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Original Article

Does the testing effect depend on presentation modality?

Benton H. Pierce[a,*], Melissa J. Hawthorne[b]

[a] Texas A&M University-Commerce, Department of Psychology, Counseling, and Special Education, P.O. Box 3011, Commerce, TX 75429, United States
[b] Louisiana State University Shreveport, Department of Education, One University Place, Shreveport, LA 71115, United States

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ABSTRACT

We examined whether the testing effect generalizes to an auditory presentation modality. Five lists of unrelated words (Experiment 1) and related words (Experiment 2) were presented to participants, half of whom studied them visually and half studied them auditorily. Participants in the study-only condition performed a short distractor task following lists 1–4, whereas those in the testing condition completed a short distractor task and then attempted to recall each list. Both groups were subsequently tested on List 5 and on all five lists 30 min later. In both experiments, we found a testing effect for both List 5 and for the final cumulative recall test. However, the effect did not interact with study modality, despite the fact that proactive interference was greater following auditory study. These results have important implications for educational practice, suggesting that initial testing is important for materials presented in auditory as well as visual formats.

1. Introduction

The effectiveness of retrieval practice on long-term retention has been a popular research topic in recent years (for reviews, see Roediger & Butler, 2011; Roediger & Karpicke, 2006a). This phenomenon, known as the *testing effect*, refers to superior retention on a later test if the initial study of material is followed by an immediate test than if the material is not tested. As noted in a recent meta-analysis (Rowland, 2014), the testing effect has shown to be a robust phenomenon and has been found using a variety of materials, including word lists (e.g., Carpenter & DeLosh, 2006; Rowland and DeLosh, 2015; Zaromb & Roediger, 2010), paired associates (e.g., Carpenter, 2009; Carrier & Pashler, 1992; Pyc & Rawson, 2011) and text passages (e.g., Hinze & Wiley, 2011; Meyer & Logan, 2013; Roediger and Karpicke (2006b). The effect has also been shown across various test types (e.g., Argarwal, Karpicke, Kang, Roediger, & McDermott, 2008; McDermott, Argarwal, D'Antonio, Roediger, & McDaniel, 2014) and has been demonstrated in different educational areas, such as skills learning (Kromann, Jensen, & Ringstedd, 2009), medical education (Larsen, Butler, & Roediger, 2008), and the learning of natural concepts (Jacoby, Wahlheim, & Coane, 2010).

Despite the extensive generalization of the testing effect, virtually all of the empirical research on the effect has utilized visual presentation of study material. However, recent years have shown an increase in the use of audio recording technology in education, including computers that can record voice (Skounge, Rao, & Boisvert, 2007), audiobooks, educational podcasts, ipod and other apps that provide auditory study guides, i-tunes university (Open Education Database, 2008) and other digital media that allow students to listen to lectures outside the classroom. Because of the gains that can be made in listening skills and improved reading interests, school districts are moving towards an increased integration of audio books into the classroom (Grover & Hannegan, 2008). Audio books are useful in distance learning and in providing educational opportunities to special populations, such as people with vision impairments (Ozgur & Kiray, 2007) or reading difficulties (e.g., dyslexia; Chernek, 2014). Indeed, with the passing of the National Materials Accessibility Standard, more students with learning disabilities will have access to audio books in school. In addition, there are an increasing number of resources and programs available online that are aimed at encouraging the use of audio books in the academic curriculum (K-12 and higher education; e.g., Hudson, 2013; Scholastic Inc., 2014). Therefore, it is important to examine not only whether the effects of retrieval practice generalize to material is presented in an auditory format, but whether these effects are modified by auditory presentation.

In examining whether presentation modality may differentially influence the testing effect, there are several factors that lead to different predictions. The first concerns the extent to which presentation or study modality affects recall. In terms of short-term memory, a number of studies have shown that compared to visual

* Corresponding author. Tel.: +1 903 886 5444; fax: +1 903 886 5780.
E-mail address: benton.pierce@tamuc.edu (B.H. Pierce).

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presentation, auditory presentation results in greater recall (for a review, see Penney, 1975). However, in these studies, the auditory advantage was limited to the recency portion of the study list, leading to explanations focusing on the greater persistence of the sensory auditory trace compared to the visual trace (e.g., Crowder & Morton, 1969; Watkins & Watkins, 1980). In addition, Cowan, Saults, and Brown (2004) and Harvey and Beaman (2007) later suggested that the modality effect in immediate recall is also driven by greater resistance of auditory items to output interference, particularly when recall is written rather than spoken.

In contrast to the consistent modality effects shown in short-term memory, results on long-term modality effects have been mixed. For example, Gardiner and Gregg (1979) and Glenberg (1984) found an advantage of auditory presentation for the last few items on a list, even when the items were followed by a period of oral distracting activity that should have eliminated any echoic sensory store. Gardiner (1983), Glenberg (1984), and Glenberg and Swanson (1986) suggested that these long-term modality effects stem from enhanced temporal processing afforded by auditory presentation, which is manifested only in the recency portion of a stimulus set.

However, studies that have examined modality effects on overall recall, collapsing across serial positions, have yielded different results. For example, Penney (1989) used unrelated words and found long-term modality effects in both recall and recognition, but in this case, performance was higher following visual than auditory presentation. Furthermore, Gallo, McDermott, Percer, and Roediger (2001) used associatively related word lists and found no modality differences in true recall when collapsing across serial positions. However, the authors did find an interaction, in which recall of visually presented items from earlier serial positions was greater than that of auditorily presented items, whereas recall of auditory presentation resulted in greater recall for the recency part of the serial position curve. Therefore, modality effects in long-term memory appear to depend in part on the semantic relatedness of the studied materials. In terms of the testing effect, if material that is studied in an auditory format is recalled less than when presentation is visual, one might expect that auditory study might get an enhanced benefit from initial testing. This prediction stems from recent findings by Brewer and Unsworth (2012), who found that individuals with lower performance on a set of episodic memory tasks demonstrated a greater benefit from initial testing than those with higher episodic memory performance (but see Pan, Pashler, Potter, & Rickard, 2015 for different findings). Brewer and Unsworth suggested that testing may have benefited those with lower memory ability by enhancing either encoding or retrieval strategies that may have been less than optimal. Therefore, if auditory presentation results in lower memory performance than visual presentation, perhaps due to less efficient encoding of auditorily presented material, initial testing may likewise produce greater benefits for such material.

A second factor that may lead to a greater testing effect when material is presented in an auditory format derives from the effect of modality on false memories. A number of studies (e.g., Cleary & Greene, 2002; Gallo et al., 2001; Pierce, Gallo, Weiss, & Schacter, 2005; Smith & Hunt, 1998; Smith, Hunt, & Gallagher, 2008) have found that false memories of nonpresented critical lures from associatively related word lists are lower following visual compared to auditory presentation, potentially because visual presentation is more distinctive. These findings suggest that if auditory presentation is less distinctive than visual presentation, retrieval practice after one studies material auditorily may be especially beneficial.

A third factor that may lead to a greater testing effect for auditory compared to visual presentation involves proactive interference (PI). Nunes and Weinstein (2012), Szpunar, McDermott, and Roediger (2008), and Weinstein, McDermott, and Szpunar (2011) showed that testing reduces the buildup of PI. Furthermore, there is some evidence that PI in short-term memory is greater for auditory than for visual presentation (Murdock & Carey, 1972; but see Weiman & Bevan, 1980). Therefore, if PI effects are greater for auditory than visual presentation in long-term memory, the benefits of testing may be greater for material presented in an auditory compared to a visual format.

Although all of these factors above may contribute to an enhancement of the testing effect for auditorily presented material, recent findings by Rowland (2014) suggest that modality effects in recall may actually serve to limit the effect. Rowland found that when initial test performance was low and when final test performance was not conditionalized on initial performance, testing effects at short retention intervals were eliminated. Therefore, if performance after auditory presentation is lower on initial tests than after visual presentation, the benefits of initial testing on later retention may be diminished for the auditory format. Consequently, the auditory testing effect may be similar, or even lower in magnitude, to the visual testing effect.

In the present study, we examined both modality effects in free recall and potential increases in PI resulting from auditory presentation in a long-term memory paradigm. Our primary goal was to identify if these effects exist, and if so, whether they would differentially impact the testing effect. Although several previous studies have investigated whether the benefits of testing extend to the auditory format (Butler & Roediger, 2007; Johnson & Mayer, 2009), those studies utilized either a videotaped lecture or multimedia presentation that contained both auditory and visual elements. In contrast, we used materials that were presented either auditorily or visually between subjects, so that we could directly compare the effects of one modality with the other. We adopted a procedure used by Szpunar et al. (2008) that allowed us to examine the potential effects of presentation modality on both recall and proactive interference. To summarize, we presented participants with five lists of unrelated words, using both auditory and visual presentation in a between-subjects manipulation (study-only versus study plus test). As in Szpunar et al. (2008), all participants were tested on both the last list (List 5) and on all of the lists following a 30-minute delay. The effects of presentation modality on recall were assessed for both List 5 and the final cumulative test. The effect of modality on proactive interference was assessed by measuring the number of prior-list intrusions from Lists 1–4 that appeared on List 5. In addition, we examined these factors using both unrelated materials (Experiment 1) and related materials (Experiment 2).

2. Experiment 1

2.1. Method

2.1.1. Participants

Ninety-two undergraduate students at Texas A&M University-Commerce (mean age = 21.85, SD = 5.91, 62% female, 38% male) participated in the study either for partial credit towards course requirements or for extra credit.

2.1.2. Materials and design

A total of 90 concrete words were taken from Gallo, Weiss, and Schacter (2004) and arranged in five lists of eighteen unrelated words each. Experimental condition and study modality were manipulated between subjects, resulting in a 2 (condition: study only vs. study plus test) X 2 (modality: visual vs. auditory) design. All materials were presented on a computer using E-Prime software.

2.1.3. Procedure

Participants were presented with a packet of 18 Super Tough Mazes downloaded from http://www.Krazydad.com/mazes to be