Bodner & Taikh, 2012; Bodner, Taikh, & Fawcett, 2014; Fawcett & Ozubko, 2016), the primary account of the production effect thus far is the distinctiveness account (see, e.g., Forrin, Groot, & MacLeod, 2016; MacLeod et al., 2010; Ozubko & MacLeod, 2010; Ozubko, Major, & MacLeod, 2014). Based on Hunt's (2006, 2013) distinctiveness framework, and following Conway and Gathercole (1987, 1990), MacLeod et al. (2010) posited that additional speech-related processes were invoked by reading aloud relative to reading silently, which conferred *distinctive processing* on the "aloud" items at encoding, akin to a depth of processing (Craik & Lockhart, 1972) manipulation. Furthermore, in line with Dodson and Schacter's (2001) distinctiveness heuristic, MacLeod et al. argued that participants might well retrieve distinctive speech information at test to aid their recall or recognition.

Given that there are multiple processes that differentiate reading aloud from reading silently – notably auditory processing and motor/articulatory processing – reading silently is arguably not the ideal control condition: the production effect in speech could arise due to either (or both) of those distinctive processes. To help distinguish the influence of these processes when remembering, MacLeod (2011) employed an additional study condition: hearing someone else reading aloud. In this way, the presence of auditory information was controlled across the "read aloud" and "hear other" conditions. MacLeod found superior memory for reading aloud oneself vs. hearing someone else read aloud and attributed this advantage to the active, embodied nature of speech – the part of production that is uniquely *personal*.

The purpose of the present research was to further investigate the benefit to memory that arises from the personal nature of production. Memory could be superior for words that are read aloud vs. heard because words that are read aloud are active (i.e., involve motor processing) and/or because they are associated with the self (i.e., self-referential). Our goal, therefore, was to tease apart these two potential components of the production effect:

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the motor component and the self-referential component. We accomplished this by introducing a novel condition in which participants heard recordings of themselves reading words aloud (the "hear self" condition). This new condition resulted in there now being four study conditions: read aloud, hear self, hear other, and read silently.

The read aloud vs. hear self comparison allows us to differentiate the motor component from the self-referential component of vocal production. We could now assess whether the active/generative nature of production enhanced memory above and beyond hearing the items in one's own voice. The hear self vs. hear other comparison allows us to differentiate the self-referential component from the auditory component of production. Does recollecting that it was *you* who said a word benefit memory above and beyond recollecting that you heard it said aloud? There is sizeable literature showing that self-reference benefits memory (Rogers, Kuiper, & Kirker, 1977; for a meta-analysis, see Symons & Johnson, 1997), and we anticipated that this advantage would extend to the context of the production effect.

In keeping with the distinctiveness account (Conway & Gathercole, 1987, 1990; MacLeod et al., 2010), we hypothesised finding a read aloud > hear self > hear other > read silently pattern of hit rates. Of particular note, Forrin et al. (2012) found that the pattern of recognition performance in a mixed list corresponded to the number of distinct processes involved in each study condition relative to the "baseline" silent reading condition (see also Mama & Icht, 2016; Quinlan & Taylor, 2013). For example, for a list in which some words are read aloud, others are mouthed, and others are read silently, recognition was best for words that were read aloud (which has two distinct processes relative to silent reading: auditory and motor), followed by words that were mouthed (which has one distinct process: motor), and by words that were read silently.

In the present experiment, reading aloud has two distinctive processes relative to silent reading (auditory and motor), whereas hearing oneself or someone else both involve only one distinct process (auditory). Based on their relation to silent reading, one might therefore anticipate memory to be equivalent for hear self vs. hear other. We also presume, however, that relationally distinct processing will occur across the three auditory conditions. If that is the case, then because it is personal, hearing oneself is relationally distinct (by virtue of self-reference) relative to hearing someone else and should therefore lead to better memory.

Consequently, we investigated whether there is a memory benefit of (a) reading words aloud relative to hearing oneself read words aloud and an additional benefit of (b) hearing oneself read words aloud relative to hearing someone else read words aloud. The experiment comprised two sessions. In the first session, to provide the necessary materials, we simply recorded participants reading each of a set of words aloud. In the second session (2 weeks later), participants studied half of the words in one of four different ways: reading aloud, hearing oneself, hearing someone else, and reading silently. A recognition test containing all of the words – the remaining half as distractors – followed. We hypothesised a read aloud > hear self > hear other > read silently pattern of hit rates.

Method

Participants

To detect potentially small differences between the study conditions, we collected as much data as we could across two semesters. In total, 95 University of Waterloo undergraduate students participated in the first session of the experiment and were reimbursed with 0.5 bonus course credit. Of these students, 75 (79%) returned for the second session to complete the experiment. We attribute the attrition to participants forgetting to return was due to the 2-week delay between sessions. A power analysis using G* Power (Erdfelder, Faul, & Buchner, 1996) revealed that this sample size gave us adequate power (0.80) to detect a relatively small effect (Cohen's $d = 0.33$).

Apparatus

A PC-compatible computer with a 17-inch colour monitor was used for testing. The controlling programme was written in E-prime 2.0.

Stimuli

The word pool comprised 160 nouns from the MRC Psycholinguistic Database (http://www.psy.uwa.edu.au/mrcdatabase/uwa_mrc.htm) that were four to six letters long. To create stimuli for the "hear other" study condition, the first author (male) and a research assistant (female) recorded themselves saying each word using a Logitech microphone that was connected to the computer. Audacity 2.0 was used to save each word in .wav format (with a bit rate of 1411 kbps).

Procedure

The experiment took place in a quiet laboratory room at the University of Waterloo and consisted of two approximately 15-min sessions separated by exactly 2 weeks: the recording session and the study/test session. For the recording session, participants were seated in front of a Logitech microphone and a computer monitor. The chair and microphone were adjusted such that the participant was comfortable and at mouth level with the microphone (approximately 2 inches away) and at eye level with the monitor (approximately 20 inches away). Participants were instructed that a list of common words would be presented one at a time and that they were to say each word aloud into the microphone. Participants were not told why they were being recorded saying these words and were not told the nature of the second session. Each of the 160 words was individually presented in the centre of the screen for 3000 ms, with a 500-ms interstimulus interval (ISI). Words were printed in yellow Courier New 16 pt. bold font on a black background. Participants were then thanked and reminded to return for the second part of the experiment in 2 weeks.

Before the second session, 20 of the 160 words recorded in the first session (randomly chosen for each participant) were assigned to the "hear self" study condition. A research assistant used Audacity 2.0 to remove all background "white noise" from those 20 recorded words and saved each of them as .wav files (with a bit rate of 1411 kbps). To control for sound intensity across study conditions, the research assistant adjusted the intensity of participants' sound files (using the sound intensity slider in Audacity 2.0) until he perceived them to be equal to the sound intensity of the sound files that were previously recorded for the "hear other condition".

In the second experimental session, 2 weeks later, participants were told that they would study the same words that they said into the microphone in the first session. The lengthy delay was intended to minimise memory for the words that they had read in the first session. Instructions were presented on the monitor that informed participants of the four study conditions (read aloud, hear self, hear other, and read silently). To control volume across the conditions, participants were instructed to "speak at the same volume as the words you hear". The volume was set to an identical level for every participant (both the volume setting on the computer and the speaker volume), such that every participant heard words at a moderate sound intensity (corresponding to approximately 60 dB). We controlled sound intensity across the three auditory conditions to account for the possibility that sound intensity could influence memory (e.g., see Quinlan & Taylor, 2013, for evidence that words that are read aloud loudly are better remembered than those that are read aloud at a moderate volume). Participants were told that there would be a memory test later and that they should try to remember all of the words, regardless of how they studied them. The experimenter remained in the room during this session to ensure that participants complied with the instructions (all did).

Twenty unique words were randomly assigned to each of the four study conditions. The gender of the voice in the "hear other" condition was randomised over participants.[1] Prior to each study word, a label appeared that identified the study condition [e.g., "(Hear Self)"]. The label was printed in white 12 pt. bold Times New Roman font and was displayed slightly above the centre of the screen. The study word then appeared 500 ms after the label (which remained on the screen) and was centred in 18-point bold Courier New yellow font. Each study word was presented for 3000 ms, with a 500-ms ISI.

A self-paced recognition test immediately followed the study phase and consisted of all 160 words from the pool created during the first session: 80 studied and 80 unstudied. Words were presented individually in the centre of the screen in 16 pt. bold Courier New yellow font. Participants used the "m" and "c" keys to classify words as "studied" and "new", respectively. As a reminder, the label "m – studied" was printed in the bottom right corner of the screen and "c – new" was printed in the bottom left corner. A 500-ms blank screen appeared between successive test items.

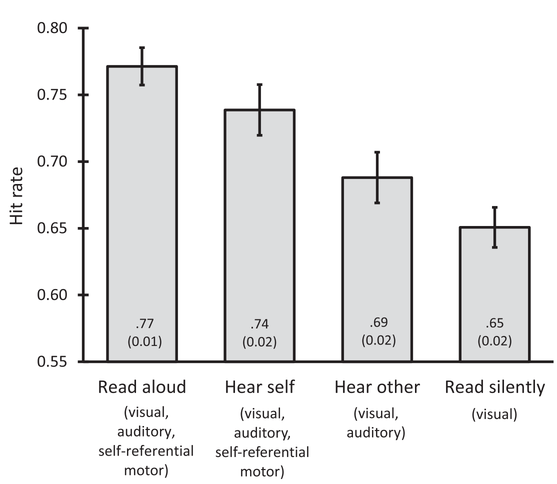

Figure 1. Mean proportion of hits (with SEs) in recognition as a function of study condition. The processing components involved in each study condition are listed below the condition labels.

Results and discussion

Figure 1 displays the proportion of hits for each of the four study conditions (false alarm rate: $M = 0.15$, SE = 0.02). A one-way ANOVA revealed that the study conditions differed significantly overall, $F(3, 222) = 17.65$, MSE = 0.01, $p < .001$, $\eta^2 = 0.19$. Of central importance, the linear trend of this ANOVA was a particularly robust effect, $F(3, 222) = 63.13$, MSE = 0.01, $p < .001$, $\eta^2 = 0.46$. Clearly, the pattern of hit rates followed the hypothesised gradient (read aloud > hear self > hear other > read silently).

The ANOVA was followed by three planned comparisons that tested for differences moving across this gradient: (1) Read Aloud vs. Hear Self, (2) Hear Other vs. Read Silent, and (3) Average (Read Aloud + Hear Self) vs. Average (Hear Other + Read Silent). The first contrast revealed that words that were read aloud had marginally higher hit rates than words that one heard oneself say, $F(1, 74) = 3.07$, MSE = 0.03, $p = .08$, $\eta^2 = 0.04$, which tentatively suggests that the motor component of production may only contribute a small memory benefit relative to the self-referential component. The second contrast revealed that words that participants heard someone else speak were better remembered than words that were read silently, $F(1, 74) = 4.01$, MSE = 0.03, $p = .049$, $\eta^2 =$

0.05, which replicates MacLeod's (2011) finding that the auditory component of production enhances memory for words (even in the absence of self-reference). And the third contrast revealed that study conditions that had a self-referential component were better remembered than those that did not, $F(1, 74) = 53.23$, MSE = 0.03, $p < .001$, $\eta^2 = 0.42$, suggesting that self-reference strongly benefits memory of produced words.

To more specifically test whether the self-referential component of production enhanced memory above and beyond the auditory component, we conducted a *post hoc* comparison (with a Bonferroni correction) of mean hit rates between the hear self and hear other conditions. (This could not be included as a planned comparison because it was non-orthogonal to the other comparisons.) Participants correctly recognised significantly more words in the hear self condition than in the hear other condition, $t(74) = 2.86$, $p = .03$, $d = 0.31$.

This pattern of results is very similar to that of MacLeod (2011) in terms of the gradient across conditions. In that earlier study, participants took part as dyads. Memory performance for a given participant – whether measured by recall or recognition – was best for self-production, next best when both participants produced, next best when only the other participant produced, and poorest when neither produced (the silent condition). In the current study, the hear self condition replaces the both produce condition in terms of the gradient, providing corroborating evidence of the stability in how production by oneself vs. another influences memory performance. Given that prior research has found a robust within-subject production effect in recall (e.g., Jones & Pyc, 2014) – and that MacLeod's pattern of results held across recognition and recall – we would also expect our gradient to replicate if recall were measured.

Our results did, however, differ from MacLeod's (2011) in terms of the size of the differences in hit rates across study conditions. For example, in two experiments, MacLeod found 29% and 33% differences in hits between his read aloud and read silent conditions (compared to 12% here) and 10% and 11% differences between his hear other and read silent conditions (compared to 4% here). The smaller cross-condition differences in hits obtained here – including the marginally significant difference between the read aloud and hear self conditions – could be attributed to the recording session (Session 1) needed for the hear self condition. Namely, the fact that all of the words had been produced in Session 1 may well have attenuated the distinctiveness of production in Session 2. Moreover, the effectiveness of a distinctiveness heuristic (MacLeod et al., 2010) may have been lessened because motor, self-referential, and auditory components were not uniquely diagnostic of study in Session 2 (due to those same components being associated with all 160 words in Session 1).[2]

There is a second issue related to our two-session methodology: During the study phase of Session 2, recognition performance may have benefited from being reminded of producing the same words in Session 1 (see Hintzman's remindings account, 1970, 2004), with remindings perhaps being more common for words in the read aloud and hear self conditions ("I remember having said that two weeks ago"). Indeed, the possibility that remindings confer a memory benefit on produced words (as has been demonstrated for generated words; see MacLeod, Pottruff, Forrin, & Masson, 2012) represents an interesting avenue for future research. In sum, there are reasons to suspect that memory for words from Session 1 may have affected recognition performance in Session 2. A longer delay between sessions would help to minimise this influence.

Overall, the recognition gradient observed here (see Figure 1) largely supported our hypothesis that performance increases in step with the number of distinctive components at study (see also Forrin et al., 2012), as shown by the strong linear trend. Reading aloud involves three distinct components (motor, self-referential, and auditory) relative to reading silently and consequently had the best recognition performance – albeit only marginally better than hearing oneself, which involves two distinct components (self-referential and auditory). Next was hearing someone else, which has only the one distinct component (auditory), and the last was reading silently. Prior research suggests that reading aloud also enhances the familiarity of words (see Fawcett & Ozubko, 2016; Ozubko, Gopie, & MacLeod, 2012). One's own voice also has familiar characteristics that are not present in hearing another person's voice (although these familiar features may be lost when hearing oneself; see Pörschmann, 2000).

What is particularly novel here is the significant advantage of hearing oneself over hearing another person when neither person produced. This suggests that part of the advantage ordinarily seen in the production effect is hearing one's *own* voice – the self-referential component – above and beyond the benefit conferred by auditory information.[3] Interestingly, this difference between the hear self and hear other conditions was numerically larger than that between the read aloud and hear self conditions (which was only marginal). This tentatively suggests that the self-referential component of the production effect may enhance memory for words to a greater extent than the motor component – a possibility that would be worth exploring in further future research.

Although the hear self > hear other result dovetails with research showing that self-reference enhances memory (see Rogers et al., 1977), an alternate explanation is that participants perceived their own recorded voice as sounding peculiar (see Pörschmann, 2000; Stenfelt & Goode, 2005), which could have provided the memory boost (see McDaniel & Einstein, 1986, for evidence that bizarre stimuli are well-remembered).[4] Future production effect research featuring a "hear self" condition might include subjective measures of peculiarity (e.g., bizarreness and discomfort) to assess whether these factors influence memory for words that one hears oneself speak.

Put simply, the present results suggest that production is memorable in part because it includes a distinctive, self-referential component. This may well underlie why rehearsal is so valuable in learning and remembering: We do it ourselves, and we do it in our own voice. When it comes time to recover the information, we can use this distinctive component to help us to remember.

Notes

1. To explore the potential effects of Gender (we had not expected any), we conducted a 2 (Participant Gender) × 2 (Other Gender) × 4 (Study Condition) mixed-model ANOVA. The ANOVA revealed non-significant main effects of Participant Gender ($F < 1$) and Other Gender, $F(1, 71) = 1.81$, MSE = 0.06, $p = .18$, $\eta^2 = 0.03$, as well as non-significant interactions for Participant Gender × Study Condition and Participant Gender × Other Gender ($Fs < 1$). The Other Gender × Study Condition interaction was marginally significant, $F(1, 71) = 2.27$, MSE = 0.01, $p = .08$, $\eta^2 = 0.03$. We suspect that this unexpected marginal effect simply reflects noise in the data (among five effects involving gender, it is reasonably likely that one would be marginal by chance).
2. As a reviewer pointed out, having novel study words in Session 2 might have ameliorated this issue somewhat. In our view, however, this approach would have introduced a confound: not only would the studied and unstudied words have differed in terms of whether they were studied in Session 2 but they also would have differed in terms of whether they were recorded in Session 1.
3. A reviewer raised the point that the hear self condition arguably features *two* differences relative to the hear other condition: not only are words that one hear oneself speak self-referential but they also have different acoustic properties than when you hear someone else speak. In our view, however, these factors are strongly interrelated and cannot be meaningfully separated because the acoustic properties of one's own voice are a large part of what makes it self-referential. That is, you could not hear a recording of your own voice without thinking "that sounds like *me*", even if you were told that someone else had said the words.
4. Individuals are used to hearing themselves via both bone-conducted and air-conducted sound when they speak, as opposed to only air-conducted sound when hearing a recording (Pörschmann, 2000; Stenfelt & Goode, 2005). However, in this age of social media, undergraduates are becoming increasingly accustomed to hearing their own recorded voice (via videos on Facebook, Snapchat, Intagram, etc.), which may lessen the extent to which it sounds unfamiliar.

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