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The impact of different background noises on the Production Effect

Yaniv Mama[a,*], Leah Fostick[b], Michal Icht[b]

[a] Department of Behavioral Sciences and Psychology, Ariel University, Israel
[b] Department of Communication Disorders, Ariel University, Israel

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ABSTRACT

The presence of background noise has been previously shown to disrupt cognitive performance, especially memory. The amount of interference is derived from the acoustic characteristics of the noise; energetic vs. informational, steady-state vs. fluctuating. However, the literature is inconsistent concerning the effects of different types of noise on long-term memory free recall. In the present study, we tested the impact of different noises on recall of items that were learned under two conditions – silent or aloud reading, a Production Effect (PE) paradigm. As the PE represents enhanced memory for words read aloud relative to words read silently during study, we focused on the effect of noise on this robust memory phenomenon. The results showed that (a) steady-state energetic noise did not affect memory, with a recall advantage for aloud words (PE), comparable to a no-noise condition, (b) fluctuating-energetic noise and fluctuating-informational (eight-talkers babble) noise eliminated the PE, with similar recall for aloud and silent items. These results are discussed in light of their theoretical implications, stressing the role of attention in the PE. Ecological implications regarding studying in noisy environments are suggested.

1. Introduction

The Production Effect (PE) is a memory phenomenon which reflects better memory for words read aloud relative to words read silently (MacLeod & Bodner, 2017; MacLeod, Gopie, Hourihan, Neary, & Ozubko, 2010). In a typical PE study, words are presented and learned in a quiet environment (controlled laboratory settings, e.g., Forrin, MacLeod, & Ozubko, 2012; Hourihan & MacLeod, 2008; Icht, Mama, & Algom, 2014; MacLeod, 2011; Ozubko, Gopie, & MacLeod, 2012). In most educational contexts, one seldom learns and memorizes material in such “sterile” surroundings, without background noise. Although noise is known to affect memory performance (Szalma & Hancock, 2011) its impact on the PE has not been tested so far.

Noise is defined as “irrelevant or meaningless data or output occurring along with desired information” (Merriam-Webster Online, 2017), and usually refers to an acoustic phenomenon - unwanted and disturbing sounds. Noises vary in amplitude, frequency, duration and waveform. The temporal characteristics of sound waves may be continuous (*steady*) or intermittent (*fluctuating*). Continuous noise is constant, with no intensity changes (e.g., white noise, which consists of equal pressure levels in every frequency band across the frequency range; Speaks, 1999). Intermittent noise changes in intensity to an appreciable extent over time (e.g., road traffic noise; Florentine, 2011). Such noises induce physical interference in the acoustic environment (in the *energetic* level; Pollack, 1975).

Another type of noise is irrelevant speech, which also carries a disruptive potency (Salamé & Baddeley, 1982). Competing speech sounds induce perceptual interference which occurs in a more central level of auditory or cognitive processing (in an energetic as well as *informational* level; Durlach et al., 2003; Schneider, Li, & Daneman, 2007; Schneider, Pichora-Fuller, & Daneman, 2010).

Understanding the effect of noise on the PE carries both theoretical and ecological implications. Hence, the goal of the present study was to evaluate the effect of different types of noise on word memory in a PE paradigm.

1.1. The impact of different background noises on memory

The negative effect of auditory background noise on human cognitive performance has been subjected to a wide line of research (Broadbent, 1958; Cohen, Evans, Stokols, & Krantz, 1986; Heinrich et al., 2016). Specifically, auditory background noise was found to impede memory for visually presented material (e.g., digits - Salamé & Baddeley, 1990; text - Takahashi, 2006). The detrimental effect of noise on visual memory performance has been investigated vastly over the past three decades within the Irrelevant-Sound Effect (ISE). This effect refers to a substantial impairment in short-term memory performance (mainly immediate memory of serial order) which occurs when people

* Corresponding author at: Department of Behavioral Science and Psychology, Ariel University, 40700, Israel.
E-mail address: yanivma@ariel.ac.il (Y. Mama).

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are exposed to task-irrelevant sound (e.g., Colle & Welsh, 1976; Ellermeier & Zimmer, 2014; Jones & Macken, 1993; Salamé & Baddeley, 1982). Findings of these ISE studies are related to the present study, which evaluates the effect of different auditory background noises on long-term memory for visually studied words, in a free recall task.

Many ISE studies aimed to identify the features of the acoustic background which give rise to the detrimental effects on memory performance observed in that paradigm. In general, several types of noise interfere with memory for visually presented items (typically, sequences of words, digits, or consonants are used in the ISE studies). Pure tones, music, narrative speech, and band-pass noise bursts were all found to disrupt short-term memory serial recall (Jones & Macken, 1993). The extent of noise interference is derived from its acoustic characteristics, mainly its acoustic variability. Steady-state sounds do not affect performance compared to quiet (Jones, Madden, & Miles, 1992), but fluctuating noise was found to be distracting (Macken, Phelps, & Jones, 2009). Many types of fluctuating background noises, such as free-running speech, sequences of different spoken words, or music, all characterized with sufficient complexity (spectro-temporal changes) yield almost equal and maximal disturbance (Ellermeier & Zimmer, 2014).

Interestingly, some studies suggested that speech and non-speech sounds might induce the same interference when both have the same amount of acoustical fluctuations (Jones & Macken, 1993, 1995; Tremblay, Nicholls, Alford, & Jones, 2000). This implies that the phonological characteristics of the sound (the informational quality) have only limited impact on its disruptive potency. Similarly, the semantic features of the irrelevant speech seems to have negligible effect (Jones, Miles, & Page, 1990), since memory performance was equally affected whether participants heard an unfamiliar language or their own language as a background noise. Note, however, that equal memory performance does not necessarily imply comparable cognitive effort, as subjects tend to assess speech as more disturbing and disadvantageous relative to non-speech sounds, regardless actual cognitive performance (Venetjoki, Kaarlela-Tuomaala, Keskinen, & Hongisto, 2006).

Other studies showed that the effect of speech and non-speech sounds might differ according to the task (Hongisto, 2005). For example, Venetjoki et al. (2006) reported differential effects of various sound environments (speech, masked speech, and continuous noise) in a cognitive task (proofreading performance), where speech was found to be more disruptive. Other tasks (reading comprehension, reaction time, subtraction, proposition, Stroop and vigilance) were similarly affected by all noise types.

Serial recall has been shown consistently to be particularly susceptible to disruption (Beaman & Jones, 1998). Yet, the impact of auditory background noise on free or delayed (rather than serial) recall for visual items is less clear. Noise of road traffic (fluctuating-energetic noise) and of meaningful irrelevant speech (fluctuating-informational noise) showed reliable effects on delayed recall (retrieval from semantic memory) in text-reading tasks (Hygge, Boman, & Enmarker, 2003). Similarly, Banbury and Berry (1998) found that meaningful speech as well as meaningless speech were equally disruptive in a prose recall task (for related results with reading comprehension and recognition, see: Oswald, Tremblay, & Jones, 2000). However, Salamé and Baddeley (1990), who evaluated the effect of background speech on immediate free recall of lists of visually presented words, found no impairment in the speech (continuous irrelevant speech) relative to the control (silent) condition.

One of the explanations that has been offered for the interference between written and spoken words is attention-based. Accordingly, the attentional system is responsible for the effects, since both relevant and irrelevant materials compete for similar available resources (Weinstein, 1977). Steady-state noises divert fewer attentional resources from the main task at hand than fluctuating noises, and hence are easier to ignore (Neath, 2000).

Common to these aforementioned studies is the fact that the visually presented target stimuli were learned by a similar method (e.g., silently reading lists of words - Salamé & Baddeley, 1990; silently reading a text– Hygge et al., 2003), accompanied by different types of noises. No study to date compared the effect of background noise on long-term recall for target items that were learned by different methods, such as some by silent reading and others by reading aloud. Such opportunity can be provided with the PE paradigm.

1.2. The Production Effect

In a typical PE experiment, participants are required to study a list of visually presented words for a following memory test. Half of the words are to be learned by reading aloud, and the remaining words are read silently. The typical result of such experiments is that words that were read aloud (vocally produced) show a significant advantage over words that were read silently (Hourihan & MacLeod, 2008; Lambert, Bodner, & Taikh, 2016; MacLeod et al., 2010; Mama & Icht, 2016b; Ozubko, Gopie, & MacLeod, 2012; Ozubko, Hourihan, & MacLeod, 2012; Ozubko & MacLeod, 2010), the PE.

Different PE studies demonstrated that various types of productions, such as whispering, mouthing, spelling, typing and writing bring about a better long-term memory relative to silent reading (Castel, Rhodes, & Friedman, 2013; Conway & Gathercole, 1987; Forrin et al., 2012; Gathercole & Conway, 1988; MacLeod et al., 2010; Mama & Icht, 2017). Yet, when words are visually presented, reading aloud seems to be the best mnemonic (MacLeod et al., 2010).

MacLeod and his colleagues suggested that enhanced distinctiveness is the main mechanism underlying the PE (MacLeod et al., 2010; Ozubko & MacLeod, 2010). According to the distinctiveness account, vocally producing a word enhances its memory trace relative to the other non-produced words (silently read) as it involves a greater number of unique encoding processes. During a recall or recognition test, this superior memory record is available for the participants, improving the memory performance of vocally produced items relative to non-produced words. Vocally producing a visually presented word involves three separate encoding processes: a) reading, b) articulating (motor response), and c) hearing (your own voice). Conversely, silent reading involves only a single encoding process of reading. As the number of distinct encoding processes increases, memory performance improves. The high relative distinctiveness of reading aloud explains well its superiority over silent reading as well as over other productions (such as mouthing, which carries only a pair of processes - reading and articulating). Several studies have directly tested the distinctiveness account, with positive results (Icht et al., 2014; Mama & Icht, 2016a; Ozubko & MacLeod, 2010; Ozubko, Major, & MacLeod, 2014).

Interestingly, the role of (differential) attention in the PE has been mentioned in the context of encoding distinctiveness. Accordingly, vocal production provides a boost to memory by selectively focusing attention on aloud over silent words (Ozubko, Hourihan, & MacLeod, 2012). MacDonald and MacLeod (1998) stated that "words that received more attention at encoding were better recognized than words that received less attention. The more thorough processing of words that were read aloud at study led to better direct remembering." (p. 306, see also: Forrin, Jonker, & MacLeod, 2014; Ozubko, Gopie, & MacLeod, 2012).

1.3. The present study

The aim of the present study was to test the effect of different types of background noise on long-term verbal memory as reflected in a PE task. Two experiments were conducted using three different types of background noise: (a) steady-state (energetic), (b) babble (fluctuating-informational; both used in Experiment 1), and (c) fluctuating-energetic (Experiment 2). The different noises that were used in this study, and their acoustic characteristics, are summarized in Table 1.