Influence of Retrieval Mode on Effects of Production: Evidence for Costs in Free Recall

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Study modality (visual, auditory) of words as well as production mode (reading aloud, writing down) have been shown to influence the production effect (PE). When study words are presented visually, reading them aloud yields superior memory. However, when the same study words are presented aurally, writing them down leads to superior memory. Missing in PE studies is the variable of retrieval mode (written, aloud), which was addressed in the present study. In a pair of experiments, we manipulated the 3 variables—study modality, production mode, and retrieval mode—in a factorial fashion. With visual study, aloud production mode (vocalizing) was found to be superior to written production, in both retrieval modes (written and aloud). However, the difference between the productions was significantly smaller in the aloud retrieval mode relative to the written retrieval mode. With auditory study, written production mode was superior to aloud production mode, in the written as well as in the aloud retrieval modes. Here, the difference between the productions was significantly smaller in the written relative to the aloud retrieval mode. In other words, the difference between productions was smaller for the retrieval mode that matched the superior production. We interpret these findings using a retrieval-cost account.

Keywords: production effect, study modality, retrieval mode, retroactive interference, free recall

The production effect (PE) represents a robust memory phenomenon—the enhancement of memory from reading a word aloud relative to reading it silently (MacLeod, Gopie, Hourihan, Neary, & Ozubko, 2010). In a typical PE experiment, participants are asked to study a list of visually presented words for a later memory test. Half of the words are learned by reading aloud (vocal production) and the remaining half by silent reading (a within-subject design). On a subsequent memory test (recall: Lin & MacLeod, 2012; Icht, Mama & Algom, 2014; recognition: Forrin, MacLeod, & Ozubko, 2012; MacLeod et al., 2010), words that were read aloud usually show an advantage of 10%–20% over words that were merely read silently. Recently, the effect was expanded to the auditory modality. Mama and Icht (2016) asked their participants to study a list of auditory presented words, and found a memory advantage for words that were produced by writing over words that were vocally produced (and over nonproduced words, which were merely heard). It appears that different types of production (e.g., speaking, writing) enhance future recall and recognition, depending on the modality of presentation.

The PE is commonly attributed to encoding distinctiveness (MacLeod et al., 2010; Ozubko & MacLeod, 2010) or the fact that produced words are more distinct against a backdrop of nonproduced words, and hence are better remembered. Production leads to “deeper” memory traces than silent reading, as it involves more distinct encoding processes (Forrin et al., 2012; Quinlan & Taylor, 2013). When the study words are visually presented, reading aloud involves (1) visual processing (reading the words), (2) motor processing (articulating), and (3) auditory processing (hearing oneself saying the words). Obviously such a rich encoding procedure results in better memory relative to silent reading, which involves only visual processing.

On the other hand, when the study words are aurally presented, writing involves more distinct encoding processes (than silent reading and even than vocalization): (1) auditory processing (hearing the words), (2) motor processing (writing), and (3) visual processing (reading one’s own handwriting). Any unique process provides a distinctive cue that participants can use at test to help remember the studied words. The production that involves the greater number of unique encoding processes leads to the best memory (Forrin et al., 2012; Mama & Icht, 2016).

The PE is typically interpreted as a benefit to produced (aloud) items (MacLeod et al., 2010), but actually it can reflect a cost for nonproduced (silent) items. This alternative explanation for the PE was offered by Hopkins and Edwards (1972) and later by MacLeod et al. (2010). Bodner, Taikh, and Fawcett (2014) also suggested that in a within subject design the PE is the result of memory decrease to silent items, that is, a cost (cf. Forrin, Groot, & MacLeod, 2016).

Although the PE was studied intensively during the last few years, the literature does not discuss the impact of retrieval mode (e.g., aloud, written) on the PE, and hitherto this variable has received no attention. Yet, effects of retrieval (or testing) mode on memory and learning have been found in other areas. Kellogg (2001) evaluated recall of semantically related words, and found increased correct recall with written tests rather than spoken tests. For text recall, Kellogg (2007) found an advantage for spoken recall over written recall (mainly for aural presentation). Taken together, it seems that the effect of output modality depends on the
type of study materials. Gallo, McDermott, Percer, and Roediger (2001) found that test modality modulated the effect of study modality on false recognition. Specifically, auditory study led to greater false recognition only when the critical items were tested visually. Gallo et al. (2001) suggested that “test modality may influence false remembering by modulating the retrieval and subsequent use of study modality information in metamemorial decision processes” (p. 351).

In addition, retrieval may be affected by differences in (working) memory demands of speaking and writing (Kellogg, 2007; McPhee, Paterson, & Kemp, 2014). Writing is more demanding on both the storage and executive attention components of working memory than speaking (Kellogg, 2007). Written tests require subjects to access orthographic codes that are specific to the visual modality, whereas spoken tests do not (Kellogg, 2001). In addition, writing is less practiced and less automatic than speaking (Bourdin & Fayol, 1994; Kellogg, 2001).

In the vast majority of PE studies, the retrieval mode was visual, and recall and recognition were probe by written tests. Would aloud (oral) tests result in the familiar findings—superior memory for aloud production mode with visual study modality (Forrin et al., 2012), but superior memory for written production mode with auditory study modality (Mama & Icht, 2016)? Answering this question was the goal of the present study. We were interested in the role retrieval mode plays in the PE, and investigated how different retrieval modes (aloud, written) influence recall rates. More specifically, we were interested in whether participants can recall more aloud and written words (different production modes), that were learned visually or aurally (different study modalities), via writing or speaking (different retrieval modes). Understanding the interaction between these variables may help us understand the theoretical basis of the PE.

A Retrieval-Cost Account in Free Recall

Illuminating the effect of retrieval mode on the effects of production, we offer a cost account that lies in the retrieval phase, rather than in the study phase (cf., Bodner et al., 2014). On the one hand, encoding distinctiveness operates at study. On the other hand, a separate effect of costs operates in accordance, at retrieval. Both influence the direction and magnitude of the effects of production. The account assumes that during the study phase of a recall experiment (using production encoding tasks) each study word is encoded into memory, creating a specific memory trace. Traces are grouped according to the type of learning, forming separate subsets. These subsets of clustered items function as “recall units” in long-term memory (Bower, 1970). Indeed, participants learning a large set of material typically subdivide the material into related subsets of information, which they integrate during encoding.

Many features of study words can serve as classifying features. Usually, semantic (Miller, 1967), graphemic, or phonemic similarities enable grouping of list words. We claim that the modalities in which words are presented at study may also serve as a classifying feature, segmenting the study words into integrated subsets. As a result, different subsets are formed (encoded) in memory according to how the study words were learned (i.e., their study modality, and their mode of production). Thus, we suggest that three types of subsets can be formed: visual, auditory, and visual–auditory.

Consider a recall experiment, using production encoding tasks. When study words that are presented via the visual study modality, and silently read (no-production mode), they are encoded into the visual subset. With the same visual study modality, vocally produced words (aloud production mode) are encoded into the visual–auditory subset. Visually presented words that are produced by writing (visual study modality + written production mode) are encoded into the visual subset. However, when study words are presented via the auditory study modality, with no-production as well as aloud production modes, they are encoded into the auditory subset. With the same auditory study modality, written words (written production mode) are encoded into the visual–auditory subset.

At test, words retrieved from these subsets are also reencoded. Retrieval attempts of previously encoded words improve their memory performance on later tests (Masson & McDaniel, 1981; Wenger, Thompson, & Bartling, 1980). Similarly, retrieval on a first test affects performance on a second test (the testing effect; Roediger & Karpicke, 2006; Roediger, Putnam, & Smith, 2011; Putnam & Roediger, 2013). Hintzman (2011) also suggested that a second experience with an item results in a reminding, forming an additional trace. This trace could produce a benefit to repeated processing, influencing recall. MacLeod, Pottruff, Forrin, and Masson (2012) investigated the consequences of reading and generating target items, when participants processed them twice. They found superior free recall after generating twice relative to generating and reading, and to generating once.

Finn and Roediger (2011) stressed that when memories are retrieved, they become labile and amenable to change. Finn and Roediger (2011) noted that “reactivation of a memory trace changes its subsequent retrievability, either positively . . . or negatively” (p. 781). Negative effects on memory have also been mentioned in the reconsolidation hypothesis (Spear & Mueller, 1984), assuming that memory can be modified via reactivation. Accordingly, every retrieval operation triggers a reconsolidation process (reencoding), resulting in changes of the information content of the “trace” (Sara, 2000).

We assume that reencoding at test is modality dependent. When taking a written free-recall test, participants write down their responses, and see their written output, resulting in visual reencoding. However, when participants are tested orally, they say the recalled words aloud, resulting in auditory reencoding. These different reencoding processes may differentially affect memory performance and can also induce interference, as discussed next.

We suggest that reencoding a retrieved word induces retroactive interference on the remaining to-be-retrieved words. Retrieved memories are susceptible to interference from new material introduced during their reactivation. For example, filling a retention interval with tasks and material may cause an interference with the primary learned items (Tomlinson, Huber, Rieth, & Davelaar, 2009). Therefore, a newly learned (encoded) word may impede and interfere with the recall of previously learned words. This negative effect is usually referred to as retroactive interference (RI: Anderson, 2003; Marsh, Landau, Hicks, & Bink, 1998; McGeeoch & McDonald, 1931; Mensink & Raaijmakers, 1988; Wohldmann, Healy, & Bourne, 2008). Typically, such interference occurs during long-term memory retrieval, in situations where old and new
learning items are strongly associated (Baddeley & Dale, 1966; Crowder, 1976). RI occurs due to a high resemblance in the retrieval cues of these items (Skaggs, 1933; McGeoch & Nolen, 1933; Mensink & Raaijmakers, 1988; Anderson & Bjork, 1994), or due to their similar memory traces (von Restorff, 1933, cited by Hunt, 1995). Indeed, recall performance tends to be more accurate for events that are followed by dissimilar events, rather than by similar events. Words from a similar subset (associates) may serve as competitors that block recall of other item in that subset (Bower, Thompson-Schill, & Tulving, 1994; Melton & Von Lackum, 1941).

This negative effect of RI produces a retrieval cost. During recall in a PE experiment, participants access the recently formed memory subsets (visual, visual–auditory, etc.). Retrieval results in reencoding into one of the memory subsets. The retrieved word is either reencoded back into the original subset or into a different subset, depending on the type of response at test. Reencoding of a word into the old subset does not change the subset’s composition, hence does not cause interference with other words from the same source. However, reencoding of a word into a different memory subset may interfere with recalling the other words in that subset, thus inducing costs.

Consider, for example, a PE experiment using visual presentation of the study words, with half of the words vocally produced, and the remaining half produced by writing. A visual description of such an experiment is provided in Figure 1. According to encoding distinctiveness, the superior production mode is vocalizing (aloud). Hence, vocally produced words should be better recalled than written words. By the retrieval-cost account, this study procedure will lead to the formation of a visual–auditory subset (aloud words) and a visual subset (written words). At test, the participants will access these subsets in order to retrieve the study words.

In a written memory test, retrieval of the study words leads to visual reencoding. So, retrieval of an aloud word (initially encoded into the visual–auditory subset) leads it to be reencoded into the visual subset which holds the words that were produced by writing. Consequently, the visual subset now holds an additional (previously aloud) word. This increase in the number of items within the subset increases intrasubset competition. As a result, RI is induced on the old items (e.g., the written words) within that subset. The retrieval of aloud words thus interferes with the retrieval of written words—a cost effect.

In contrast, written retrieval of a word first learned by writing (visually encoded), leads to visual reencoding into its original (old) visual subset. Because this word is reencoded into its primary visual subset, it does not alter the subset’s composition, and does not induce RI with other written words. Accordingly, the retrieval of written words (from the visual subset) does not result in a cost effect.

Consider now a similar experiment, but with an aloud free-recall test. Aloud (vocal) retrieval of study words (aloud words from the visual–auditory subset as well as written words from the visual subset) involves their auditory reencoding into a new auditory subset. As the recalled words are reencoded into a new auditory subset, no RI is induced, and no retrieval cost effect should occur.

Taken together, the retrieval-cost account predicts that with visual study modality and written retrieval mode, the difference

![Figure 1](image-url). A retrieval-cost account with visual study modality and productions by vocalizing and writing. With a written retrieval mode, the recall of a vocalized word interferes with the recall of written words—a cost effect. In contrast, with an aloud retrieval mode, the recall of vocalized and written words does not induce retroactive interference (RI); thus no cost effect occurs.
between the recall rates of aloud and written words will be relatively large. In contrast, with aloud retrieval mode, the difference between the recall rates of aloud and written words will be smaller, due to the lack of cost for the written words.

The Present Study

In Experiment 1 we used this procedure (visual study modality) in order to test the retrieval-cost account, and clarify the role retrieval mode plays in free recall. Experiment 2 used auditory study modality in a similar fashion. Note that we did not measure a standard PE, because a silent condition was not used. Rather, we directly compared two modes of active production (aloud, written).

Experiment 1—Visual Study Modality

Method

Participants. Undergraduate students from Ariel University (N = 77; 52 females; mean age: 26.2 years) received course credit for participating. All were native Hebrew speakers who reported no language or learning disabilities. The participants were randomly assigned to one of two free-recall testing conditions, differing in their retrieval mode—written (N = 39) or aloud (N = 38). This study received prior approval from the university ethics committee, and all participants signed an informed consent form.

Apparatus and stimuli. The pool of words consisted of 80 common Hebrew bisyllabic nouns, 3–5 letters long, used in Icht et al. (2014). From this pool, a random sample of 30 words was selected for study for each participant.

During study, each word was presented at the center of a 15-inch color laptop monitor under control of the DirectRT program. The words were presented in black (28-point Arial font), against a white background. On each trial, a small icon (2 cm²) appeared approximately 5 cm above the study word. The icon depicted a microphone or a pen, indicating the required mode of production for that word, namely aloud production mode or written production mode, respectively.

Procedure. Participants were tested individually in a quiet room in the university lab. A research assistant was present throughout the experiment. The participants viewed the screen from a distance of 60 cm. They were told that the goal was to learn each word via the production mode signaled by the icon (microphone, pen) and that a free-recall test would follow the presentation of the words.

The 30 study words were randomly divided into two equal subsets defined by the production mode (aloud and written). Each word was presented for 3 s followed by a 1-s blank screen. For the written production mode, the participants wrote each study word on a separate piece of paper. After writing each word, the experimenter took away the note with the written word, preventing further rehearsal of the written word. Four arithmetic problems (multiplication of four-digit numbers) printed on an A4 paper were prepared for a filler task. Participants were given 4 min to complete these problems. At test, free recall was used. In the written retrieval mode, participants were asked to write down from memory as many study words as they could recall. The remaining half of the participants performed the aloud retrieval. They were asked to say aloud the words they could remember from study, and the experimenter wrote down the recalled words (the participants could not see the experimenters’ writing). Free recall was performed without explicit time constraint. The experimental session lasted approximately 20 min.

Results

Shown in Figure 2 are the proportions of words correctly recalled for the two production modes (aloud and written) for both written (left-hand part) and aloud (right-hand part) retrieval modes. Inspection of Figure 2 reveals the superiority of aloud over written production for both the written retrieval mode (.35 vs. .20) and the aloud retrieval mode (.34 vs .28). However, the difference between the production modes was smaller on the aloud retrieval mode than on the written retrieval mode, due to improved recall of words that were produced by writing.

Statistical analysis supported these conclusions (results were significant at the .05 level unless otherwise indicated). A repeated-measures analysis of variance (ANOVA) was conducted with production mode (writing, aloud) as a within-subject variable and retrieval mode (written, aloud) as a between-subjects variable. This analysis revealed a significant main effect for production mode, F(1,75) = 22.09, p < .01, η² = .23, with an advantage for aloud over written production. No main effect for retrieval mode was found, F(1,75) = 2.56, p = .11, η² = .03. We also found a marginally significant interaction, F(1,75) = 3.86, p = .05, η² = .05. The source of this interaction was a significant difference in the recall rates for written produced words between the two retrieval modes, t(75) = 2.79, p < .01. The difference in recall rates for words produced aloud between the two retrieval modes was not significant, t(75) = .14, p > .05.

The difference between written and aloud production modes was significant for both the written retrieval mode, t(38) = 5.53, p < .01, and the aloud retrieval mode, t(37) = 1.70, p < .05.

Discussion

Forrin et al.’s (2012) written retrieval mode pattern was replicated, showing the superiority of aloud over written production mode. This result is well explained by encoding distinctiveness.
With visual study modality, vocalizing involves more distinct encoding processes than writing (three vs. two, respectively). Hence, aloud words are relatively more distinct at study, and easily retrieved at test.

However, the use of an aloud retrieval mode altered the results. Again, the number of recalled aloud words was higher relative to that of written words. But, the difference between the two types of production was significantly smaller. Encoding distinctiveness fails to provide an explanation for this result. The number of distinct encoding processes did not change, as the study phase was identical for both retrieval modes.

The retrieval-cost account provides a reasonable explanation for the relatively small difference between the two production modes in the aloud retrieval mode (relative to the written retrieval mode). At study, the to-be-remembered words were grouped into two separate subsets in memory, defined by the modalities involved in learning: visual-auditory subset (aloud words), and visual subset (written words). In the written retrieval mode, writing down the recalled words resulted in visual reencoding. Written retrieval of an aloud word led to its reencoding into the visual subset, thus interfering with the retrieval of other written words (stored in that same subset), inducing a cost (i.e., reduced recall of written words). In contrast, in the aloud retrieval mode, vocalizing the recalled words resulted in auditory reencoding. Because the recalled words were reencoded into a new auditory subset no RI and hence no cost occurred. As a result, recall of written words was higher than for the written retrieval mode.

**Experiment 2—Auditory Study Modality**

To further explore the proposed account, Experiment 2 used an auditory presentation of the study words (see also Mama & Icht, 2016). As in Experiment 1, we again compared aloud and written production modes. With auditory study modality, we expected to replicate Mama and Icht (2016) superior recall for written over aloud production, as writing involves a larger number of distinct encoding processes. A visual description of the retrieval-cost account with auditory study modality is provided in Figure 3.

The retrieval-cost account predicts that auditory presentation of the study words will lead to the formation of two subsets of words in memory, characterized by the modalities at study: auditory subset (for aloud words) and auditory–visual subset (for written words). In an aloud retrieval mode, recall of study words leads to auditory reencoding. Retrieval of a word that was initially written (encoded into the auditory–visual subset) leads to its reencoding into the auditory subset, which contains the aloud words. Consequently, the auditory subset now holds another new (written) word; thus intrasubset competition rises, and RI is induced on the aloud words within that subset. In other words, the retrieval of written words interferes with the retrieval of aloud words—a cost effect. In contrast, aloud retrieval of aloud words leads to auditory reencoding into the former (original) auditory subset, and thus does not result in RI with other aloud words. Therefore, the retrieval of vocalized words does not result in a cost effect.

Consider now the written retrieval mode, which leads to visual reencoding of the study words. Retrieving an aloud word (auditory

![Figure 3](image-url). A retrieval-cost account with auditory study modality and productions by vocalizing and writing. With an aloud retrieval mode, the recall of a written word interferes with the recall of aloud words—a cost effect. In contrast, with a written retrieval mode, the recall of vocalized and written words does not induce retroactive interference (RI); thus no cost effect occurs.
subset), as well as retrieving a written word (auditory–visual subset), lead to their reencoding into a new visual subset. As a result, no RI (cost) occurs. Consequently, the difference between the productions (favoring the written words) should be larger for the aloud relative to the written retrieval mode.

Method

Participants. A group of 78 undergraduate students (59 females, mean age: 23.7 years), from the same source and inclusion criteria as in Experiment 1 participated for bonus course credit. All showed hearing thresholds of at least 25 dB sound pressure level for 500, 1,000, 2,000, and 4,000 Hz. Each participant was randomly assigned to one of two retrieval modes—written (N = 38) or aloud (N = 40).

Apparatus and stimuli. We used the same pool of words deployed in Experiment 1. The words were announced by a female speaker and recorded in a professional radio studio. From this pool, 30 words were selected for study, a random sample for each participant. During study, each of the 30 study words was aurally presented via two computer personal loudspeakers, each positioned at the height of the listener’s head at 45° azimuth, at 35 dB sensation level (most comfortable loudness), under the control of DirectRT program.

On each trial, a small icon (2 cm²) of a microphone or of a pen appeared on the upper part of the computer screen (approximately 5 cm above the center), indicating the appropriate production mode (aloud and written, respectively).

Procedure. The study phase was similar for all the participants, as they were aurally presented with a list of 30 words (a random 15 were produced aloud, and the remaining 15 were produced by writing). Each experimental trial started with a visual presentation of the icon. The study word was aurally presented 300 ms following the icon’s appearance. After the item’s presentation, the icon remained visible for 3 s. A blank screen for 1 s followed (thus the interval between words was about 4 s). The filler task and the free recall tests were the same as in Experiment 1.

Results

The proportions of words correctly recalled for the two production modes (aloud and written) of both aloud (right-hand part) and written (left-hand part) retrieval modes are provided in Figure 4. Inspecting this figure reveals that written production was better than aloud production for both the written retrieval mode (.27 vs. .23) and for the aloud retrieval mode (.28 vs. .18). The difference between the production modes was smaller on the written than the aloud retrieval mode, due to improved recall of aloud words.

Statistical analysis supported the aforementioned conclusions. A repeated-measures ANOVA with production mode (aloud, written) as a within-subject variable, and retrieval mode (written, aloud) as a between-subjects variable, revealed a significant main effect for production mode, $F(1, 76) = 19.01, p < .01, \eta^2 = .20$, with an advantage for written over aloud production. No main effect for retrieval mode was found, $F(1, 76) = 1.01, p = .31$. We also found a marginally significant interaction, $F(1, 76) = 3.89, p = .05, \eta^2 = .05$. This interaction is related to the significant difference in the recall rates of aloud words between the two retrieval modes, $t(76) = 1.98, p < .05$. No difference was found in the recall rates of written words between the retrieval modes, $t(76) = .33, p = .30$.

Discussion

The results of the present experiment revealed the superiority of written over aloud production mode with auditory study modality, regardless the retrieval mode, supporting the findings reported by Mama and Icht (2016). Encoding distinctiveness, the prevailing PE account, well explains these results. With auditory study modality, writing entails three distinct encoding processes, yet vocalizing involves only two. Therefore, written words are more distinct at study, and better recalled at test.

However, the difference between the productions was greater with the aloud than with the written retrieval mode. According to the retrieval-cost account, written retrieval involves visual reencoding of the study words into a new visual subset. Hence, no costs occur, and the difference between aloud and written words is rather small. However, the aloud retrieval leads to auditory reencoding. As the aloud words are already stored in that auditory subset, they are susceptible to RI induced by the retrieval of the written words. As a result, the difference between the productions is larger (cost).

Comparison of Experiment 1 Versus 2

Finally, visual comparison of Figures 2 and 4 reveals a mirror image. In other words, changing the study modality to auditory (Experiment 2) resulted in a recall pattern that formed a mirror image of that obtained with the visual study modality (Experiment 1). Verifying this pattern, a three-way ANOVA was conducted, with the following variables: (a) study modality (visual—Experiment 1, or auditory—Experiment 2, a between-subjects variable), (b) retrieval mode (written or aloud, a between-subjects variable), and (c) production mode (aloud, written, a within-subject variable). As expected, no main effect for production mode was found, nor for retrieval mode ($ps > .05$), yet a main effect for study modality was found, $F(1, 151) = 8.70, p < .01, \eta^2 = .05$, since higher recall rates were observed in Experiment 1 (visual study modality) relative to Experiment 2 (auditory study modality). In accord with the previously reported analyses, a pair of two-way
General Discussion

The present study addressed for the first time the effect of retrieval mode (written vs. aloud) on the effect of production. Along with this factor, we manipulated another pair of variables: the study modality (visual—Experiment 1, auditory—Experiment 2) and the production mode (aloud, written). These experiments allowed us to evaluate a retrieval-cost account that predicts an effect of retrieval mode on the effect of production. As expected, the results showed an impact of retrieval mode on the difference between productions. With visual study modality (Experiment 1), overall recall rates were higher using aloud retrieval mode, and lower using written retrieval mode. This reduction was due to cost for words that were produced by writing. A mirror image was documented with auditory study modality (Experiment 2): Overall recall rates were higher using written retrieval mode, and lower using aloud retrieval mode. We attribute this decrease to a cost for aloud words. This pattern of results supports the retrieval-cost account. The account well explains the combined effect of study modality and production mode, along with retrieval mode on the effects of production.

The current results suggest that the most effective study strategy depends on the study modality. When a student studies written material, saying aloud the important words or sentences may improve memory. In contrast, when a student listens to a lecture, writing down the important portions should boost memory. Moreover, it appears that retrieval mode also affects memory. The student who learned visual items by vocalizing may achieve better results with an oral exam (aloud retrieval mode), since there may be no retrieval-cost for written words. The student who heard the study material and wrote it down, may succeed more on a written test, due to no retrieval-cost for aloud words.

Let us stress that our account explains PE results with free-recall testing. As detailed above, the account emphasizes two processes at active retrieval: (1) reencoding the retrieved study words into an appropriate memory subset (according to the modalities involved) and (2) interference (RI) induced on the following to-be-retrieved words by reencoding of a word into their subset. Recall is usually a more difficult task than recognition (Craik & McDowd, 1987), and requires more self-initiated processing (Craik, 1983). Humphreys (2001) argued that “in recall, context is used as a retrieval cue, and it activates the other items in the list. . . . This activation of other items produces a nonspecific source of noise, which reduces recall” (p. 874).

Different processes are emphasized on recognition tests, which are more passive in nature and less effortful (Hasher & Zacks, 1979). In a recognition test, the study information is represented to the participants. Because participants see the words (hence do not actively retrieve them), fewer cognitive resources are required (Craik & McDowd, 1987). Thus, representation of the study items does not produce interference (Dennis & Humphreys, 2001). Indeed, Humphreys (2001) noted that “interference depends in a complex way on the type of task (recognition vs. recall)” (p. 877). This may explain the lack of effect of test mode on the PE reported by Forrin and MacLeod (in press), using recognition tests.

Future Recommendations

We focused on study modality (visual or auditory) and production modes (aloud, written). The retrieval-cost account assumes that the study words are grouped according to these variables, creating different memory subsets—visual, auditory or visual–auditory (for a similar logic see: Bower, 1970). However, it is possible that the produced study words also share a motor feature. The execution of a motor action (motor production) characterizes all active productions. Speaking, mouthing, and whispering, involve articulation, and writing and typing, involve finger movements. All these productions have a “motor” quality, and involve a motor trace (Bower, 1970); thus this trait may not be specific enough to serve as a “classifying feature” that can be used to segment the study words into different subsets (Miller, 1967). Comparing active motor productions (e.g., vocalizing, writing) to nonproduction conditions (e.g., silent reading, listening) and nonmotor productions (e.g., offline productions; Jamieson & Spear, 2014) thus provides an important direction for future research.

Résumé

Il a été démontré que la modalité d’étude (visuelle, auditive) des mots ainsi que le mode de production (lecture à haute voix, écriture) ont une influence sur l’effet de production (EP). Lorsque les mots à l’étude sont présentés visuellement, le fait de les lire à voix haute augmente la capacité de mémorisation. Or, lorsque les mêmes mots à l’étude sont présentés oralement, le fait de les écrire augmente la capacité de mémorisation. Étant donné que la variable du mode de récupération était omise dans les études sur l’effet de production (par écrit, à voix haute), nous l’avons incluse dans la présente étude. À partir de deux expériences, nous avons manipulé les trois variables — la modalité d’étude, le mode de production et le mode de récupération — de manière factorielle. Suite à l’expérience visuelle, le mode de production à voix haute (vocalisation) a généré des résultats supérieurs par rapport au mode de production écrit dans les deux modes de récupération (par écrit et à voix haute). Or, la différence entre les modes de production était significativement moins marquée pour le mode de récupération à voix haute que pour le mode de récupération écrit. Suite à l’expérience auditive, le mode de production écrit a généré des résultats supérieurs par rapport au mode de production à voix haute, et ce tant au niveau du mode de récupération écrit que de celui à voix haute. Dans le cas de l’étude, la différence entre les modes de production était significativement moins marquée pour...
le mode de récupération écrit que pour le mode de récupération à voix haute. En d’autres termes, la différence entre les modes de production était moins marquée pour le mode de récupération qui correspondait au mode de production supérieur. Nous interprétons ces résultats en utilisant un postulat de récupération-coût.

Mots-clés : effet de production, modalité d’étude, mode de récupération, interférence rétrospective, rappel libre

References
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