THE PRODUCTION EFFECT:

THE ROLE OF ATTENTIONAL RESOURCES

by

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ABSTRACT

The *production effect* is the benefit in memory found for produced (i.e., read aloud) words relative to words read silently. It is proposed that the production effect occurs as a result of the enhanced distinctiveness associated with the produced items. The current research investigated whether attentional resources are required to encode and/or retrieve the distinctive information associated with the produced words. The literature suggests that the encoding of this distinctive information occurs automatically, but at test, purposeful attention is required to retrieve this distinctive information. To test this, participants read words aloud and silently, under either full or divided attention. Participants then completed either a recognition (Experiment 1) or free recall (Experiment 2) memory test under either full or divided attention. The findings show that when attention is divided at encoding, the benefit for aloud words remains for both recognition and free recall. When attention is divided at test, however, the benefit for aloud words remains for recognition but is absent for free recall. Overall, these results suggest that the distinctive information associated with produced words is encoded automatically, but it may not be accessible at test under attentionally demanding conditions.

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The Production Effect: The Role of Attentional Resources

In today's society individuals are constantly looking for ways in which to improve their memory both for our everyday lives, such as remembering what items need to be picked up at the grocery store, and for our academic lives, such as students who are trying to study material for a future test. Although the literature surrounding this topic has been plentiful, the list of encoding techniques that have repeatedly shown substantial memory benefits is rather small. This list includes, but is not limited to, rehearsal (Driskell, Cooper, & Moran, 1994), imagery (Paivio, 1971), and elaboration (Craik & Tulving, 1975). Another encoding technique that has shown substantial and consistent memory benefits is known as generation. The generation effect is the phenomenon that memory for verbal material created by the individual is better than memory for verbal material that is simply read (Slamecka & Graf, 1978). Bertsch, Pesta, Wiscott, and MacDaniel (2007) completed a meta-analytic review of the generation effect and found that this simple encoding technique provides the user with an average improvement in recognition of previously studied material of approximately 10%.

More recently another encoding method, known as production (MacLeod, Gopie, Hourihan, Neary, & Ozubko, 2010), has received increased interest as it too has been repeatedly shown to produce memory benefits of a similar magnitude as the generation effect (e.g., Forrin, MacLeod, & Ozubko, 2012; Ozubko, & MacLeod, 2010; Ozubko, Gopie & MacLeod, 2012). Before this encoding strategy was defined – as the robust benefit in memory shown for words read aloud (produced) versus words read silently

(MacLeod et al., 2010) – little research had investigated its benefit with respect to subsequent memory performance.

The following provides a review of the literature surrounding the production effect, with respect to both a distinctiveness account and strength based account, identifying a gap in the literature that inspired the current research. The effects of divided attention will then be briefly outlined with respect to its effects on encoding and retrieval for both recognition and free recall memory tests. Finally a detailed description of two experiments will be given. Both experiments investigated the role of attentional resources during the encoding and testing phases of a standard production effect memory task, using a recognition and free recall memory test. This research is being conducted to assess whether attentional resources are required to encode and retrieve the additional information that is associated with items that are read aloud.

The Production Effect

The production effect is defined as the robust benefit in memory for produced items (words read aloud), in comparison to items that are not produced (words read silently) (MacLeod et al., 2010). This phenomenon was first examined indirectly by Hopkins and Edwards (1972) who had participants complete a mixed list study phase in which half of the items were to be read aloud (produced), and half were to be read silently. The goal was to test a key assumption of the frequency theory (Ekstrand, William, & Underwood, 1966); that recognition for produced words should be better than for unproduced words because pronouncing a word increases its frequency in memory (i.e., one instance for the visual information and one for the pronounced information). The results showed an approximate benefit of 10% in recognition for the produced words relative to the unpronounced words; this benefit is known today as the production effect.

Following the work of Hopkins and Edwards (1972), Conway and Gathercole (1987) had participants incidentally learn a mixed list of items that were read silently, mouthed, or read aloud, followed by a delayed old/new recognition test. The results showed once again that reading a word aloud provided substantial memory benefits over words read silently. The authors stated that saying a word aloud increases its general distinctiveness by adding an acoustic attribute to these items along with the visual attribute obtained when reading the item. In contrast, the general distinctiveness of a silent item is limited to a single distinctive attribute, the non-acoustic visual attribute. When tested on these items, the general distinctiveness of the aloud items has two available attributes in memory whereas the silent items only have one; the resulting outcome is better memory for the aloud items.

MacLeod et al. (2010) reported a series of experiments, similar to those completed by Slamecka and Graf (1978) with respect to the generation effect, to define and delineate the production effect. Experiment 1 was conducted to reproduce the production effect with an explicit recognition test (Conway and Gathercole, 1987; Hopkins & Edwards, 1972; MacDonald and MacLeod, 1998), using a within-subjects design. Participants were asked during study to either read items aloud or silently, followed by a yes/no recognition memory test. The results of this experiment replicated previous findings that producing an item results in a substantial memory benefit over items read silently in a within-subjects design. Experiment 2 utilized the same procedure but was completed as a between subjects design rather than within subjects. The between subjects design showed no benefit for aloud items, an absence of the production effect.

In Experiments 4 and 5 (MacLeod et al., 2010) investigated the importance of the response made to aloud items to test whether unique responses to items were required in order to produce future memory benefits. The results showed that performing a repeated response, whether a manual response (a key press; Experiment 4A), or the same vocal response (saying “yes” to all aloud items; Experiment 5), did not result in a production effect. This suggests that a unique vocal response must be made in order for a production effect to be observed. The production effect was also not limited to word stimuli as a benefit in memory was also found for pronounceable nonwords that were read aloud over pronounceable nonwords read silently (Experiment 6).

In the final two experiments of MacLeod et al.’s (2010) work, two other aspects of the production effect were investigated. Experiment 7 investigated whether a richer encoding task that leads to superior memory performance, generation, would exhibit a production effect. The results showed that, even when a richer encoding task is implemented, a production effect is still observed, demonstrating that production can increase memory for items that are already very well remembered. Lastly, Experiment 8 investigated the possibility that the production effect occurred as a result of the inferior encoding of silent items as a result of “lazy reading” (Begg & Snider, 1897). The lazy reading hypothesis proposes that in a mixed list design the benefit for produced items is not the result of superior encoding of that item type, rather, the benefit occurs as a result of the inferior encoding that occurs for silent items as they receive less attention. To overcome the inferior encoding of silent items that would be predicted by a lazy reading hypothesis, all participants completed a semantic judgement for both aloud and silent items during encoding. Once again a production effect was observed, refuting the idea that lazy reading underlies the production effect.

In subsequent research Forrin, MacLeod, and Ozubko (2012) compared the act of producing an item to mouthing, writing, whispering and silent reading. All four methods of production resulted in memory benefits when compared to silent reading, however the most substantial benefit in memory was found for saying the word aloud. These results, in parallel with the results of MacLeod et al., (2010) Experiment 5, show that a unique, item specific response is required to create a distinctive record in memory that can be utilized during a memory test.

Distinctiveness Account

The fact that produced items are better remembered than silent items is a finding that has frequently been explained by a distinctiveness account. The role of distinctiveness was first investigated by von Restorff (1933) who found that when one item in a list differs from the remaining items on one or more dimensions, this item is remembered better than when it is presented in a list of items that share a similar dimension, (e.g., presenting a three-letter string in a series of three-number strings as compared to a list of three-letter strings). More recently distinctiveness has been defined as a kind of processing rather than an aspect of the material being processed; future memory is supported by a deeper level of processing of the distinctive item(s) relative to the other items within a list (Craik & Lockhart, 1972).

Ozubko and MacLeod (2010) elaborated upon Conway and Gathercole's (1987) idea of general distinctiveness to state that producing an item (reading it aloud) makes it more distinctive than items not produced (read silently), resulting in better recognition for these items in a future recognition memory test. In a recognition memory test a participant is presented with a series of words individually and memory judgements for these items rely on the use of distinctiveness heuristic (Dodson & Schacter, 2001). When presented with a single word that has been read aloud a participant can say to themselves, "I remember saying this word aloud, therefore it must be a studied word," whereas the same cannot be true for words not produced: Both new words and words studied silently were not read aloud.

Support for the distinctiveness account of the production effect has been demonstrated using a list-discrimination paradigm (Ozubko & MacLeod, 2010). In this study, participants were presented with two lists of items to study; a mixed list containing items to be read aloud as well as read silently, and a pure list containing either all aloud items or all silent items. After studying both lists participants were presented with all studied items, from both the mixed and pure lists, and asked to identify which list each word came from. In a standard recognition test, recalling an item as read aloud is useful for identifying this item as previously studied because the distracting items were not read aloud. In a list discrimination task involving a pure list of all aloud items, the ability to recall an item as read aloud will not aid in the identification of which list the item belongs to, as the mixed list and pure list both contained aloud words. However when the pure list contains all silent items, recalling that an item was read aloud does assist with list discrimination as only the mixed list contained these items. Therefore a production effect, in list discrimination accuracy, should be observed when the pure list contains all silent items.

Regardless of whether the pure list was presented prior to or after the mixed list, the results reported by Ozubko and MacLeods (2010) were the same. A reliable production effect was found for the mixed list when the pure list contained all silent items, however, the production effect was absent for the mixed list when the pure list contained all aloud items. These two experiments support the distinctiveness account of production in that saying an item aloud provides extra distinctive information which can be used heuristically at test, in this situation to improve list discrimination performance. Furthermore, the data also showed that performance on the pure lists was equivalent for both list types, aloud and silent, consistent with the absence of a between subjects production effect.

The production effect has also been shown to be enhanced by adding additional distinctive elements to the produced items. In a series of experiments Quinlan and Taylor (2013) presented participants with a mixed list of items that were to be read silently, read aloud, read aloud loudly (instructed to read louder than they would in a normal day-to-day interaction), or sung aloud. Superior memory performance was shown for all three vocalization methods relative to words read silently. Additionally, this study showed that both reading words aloud loudly and singing provided greater recognition than reading aloud in a normal voice, with singing providing the most substantial benefit in recognition memory relative to silently read items. In relation to the distinctiveness account it appears that reading items aloud loudly and singing items during encoding provides the participant with further distinctive cues to retrieve at test. The loudly-read items receive the additional cue of increased intensity of audition and the sung items receive additional distinctive cues associated with intensity, pitch, and/or timbre.

The evidence surrounding the distinctiveness account is consistent with the idea that, at test, individuals retrieve the distinctive information from memory that is associated with produced items, thus resulting in a benefit for this item type over items read silently. Lin and MacLeod (2012) tested a population known to have difficulty with using distinctive information in memory (e.g., Butler et al., 2010): older adults. Although the older group did exhibit a significant production effect, the benefit was much smaller than that observed in the young adult group. This study supports the idea that individuals monitor their memory for the distinctive information associated with aloud words, and, if found, this information provides the benefit in memory for these items over items read silently.

The accumulation of evidence supports the distinctiveness account of the production effect. It seems that producing an item, by saying it aloud, makes that item more distinctive than simply reading an item silently for mixed list designs. An alternative account of the production effect is based upon a more classical cognitive theory known as the strength account.

Strength Account

The strength theory of memory suggests that test performance is a function of the strength of a memory trace and the decision that is made based upon this memory. At test the trace strength of an item is compared to a criterion level before a decision is made as to whether the item is old or new (Murdock & Dufty, 1972). The rules that govern the decision making system are similar to those of signal detection theory (e.g., Green and Swets, 1966), and were developed and evaluated by Wicklegren and Norman (1966). When the trace strength of an item surpasses a set criterion, an individual will identify an item as having been previously studied: However, if the trace strength does not surpass the criterion, the item will be judged as new.

The strength account of the production effect states that stronger memory traces are formed for aloud words than silent words; therefore, aloud words should outperform silent words on a memory task (Bodner & Taikh, 2012). This account has also been expanded and termed an *evaluated-strength account* that states that a production effect will occur on a task if the participant can engage in an intentional evaluation of the memory strength of items. This account predicts a benefit in memory for aloud items over silent items in a within subjects design based on the fact that aloud items have stronger memory traces, and so are therefore more likely to be identified as a studied item. However, the strength based account also predicts a between subjects production effect as memory strength is not based upon the direct contrast between aloud and silent items. In a meta-analytical review of the literature, Fawcett (2013) addressed whether the production effect was observed in studies that used a between subjects design. The results showed that a between subjects production effect does occur, however the effect is usually weaker than the effect that is observed in a within subjects design (a trend found within the generation effect as well; Bertsch et al., 2007). These findings support the idea of a strength based account in memory but do not refute the possibility that distinctiveness can be an explanation as well.

More recently, Bodner, Taikh and Fawcett (2014) completed a study and meta-analysis to examine whether the within subjects production effect occurs as a result of the enhanced recognition of aloud items and/or the impaired recognition of silent items. Participants completed a study phase that consisted of either a mixed list (aloud and silent items), a pure list (all silent or all aloud items), or a blocked list (all silent items presented in the first half followed by all aloud items, or vice versa), followed by an old/new recognition test. Participants in the mixed list, and both blocked list groups, exhibited a significant production effect; however, the production effect was smaller for the blocked lists. With respect to the pure list, there were similar aloud and silent hits rates between the two lists; however, discriminability scores (d') showed a significant production effect in this between subjects design. To assess the cost/benefits associated with aloud and silent items the discrimination scores for both item types were compared for the mixed and pure list. These analyses showed no evidence that recognition of aloud items was improved more in a within subjects design than in a between subjects design; instead the discrimination scores were similar for aloud items for the mixed, blocked and pure aloud groups. Furthermore, the results suggest that in a mixed list design the production effect may occur as a result of a cost to silent items rather than a benefit for aloud items, supported by the finding that a production effect occurred in a mixed list design. However, this cost was eliminated when the study list was blocked, yielding a production effect half as large as that obtained in the mixed group.

Test Format

Several dual-process models suggest that memory performance is based on two processes, familiarity and recollection. Familiarity has been shown to reflect a continuous index of memory strength, whereas recollection is thought to reflect the retrieval of specific information associated with a studied item (Atkinson & Juola, 1974; Yonelinas 1997). Jacoby (1991) has also suggested that familiarity reflects an automatic process whereas recollection is a more controlled memory process.

The effect of production with respect to familiarity and recollection was investigated by Ozubko, Gopie, and MacLeod (2012) in a series of experiments in which participants studied a mixed list of items, half of which were to be read aloud and half read silently. In Experiment 1 participants completed a recognition memory test which asked them to make a “new,” “know,” or “recollect” response to all presented items. Producing items was found to increase both familiarity (“know” response accuracy) and recollection (“recollect” response accuracy) over items read silently. In Experiment 2, participants were asked to provide confidence judgements for their recognition decisions. Using a dual-process signal detection model both recollection and familiarity advantages were observed for words read aloud at study. In Experiment 3 participants were to make “aloud,” “silent,” or “new” judgements to items presented at test to investigate whether participants could retrieve the contextual details associated with produced items. Participants were better able to identify qualitative information about the produced items; that is, they were better able to identify aloud words as produced during encoding. Taken together these three experiments show that the act of producing an item at study enhances both the familiarity and recollection of these items over items read silently.

The majority of the research involving the production effect has focused primarily on recognition memory tests. As a result, both the distinctiveness and the strength account were built around the factors affecting recognition memory, such as distinctive information and strength. Another important line of research involves free recall, where memory is based on retrieval of the studied stimuli rather than the recognition that a presented item was presented at study. If memory strength underlies the production effect, individuals should be more likely to access memory for produced words in comparison to silent words in a free recall. The same pattern is predicted by a distinctiveness account as individuals will be more easily able to recall words with multiple distinctive elements (words read aloud) than those with only one distinctive element (words read silently).

One of the first studies to address the role of production in a free recall test was conducted by MacLeod (2011). In this study participants completed a location based production task with either an experimenter or another participant. During the study portion of the experiment participants self-produced the study item, produced the study item simultaneously with a partner, listened to the other person produce the item, or read the item silently; production method was determined based on the location of the studied stimuli on a computer screen. Immediately following the study phase participants completed a self-paced free recall test followed by an old/new recognition test. Despite lower performance in free recall compared to recognition, both test conditions showed the same general trend: participants showed the largest overall benefit in memory when items were self-production followed by joint production with another individual, production by another individual, and reading silently. Although memory benefits are shown when an item is read aloud by another individual and when an item is jointly-produced, relative to items read silently, the largest benefit in memory is observed when an item is self-produced.

Two other studies have also investigated the production effect in a free recall. Lin and MacLeod (2012) investigated the memory benefits associated with production in both a free recall and recognition test, with both younger and older adult populations. For both groups, a significant production effect was observed in both free recall and recognition, but there was a larger benefit for produced items in the younger adults. Jones and Pyc (2014) also found that a production effect occurred for free recall in a within subjects design, however no benefit was found in the between subjects design.

Comparing Theoretical Accounts

To date many facets of the production effect have been examined. A review of the literature has shown that the production effect is evident in a within subjects design (Forrin, MacLeod, & Ozubko, 2012; MacLeod et al., 2010; Quinlan & Taylor, 2013), as well as in a between subjects design (Bodner & Taikh, 2012; Fawcett, 2013). Furthermore it has been shown that multiple production methods including whispering and mouthing (Forrin, MacLeod, & Ozubko, 2012), and joint and other production (MacLeod, 2011) result in memory benefits for the produced item; however, memory is best when the item is self-produced. The act of production has also been shown to improve source memory (Ozubko, Major, & MacLeod, 2014). However, the debate remains as to whether the distinctiveness account or the strength account provides the best explanation as to why the production effect occurs.

Ozubko, Major and MacLeod (2014) reported three experiments that were designed to differentiate between a strength account and a distinctiveness account, by testing source memory (i.e., remembering whether an item was studied Aloud or Silently). The strength account (Bodner & Taikh, 2012) suggests that the production effect occurs as a result of the increased memory strength associated with produced items over those read silently. If a participant were to adopt a strength based decision making strategy while completing a source judgement they would have to set two criteria for making their decisions. If a presented item passes a criterion set for aloud items then the participant should respond "aloud" when asked to make a source memory judgement. Participants should therefore respond "silent" for all presented items that do not meet the aloud criterion, but surpass the lower silent criterion, and respond new to items that have a weaker memory strength than the lower criterion set for silent items. In contrast a distinctiveness account suggests that individuals do not assess their memory for strength; rather, they attempt to retrieve other information. Specifically, when presented with an item at test, participants search their memory for evidence that the item has recently been read aloud. If their search results in finding this information, then the individual would respond by saying the item is “aloud”, and respond “silent” when there is only some evidence that the word was studied aloud, and failing this they would respond “new.”

To differentiate between the two explanations, Ozubko et al. (2014) had participants study items that were to be read aloud or read silently. Critical to the design, silent studied items were either presented once or presented twice to participants during the encoding phase. This manipulation allowed the researchers to increase the strength of silent items in memory. The increase in strength associated with the repeated silent items would, by a strength account, result in the absence of a production effect by boosting recognition of silent items. However, a distinctiveness account would predict that a production effect would be present as a result of answering the self-proposed question of whether or not the item was said aloud.

In Experiment 1 Ozubko et al.’s, (2014) gave participants a single presentation of 20 words to be read aloud, a single presentation of 20 words to be read silently, and two presentations of 20 items to be read silently. Experiment 2 and 3 followed the same procedure as Experiment 1 except total aloud trials and total silent trials were equated; 60 aloud trials, 20 silent trials and 20 silent repeated trials. The source judgement test asked participants to identify a presented item as “aloud/silent/new” in Experiment 1 and 2, in Experiment 3 the test was modified to separate silent judgements into “silent presented once” and “silent presented twice.” The strength based account would predict that “aloud” ratings should scale linearly with strength, and therefore be significantly greater for twice studied than once studied silent items. In contrast the distinctiveness account predicts that there would be more “aloud” ratings for words read aloud at study compared to words read silently, with no difference in “aloud” ratings between once and twice studied silent items.

In both Experiments 1 and 2 aloud items were more likely to be rated as “aloud” than any other category; similarly, twice studied and once studied silent items were also more likely to be rated “silent” than any other category. In Experiment 3 the same trend was present: aloud items were more likely to be rated as “aloud,” twice silent items were more likely to be rated as “twice silent” and once silent items were more likely to be rated as “once silent,” than any other categories for each type. These results demonstrate that participants are able to make accurate study mode judgements, and that they do so regardless of memory strength, a conclusion inconsistent with strength based memory account. Rather Ozubko et al.’s., results suggest that participants attempt to retrieve from memory whether or not an item was read aloud, and this additional information is what underlies the production effect.

Attentional Resources and Memory

We, as individuals, have a limited set of resources available to use for a given task, and the more tasks we attempt to complete simultaneously, the more our resources are limited for each of the separate tasks. Research suggests that encoding is under cognitive control, based on the trade-off that exists between memory performance and secondary task performance. When asked to complete a memory task and distractor task at the same time, memory performance is enhanced when emphasis is placed on the memory task, and suffers when emphasis is placed on the secondary task (Craik et al.,1996).

When attention is divided at encoding, subsequent memory performance is hindered, an effect shown by Murdock (1965) and replicated in later studies (e.g., Baddeley, Lewis, Eldridge, & Thompson 1984; Fernandes and Moscovitch, 2000). Furthermore, these findings are shown in a variety of memory tests including free recall, cued recall, and recognition (e.g., Craik, Govoni, Naveh-Benjamin, & Anderson, 1996; Craik, Naveh-Benjamin, Ishaik, & Anderson, 2000). Taken together these findings suggest that memory encoding is not only resource demanding but it is also under cognitive control. When attention is divided at retrieval/test, memory performance has been shown to suffer relative to a full attention condition; however the magnitude of the memory reduction is less than that observed when attention is divided at encoding (e.g., Naveh-Benjamin, & Guez, 2000). This effect is observed with cued recall as well as the more resource demanding free recall memory test procedures (Naveh-Benjamin, Craik, Guez, & Dori, 1998).

Current Research and Hypotheses

Despite the increasing amount of research that has been conducted over the past decade with respect to the production effect there remains an evident gap in the literature: the role of purposeful attention with respect to encoding, and retrieving, the benefit in memory associated with producing items. Addressing this will allow us to determine if attentional resources are required to encode the “aloudness” information associated with producing an item, by having individuals complete a secondary task at encoding. The role of attentional resources will also be investigated at test to determine whether retrieval of additional distinctive information associated with aloud items requires attentional effort.

Thus, the main objective of the current research was to investigate the role of attentional resources in the production effect to determine whether purposeful attention is necessary for the encoding and retrieval of the “aloudness” information associated with produced words. Additionally the current study has the potential to differentiate which of the two proposed accounts of the production effect, strength or distinctiveness, is the better explanation for the benefit in memory associated with produced items. A strength based theory of production predicts that dividing attention, at encoding and at test, would result in an overall decrease in memory performance with a significant production effect remaining in both. In contrast, a distinctiveness account makes a different prediction with respect to the effect of divided attention. In agreement with a strength account, a distinctiveness account also predicts that dividing attention during encoding will have no effect on the production effect, as this information is assumed to be encoded relatively automatically (i.e., without requiring attention; see Ozubko, Forrin, & Major, 2015). However, at test a distinctiveness account would predict an absence of a production effect as attentional resources are required to retrieve the aloudness information associated with produced items.

In both experiments participants completed a production effect memory task in one of three conditions: Full Attention, Divided Attention at Encoding, or Divided Attention at Test. For Experiment 1 all participants completed an old/new recognition memory test following the mixed list study phase, whereas in Experiment 2 all participants completed a free recall memory test. For both experiments it is hypothesized that overall memory performance will be reduced in the Divided Attention at Encoding and Divided Attention at Test conditions relative to Full Attention, with the Divided Attention at Encoding conditions producing the lowest overall memory performance (Naveh-Benjamin & Guez, 2000).

If a distinctiveness account offers the best explanation for the production effect we would expect to see a production effect in the Full Attention and Divided Attention at Encoding conditions for both experiments. Research on the production effect and aging suggests that effortful attention is required to retrieve the information associated with produced items (Lin & MacLeod, 2012). Older adults in this study showed a reduced production effect due to the reduced ability to monitor memory (see e.g., Daniels et al., 2009; McIntyre & Craik, 1987) and generally show more of a cost in memory for distinctive events, such as aloud words, (e.g., Butler et al., 2010). Therefore in the Divided Attention at Test conditions a reduction in the magnitude of the production effect, or a complete absence of a production effect should be observed. This result is expected as dividing attention during the test phase of the memory task would disrupt a participant's ability to actively retrieve the distinctive information associated with produced words, an action that likely requires attentional resources. In contrast, if a strength account best explains the production effect, then we should observe a production effect in all three conditions because produced words result in a stronger memory trace than words read silently. This result is expected as the benefit for aloud items do not occur as a result of the retrieval of any additive information, therefore requiring no additional attentional resources.

Experiment 1

Methods

Participants

Participants in the current study were 62 undergraduate students from Memorial University of Newfoundland; two participants were dropped from the analyses because they failed to complete the secondary task in their respective divided attention conditions. There were 48 females and 12 males. All participants were compensated for their time by receiving either $10 or course credit for their participation through the Memorial Psychology Research Experience Program (PREP). All individuals were assigned to one of the three study conditions based upon order of participant appearance, resulting in 20 participants in each of the three conditions.

Materials

The word pool used was from MacDonald and MacLeod (1998). The word stimuli were all nouns, five to ten letters long, that had frequencies greater than 30 per million (Thorndike & Lorge, 1944). All stimuli were presented in 18-point Courier New font, in lower case against a black background. The instructions and the memory test stimuli were presented in yellow font. The controlling program was written with E-Prime version 2.0 (Psychology Software Tools, Pittsburgh, PA) and presented on a PC-compatible computer with a 23-in colour monitor. Stimuli were randomly assigned to conditions for each of the participants.

The auditory stimuli for the secondary task were presented through two speakers placed in front of the computer's monitor. Three tone types were used in the tone discrimination task: a low, medium and high tone with frequencies of 250Hz, 500Hz, and 750Hz respectively, each presented for 500ms. All tones were randomly assigned to subtrials within the divided attention conditions, and participants had 1000ms to respond from the onset of the tone.

Procedure

Experiment 1 consisted of a study phase and a testing phase, and participants completed the experiment in one of three conditions: Full Attention, Divided Attention at Encoding, or Divided Attention at Test. All participants completed an initial study phase that presented 80 words in total, one at a time, with half of the words appearing in blue font and half of the words appearing in white font, in a random order. Participants were instructed prior to the experiment beginning, and again before the study phase, to read all words presented in blue font aloud and to read all words presented in white font silently. During the study phase the researcher remained in the room with the participant to record trial errors (e.g., saying a word aloud which was supposed to be read silently).

Each of the study trials had a duration of 5000 ms and presented the participants with a single study word. Each trial was subdivided into 1000 ms subtrials to accommodate the inclusion of a secondary task for participants within the divided attention conditions. The initial subtrial presented participants with a fixation cross (“+”) centered on the screen. This fixation was followed by a 1000 ms blank, subtrial two, prior to the presentation of the trial’s word stimulus. Subtrials three and four presented the participant with the word stimulus (2000 ms total presentation time), followed by a 1000 ms blank subtrial before the onset of the next trial. During the encoding phase a microphone was placed in front of the participants to encourage vocalizations; however the microphone did not record any verbal responses during this phase of the experiment.

An old/new recognition test followed the encoding phase for all participants in this experiment. The recognition test consisted of the entire word pool: the 80 studied items (40 aloud and 40 silent) as well as 40 new items. Each recognition test trial consisted of three subtrials each with duration of 1000 ms. The first two subtrials presented individuals with the test word stimuli in yellow font for 2000 ms followed by a 1000 ms blank subtrial prior to the onset of the next test trial. Participants were asked to verbally indicate whether the presented test word was previously studied, by saying “studied” aloud, or a new item, by saying “new” aloud. Oral recognition was used for pragmatic reasons as participants in the divided attention conditions completed a secondary task that required a manual response. A microphone was placed in front of the participants to record their verbal responses during the test phase, and the researcher remained in the room to record any missed trials.

Participants in the divided attention conditions completed a single phase of the experiment under divided attention. The study phase and test phase procedure remained the same for all divided attention participants with the addition of a secondary task. The secondary task was a tone discrimination task which presented participants randomly with one of three tone types: low, medium, and high. A single tone was presented during each of the subtrials and participants were asked to make a response whenever the "high" tone was presented; responses were made by pressing a button on a five-option button box. Response time and accuracy were recorded for all responses relative to the onset of each of the tone within a subtrial. Responses were counted as correct if the response was made to a high tone within the 1000 ms subtrial in which the tone was presented.

All participants in the divided attention conditions completed a practice phase of the tone discrimination task preceding the phase of the experiment in which the secondary task was implemented. The practice phase introduced the participants to each of the three tone types, followed by a one minute practice block which provided participants with immediate feedback following each tone presentation and response. Participants were given the option to complete the practice block multiple times if needed; all participants had to complete at least one single minute practice session before continuing onto their respective divided attention phase. Participants in the full attention condition completed the practice block for the secondary task between the encoding and test phases of the experiment.

Results

Test Performance

Mean hit rates for each of the three conditions are summarized in Table 1. The mean hit rates were calculated based upon the number of trials in which a participant made a verbal response, therefore not all hit rates for each of the participants are based on 80 test trials; the average number of omitted trials was 1.35, (SD = 2.43). The mean hit rates were analyzed in a 3 (Group: Full Attention vs. Divided Attention at Encoding vs. Divided Attention at Test) X 2 (Production: Aloud vs. Silent trials) mixed factors analysis of variance (ANOVA) with group as a between subjects factor variable and production as the within subjects variable. A significant main effect of Production was present F (1,57) = 159.5, MSE = .007 p <.001, η_p^2 = .737, with higher hit rates for Aloud items than Silent items.

A significant main effect main effect of Group was also evident, F (2,57) = 6.14, MSE = .033 p = .004, η_p^2 = .177, with significantly higher hit rates in the Full Attention condition as compared to both Divided Attention at Encoding, p = .001, and Divided Attention at Test, p = .025. A comparison between both Divided Attention conditions shows numerically higher hit rates in the Divided Attention at Test condition, however the difference was not significant (p = .26). The Group X Production interaction was non-significant, F (2,57) = 0.05, MSE = .007 p = .951, η_p^2 = .002, however a priori paired samples t-test were completed to assess the presence of the production effect within each of the three conditions. This set of analyses showed that all three conditions exhibited significant production effects (all *p*s < .001).

The false alarm rates for each of the three conditions can be seen in the bottom of Table 1. The false alarm rates, like the hit rates, were calculated for trials in which a participant made a verbal response. Therefore not all participants' false alarm rates are based on 40 trials; the average number of omitted trials was 0.73 (SD = 1.47). A One-way

ANOVA showed no significant differences in false alarm rates between each of the three groups, F (2,59) = 1.24, MSE = 0.011, p = .296, η_p^2 = .042.

Table 1

Mean Proportion of "Studied" responses (Hits for Studied words and False Alarms for New words) for Recognition Memory Test.

	Full Attention	**Divided Attention at Encoding**	**Divided Attention at Test**
Studied Items			
Aloud	.81 (.15)	.67 (.13)	.71 (.13)
Silent	.61 (.17)	.48 (.15)	.53 (.09)
Mean	.71 (.19)	.57 (.17)	.62 (.15)
New Items			
False Alarms	.18 (.09)	.23 (.12)	.19 (.10)

Note: Standard Deviations presented in parentheses with means

Secondary Task Performance

Performance, accuracy and response times, across subtrials for the secondary task within the Divided Attention at Encoding condition can be seen in Figure 1. Accuracy was analyzed in a 2 (Production: Aloud vs. Silent) x 5 (Subtrial: 1-5) repeated measures ANOVA. A significant main effect of Production was not observed, F (1,76) = 2.357, MSE = .013, p = .141, η_p^2 = .11, with equivalent accuracy rates for aloud and silent trials.

The main effect of subtrial was significant, F (4,76) = 10.72, MSE = .017, p < .001, η_p^2 = .361. The Production x Subtrial interaction was non-significant, F (4,76) = 0.82, MSE = 0.013 p = .517, η_p^2 = .041. An a priori contrast was also completed comparing subtrials in which the study word was present (subtrials 3 and 4) and subtrials in which the study word was not present (subtrials 1, 2, and 5). This analysis showed a significant reduction in accuracy on subtrials when the study word was presented, t (95) = 2.30, p = .024. Follow up paired samples *t*-tests showed no difference between aloud and silent trial accuracy on subtrials 3 and 4, (p = .59 and p = .93, respectively), showing that although accuracy was diminished for these subtrials, performance was equivalent for aloud and silent items.

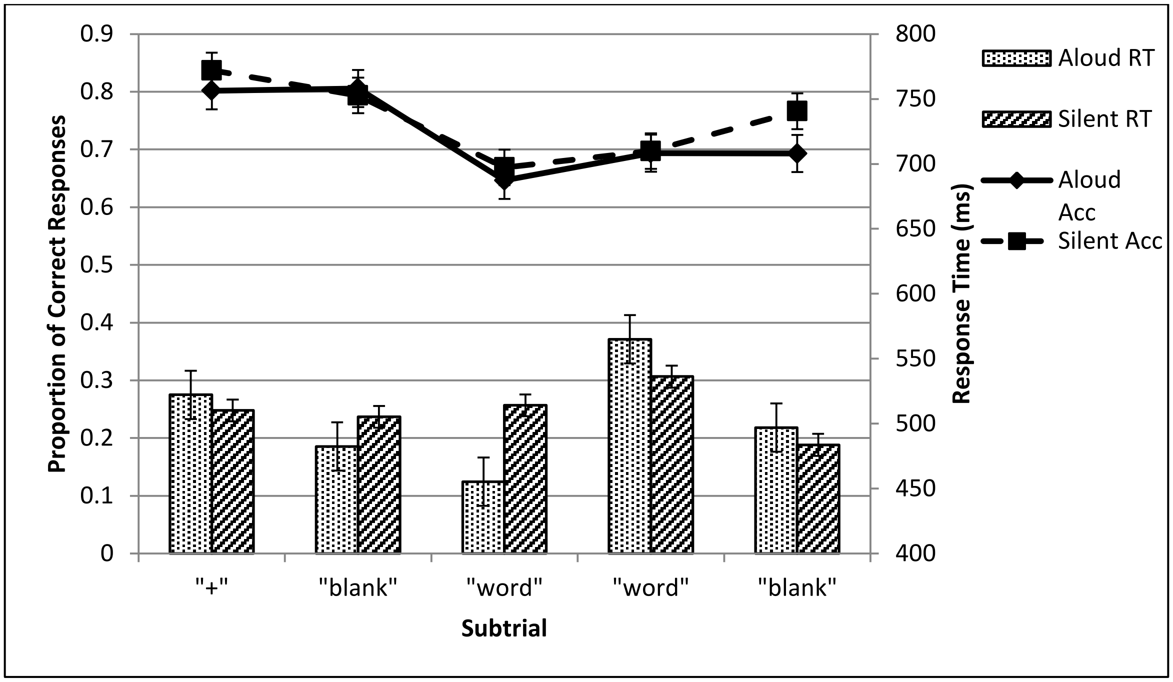

Figure 1. Proportion of correct responses and mean response time (in milliseconds) in the localization task for Aloud and Silent trials across study phase subtrials 1-5. Error bars show the standard errors of the means.

Response times for the secondary task were also analyzed in a 2 (Production: Aloud vs. Silent) x 5 (Subtrial: 1-5) repeated measures ANOVA. The main effect of Production was not significant, F (1,72) = .008, MSE = 3748, p = .928, η_p^2 = 0.00, showing no difference in response time for aloud and silent trials. The main effect of Subtrial was significant, F (4,72) = 5.94, MSE = 3459, p < .001, η_p^2 = .248, and the Production x Subtrial interaction was also significant, F (4,72) = 3.36, MSE = 3674, p = .014, η_p^2 = .158. A-priori paired sample t-tests showed significantly slower response times for silent trials at subtrial 3, t(19) = 2.90, p = .009. All other paired t-tests were non-significant, all ps > .087. As with accuracy, a contrast between subtrials with the word present and subtrials with the word absent was completed, this analysis showed no significant difference between these two conditions, t (95) = .459, p = .647.

Accuracy and response time on the secondary task were also analyzed for the Divided Attention at Test condition, see Figure 2. A 2 (Production: Aloud vs. Silent) x 3 (Subtrial: 1-3) repeated measures ANOVA was completed for secondary task accuracy. There was no significant main effect of Production $F(1,38) = 1.65$, $MSE = .016$, $p = .215$, $\eta_p^2 = .08$. The main effect of Subtrial was significant, $F(2,38) = 14.14$, $MSE = .018$, $p < .001$, $\eta_p^2 = .427$. The Production x Subtrial interaction was non-significant, $F(2,38) = 2.31$, $MSE = .015$, $p = .113$, $\eta_p^2 = .108$. Follow up paired samples t-tests found that accuracy during aloud trials was marginally higher than accuracy on silent trials within subtrial 2, $t(19) = 2.10$, $p = .049$. Accuracy for aloud and silent trials did not differ on subtrial 1, ($p = .278$), or subtrial 3, ($p = .347$). The a priori comparison between subtrials 1 and 2 (word present) and subtrial 3 (word absent) was not significant, $t(57) = 1.52$, $p = .135$.

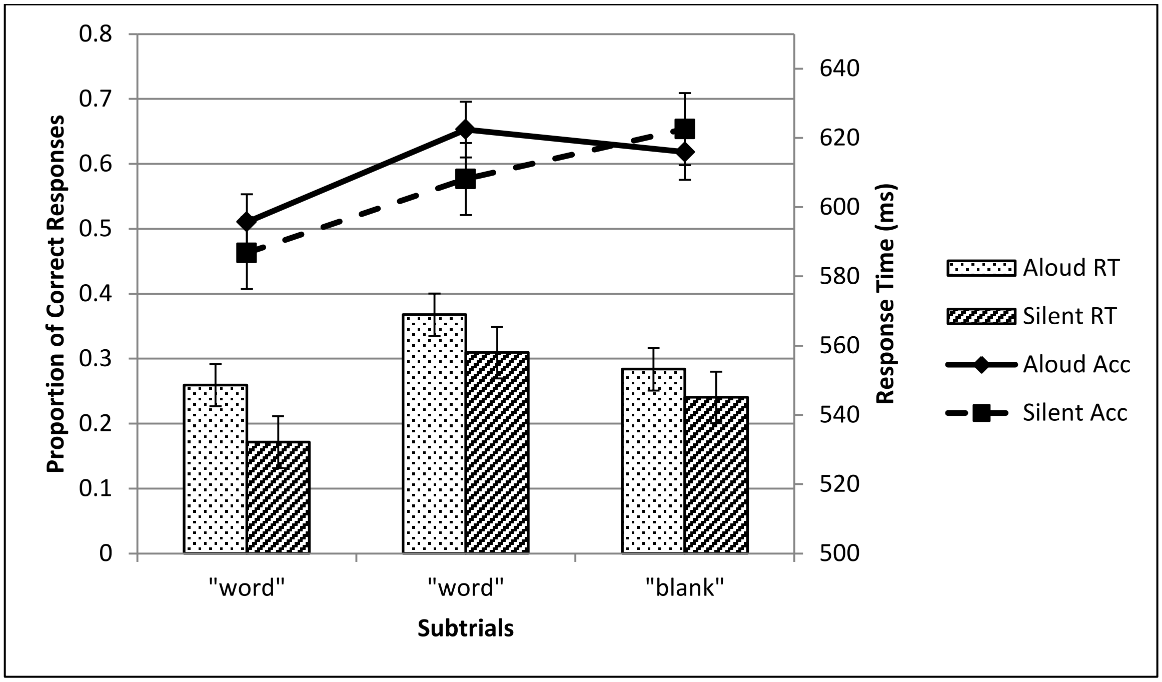

Figure 2. Proportion of correct responses and mean response time (in milliseconds) in the localization task for Aloud and Silent trials across recognition test subtrials 1-3. Error bars show the standard errors of the means.

A 2 (Production: Aloud vs. Silent) x 3 (Subtrial: 1-3) repeated measures ANOVA was also completed for response times across subtrials for aloud and silent items. The main effect of Production, the main effect of Subtrial and the Production x Subtrial interaction were all non-significant, all *p*s > .42. Follow up paired t-tests showed no significant differences between aloud and silent items across all subtrials, all *p*s > .52, and the contrast between word present (subtrials 1,2) and word absent (subtrial 3) was also non-significant $t(57) = .332$, $p = .741$.

Discussion

For all three conditions in Experiment 1 a significant benefit in recognition for aloud items over silent items was observed; all conditions showed a production effect. A distinctiveness account predicts that dividing attention at encoding would have no effect on the benefit for aloud items as the "aloudness" information that provides the benefit is encoded relatively automatically, a hypothesis supported by the current results. The presence of a production effect at encoding also supports the strength account as this theory relies upon the increased strength in memory for aloud items relative to silent, an effect that requires no attentional resources during study.

When attention was divided at test the same result was found: a production effect was present. This result supports the strength account as the benefit in memory for aloud items is not based upon additional information that has to be retrieved, rather it is the strength of the memory the causes the production effect. According to a distinctiveness theory, dividing attention at test should result in a disruption in one's ability to retrieve the distinctive information associated with aloud items thereby eliminating the benefit: this prediction was not supported. The completion of the secondary task did result in a significant reduction in overall memory performance for the divided attention conditions relative to full attention; however the secondary task utilized in the current research may not have been difficult enough to disrupt participants' use of a distinctiveness heuristic when making recognition judgements. As stated previously producing items has been shown to increase familiarity and recollection of these items (Ozubko, Gopie, & MacLeod, 2012), and recognition can be completed on the basis of familiarity alone.

In Experiment 2 free recall was used, rather than recognition. As a result of the increased attentional resources required for retrieval, memory performance may be more susceptible to the effects of divided attention.

Experiment 2

Experiment 2 followed the same procedure as Experiment 1 for the encoding and divided attention tasks, however at test participants were asked to complete oral free recall. For both the strength and distinctiveness accounts the same predictions are made for Experiment 2 as were made for Experiment 1. By a strength account we would expect to observe a production effect in all three conditions as memory strength is increased by production automatically and its retrieval does not hinge on the availability of attentional resources at test. In contrast, a distinctiveness account predicts the presence of a production effect in the Full Attention and Divided Attention at Encoding conditions once again as a result of the relatively automatic encoding of the “aloudness” information associated with produced items. At test the distinctiveness account predicts an absence of a production effect when attention is divided as this will disrupt the strategic search for the additional information known to benefit aloud items.

Methods

Participants

Experiment 2 was completed by 61 undergraduate students from Memorial University of Newfoundland; one participant was dropped from the analyses because they failed to complete the secondary task. There were 42 females and 18 males in the final sample. All participants were compensated for their time by receiving either $10 or course credit for their participation through the Memorial Psychology Research Experience Program (PREP). All individuals were randomly assigned to one of the three study conditions based upon order of participant appearance, resulting in 20 participants in each of the three conditions.

Materials

The stimulus materials used in this study were the same as those used in Experiment1.

Procedure

Experiment 2 consisted of a study phase and a testing phase, and participants completed the experiment in one of three possible conditions: Full Attention, Divided Attention at Encoding, or Divided Attention at Test. The study phase for Experiment 2 was identical to the study phase used in Experiment 1. However the test phase of Experiment 2 was a Free Recall Test instead of the old/new recognition test used in Experiment 1.

Following the study phase participants completed a free recall test in which they were asked to verbally recall as many words as possible from their encoding phase. Oral free recall was used for pragmatic reasons as participants in the divided attention conditions had to complete a manual response for the secondary task. Participants were informed that the free recall test was self-directed and that there would be no time limit for this phase of the experiment. When the participants had free recalled as many words as possible they were asked to let the experimenter know. During the test phase a microphone was placed in front of the participant to record verbal responses and the researcher remained in the room with the participants.

Individuals in the divided attention conditions completed the secondary task during either the study or at test. The procedure for the secondary task and the stimuli used were identical to that outlined in Experiment 1. As with Experiment 1 all participants completed a practice block of the secondary task at least once before proceeding onto the portion of the experiment in which the secondary task was implemented.

Results

Test Performance

The average numbers of Aloud and Silent words recalled are presented in Table 2. The total recalled items were analyzed in a 3 (Group: Full Attention vs. Divided Attention at Encoding vs. Divided Attention at Test) x 2 (Production: Aloud vs. Silent) mixed factors ANOVA with Group as the between subjects variable and Production as the within subjects variable. A significant main effect of Production was present $F\ (1,57) = 11.39$, $MSE = 7.32$, $p = .001$, $\eta_p^2 = .167$, with higher numbers of aloud items being recalled than silent items.

A significant main effect of Group was also present, $F\ (2,57) = 9.78$, $MSE = 13.84$, $p < .001$, $\eta_p^2 = .255$, with both Full Attention and Divided Attention at Test having significantly more items recalled than the Divided Attention at Encoding condition (both *p*s < .001). A comparison between total recalled items for the Full Attention and Divided Attention at Test condition revealed no significant difference between the two, $p = .511$.

The Group x Production interaction was not significant, $F(2,57) = 0.52$, $MSE = 7.32$, $p = .597$, $\eta_p^2 = .018$, however a-priori paired samples t-tests were completed to assess the presence of a production effect within each of the three conditions. This set of analyses showed that there was a significant production effect in both the Full Attention and Divided Attention at Encoding conditions ($p = .002$ and $p = .003$, respectively); however a production effect was not observed in the Divided Attention at Test condition, $t(19) = 0.913$, $p = .373$.

The intrusion rate can be seen in the bottom of Table 2. A One-way ANOVA revealed no significant difference in intrusion rates between the three conditions, $F(2,57) = 0.233$, $MSE = 1.79$, $p = .793$, $\eta_p^2 = .008$.

Table 2

Mean Number of Studied Words Recalled, and Intrusions, for the Three Free Recall Memory Test Conditions

	Full Attention	**Divided Attention at Encoding**	**Divided Attention at Test**
Studied Items			
Aloud	7.0 (3.2)	3.7 (1.8)	7.0 (5.0)
Silent	4.7 (2.9)	2.2 (1.6)	5.8 (3.8)
Mean	5.8 (3.2)	3.0 (1.9)	6.4 (4.4)
New Items			
Intrusions	0.85 (1.4)	1.1 (1.3)	1.1 (1.4)

Note: Standard deviations are provided in parenthesis with means.

In order to analyze whether there was a bias to recall Aloud items first, average output order was analysed with 2 (Production: Aloud versus Silent) x 3 (Group: Full Attention vs. Divided Attention at Encoding vs. Divided Attention at Test) mixed factors ANOVA, with Production as the within subjects variable and Group as the between subjects variable. The main effect of Production and the Production x Group interaction were both not significant, p = .476 and p = .367 respectively. The main effect of Condition however was significant, $F(2,52) = 4.87$, $MSE = 15.46$, $p = .012$, $\eta_p^2 = .158$. Follow up paired t-tests showed that the main effect of condition occurred as a result of the significantly lower number of total items recalled in the Divided Attention at

Encoding than Divided Attention at Test and Full Attention. Only the comparison between Divided Attention at Encoding and Divided Attention at Test was significantly different, $p = .003$.

A One way ANOVA was also completed to analyze the potential difference in total recall duration (seconds) between each of the three conditions. An overall difference was observed between the three conditions for total recall duration, $F(2,57) = 4.23$, $MSE = 13173$, $p = 0.019$. Follow up pairwise comparisons revealed that the Divided Attention at Encoding condition ($M = 118$, $SD = 82$) was significantly shorter than the Divided Attention at Test condition ($M = 222$, $SD = 149$), $p = 0.006$. No significant difference was observed between Full Attention ($M = 158$, $SD = 103$) and Divided Attention at Encoding, $p = .272$, however the difference between Full Attention and Divided Attention at Test approached significance, $p = .082$.

Secondary Task Performance

Secondary task performance, accuracy and response times, for Divided Attention at Encoding condition can be seen in Figure 3 across subtrials. To assess the possibility of differences in performance with respect to accuracy a 2 (Production: Aloud vs. Silent) x 5 (Subtrial: 1-5) repeated measures ANOVA was completed for accuracy on the secondary task. The main effect of Production, main effect of Subtrial and the Production x Subtrial interaction were all non-significant, all ps > .095. Follow up paired sample t-tests were completed for aloud and silent trials within each of the subtrials and showed no significant differences between any of the five subtrial pairs, all ps > .26. Lastly an a priori analysis was completed to test if accuracy varied while the trials word was present (subtrials 3 and 4) as compared to all other subtrials (1, 2, & 5), this analysis showed no significant difference in performance when the word is present versus when the word is absent, *t* (95) = 1.97, *p* = .052, *d* = .406, although it did approach significance. A post hoc analysis of power was completed, 1-β = 0.504, suggesting we did not have enough power to accurately measure this effect.

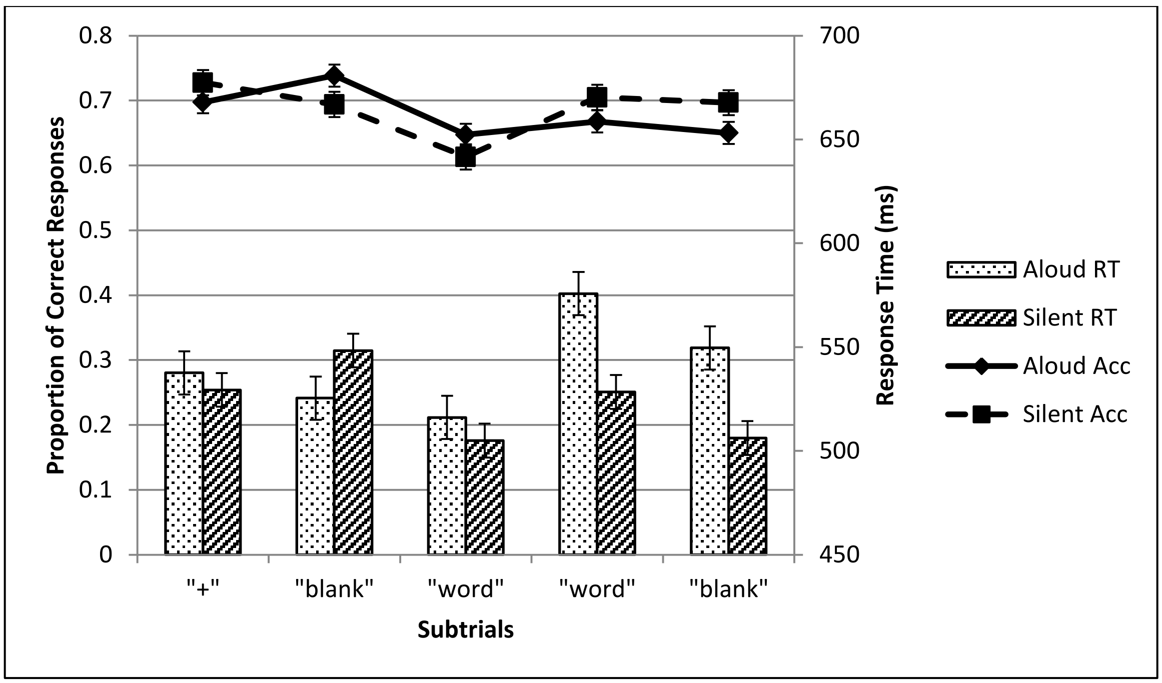

Figure 3. Proportion of correct responses and mean response time (in milliseconds) in the localization task for Aloud and Silent trials across study phase subtrials 1-5. Error bars show the standard errors of the means.

The same set of analyses was completed for the response time performance within the subtrials of the Divided Attention at Encoding condition. The same trend was exhibited for response times as accuracy, no significant main effect of production or position and no significant production x position interaction, all *p*s > .12. Follow up paired t-tests showed no difference in reaction time performance across any of the five subtrials between aloud and silent trials, all *p*s > .08. The contrast between subtrials containing a word (subtrials 3 and 4) and all other subtrials (1, 2, and 5) was also not significant, t (95) = .65, p = .515.

An analysis of the potential differences in secondary task performance between aloud and silent trials was not completed for Divided Attention at Test because participants recalled studied items in a self-directed order at their own pace. In addition to the very small number of trials that would be included in this condition, associating performance to aloud versus silent trials was not possible to do in a sensible manner. However, overall secondary task performance can be assessed for both accuracy and response times. Overall accuracy on the secondary task averaged .76 (SD = .18), and average response time was 525 ms (SD = 61).

Discussion

The results of Experiment 2 showed a significant production effect in two of the three conditions; Full Attention and Divided Attention at Encoding. A strength account predicts that the benefit in memory for aloud items occurs as a result of the increased memory strength associated with these items relative to silent items, a process which requires no attentional effort. Therefore the presence of a production effect when attention is divided during study provides support for this theory. This result also supports a distinctiveness account which predicts that dividing attention at encoding will not prevent a production effect from occurring because the encoding of the additive distinctive information associated with aloud items is a process that does not require purposeful attention.

The Divided Attention at Test condition was the only condition in Experiment 2 in which a production effect was not observed, a result that may have occurred as a result of the low overall recall exhibited in this condition. In the Divided Attention at Encoding condition a production effect was found, despite this condition having significantly lower overall recall than Full Attention and Divided Attention at Test. Therefore it is unlikely that the absence of a production effect within the Divided Attention at Test condition is a result of poor overall recall performance, although it is possible that the greater variability in this group may have contributed to the null result. The absence of a production effect within this condition also did not occur as a result of lack of effort as recall duration was longer in this condition than the other two conditions. By a strength account we would predict that a production effect would be evident as dividing attention at test does not reduce the memory strength for the aloud items that results in the production effect; this hypothesis was not supported by the current results. The absence of a production effect instead suggests that a distinctiveness account provides the better explanation of this phenomenon. Recall of the produced items is based upon the recollection of the contextual details, aloudness information, associated with these items. Dividing attention at test disrupts the ability to actively monitor and search their memory for these details resulting in a failure to recall the aloud items. This disruption of attentional resources resulted in no benefit for the aloud items in the Divided Attention at Test condition, thus supporting the distinctiveness theory.

General Discussion

The present set of experiments was completed to understand the role of purposeful attention in the production effect, as well as to determine whether attentional resources are required during encoding, and at test, in order for a production effect to occur. When attention is divided during encoding attentional resources available to the participant to actively engage in and encode the material presented to them are reduced. If the removal of these resources causes a reduction or elimination of the benefit associated with produced items then it can be concluded that one must actively encode this additional information. Alternatively if divided attention at encoding has no consequences with respect to the production effect then it can be concluded that this process occurs relatively automatically without the need of attentional resources, a prediction made by both the distinctiveness and strength account. Similarly, at test, the effects of divided attention allow us to determine whether active retrieval is required to recall the distinctive information associated with aloud items. If disrupting retrieval efforts by completing a secondary task eliminates the production effect, then this will support the distinctiveness account, which states that one must actively monitor memory for the additional encoded elements associated with produced items. In contrast, if dividing attention at test results in no disruption to the benefits associated with aloud items, then it can be assumed that memory strength underlies the production effect, as this theory states that direct attentional resources are not required at tests, memory judgements are derived from item strength and not an additional element associated with one word type and not the other.

When participants are asked to complete a secondary task it has been consistently shown that this added tasks results in worse memory performance relative to other participants who complete the task under full attention, with a larger reduction in overall memory performance when attention is divided at encoding as compared to at test (Naveh-Benjamin & Guez, 2000). This predicted trend was observed in Experiment 1 when a recognition memory test was used. However, in Experiment 2, when a free recall test was implemented, overall memory performance was equivalent in the Full Attention and Divided Attention at Test conditions with both significantly outperforming the Divided Attention at Encoding condition. The absence of a main effect of divided attention in Experiment 2 may have occurred as a result of the test phase being self-directed. Having control over the output of information at test could have potentially allowed for more task sharing between the main and secondary task, in contrast to the experimentally driven test phase within Experiment 1 that resulted in a main effect of divided attention. It is suggested that future research investigating the role of divided attention at test use a self-paced recognition memory test to control for task sharing biases.

In both experiments a significant production effect was observed under Full Attention and Divided Attention at Encoding. In the Divided Attention at Encoding conditions, an analysis of potential differences in secondary task performance, between trials in which an item was read aloud and trials in which an item was read silently, was completed for both accuracy and reaction time. For both Divided Attention at Encoding conditions no differences were observed in accuracy or reaction time between aloud and silent trials. When attention was divided at test a recognition memory benefit was observed for aloud items relative to silent items (Experiment 1). However, when participants engaged in free recall (Experiment 2) under divided attention the benefit for aloud items over silent items was no longer evident.

The presence of a production effect in both Full Attention conditions supports the idea that produced items are remembered better than items not produced (read silently) on future memory test. This same pattern was also observed in the Divided Attention at Encoding conditions in both experiments. Furthermore no differences were observed in the accuracy or reaction time between silent and aloud trials in either of the Divided Attention at Encoding conditions suggesting that participants are not neglecting the secondary task when asked to produce an item; instead they are using the same amount of attentional resources when producing an item as they are when they read an item silently. The presence of a production effect in these conditions, coupled with the secondary task information suggests that the distinctive information associated with producing an item is encoded relatively automatically and does not require purposeful attention.

Further support for the automaticity associated with the encoding of the distinctive information was observed in an unpublished study (Slaney, 2013) that investigated the role of divided attention at encoding for a recognition memory test. Slaney (2013) found a significant production effect under divided attention at encoding. Taken together these results support both a strength account and a distinctiveness account of production as both theories predict that the benefit associated with aloud items, whether a distinctive aspect or its increased memory strength, occurs automatically during encoding.

Despite the valuable insight gained from the Full Attention and Divided Attention at Encoding conditions of both experiments the debate between the two accounts of the production effect remains as the theories predict the same outcome. However when attention is divided at test two contrasting predictions are made: a distinctiveness account predicts an absence of a production effect as a result of the disruption in the ability to recall the distinctive information associated with aloud items (cf. Ozubko & MacLeod, 2010), whereas a strength account predicts a production effect based on the stronger memory traces formed for aloud words during encoding (Bodner & Taikh, 2012). Participants in Experiment 1 exhibited a recognition benefit for the produced items over the silent items when attention was divided at test, suggesting that their recognition judgements of old and new may be based on the strength of their memory trace rather than the retrieval of the distinctive information associated with the produced items. A distinctiveness account should not be entirely ruled out as the possibility exists that individuals were making recognition judgements based upon familiarity, a more automatic process. Completion of a secondary task would disrupt the participants' ability to recall the aloudness information associated with produced items as this requires attention effort, however if participants are using familiarity with the presented items to make their judgements than a production effect would still be observed as production has previously been shown to increase the familiarity of produced items (Ozubko, Gopie, & MacLeod, 2012).

When attention was divided during free recall (Experiment 2) the benefit for produced items over silent items was no longer evident. This absence of a production effect suggests that participants were unable to actively monitor their memories for the distinctive information associated with the produced items, suggesting that a distinctiveness account best explains the production effect. With respect to the strength account it appears that the stronger memory trace formed for aloud words at encoding is not enough to produce a benefit for these items at test when attentional resources are occupied by a secondary task. It is possible that a stronger memory trace for the aloud items is present, however the attentional resources required to evaluate this strength are not available as a result of the secondary task demands. For both accounts attentional resources are required to complete the controlled process of evaluation or recollection of distinctive information. Therefore completion of a secondary task disrupts these controlled processes resulting in the absence of a production effect. It is important to note that these results should be taken with some caution as the divided attention manipulation did not result in significantly worse memory performance in the Divided Attention at Test condition compared to Full Attention.

This pattern of results may have occurred as the result of the experimental set-up which had participants study a large list of items, 80 in total, before completing a subsequent free recall memory test. The large study list resulted in extremely low overall memory performance (all conditions recalling less than 25% of studied items) thereby restricting the range of possible differences in memory performance between the three conditions. Although the current study used a common study phase length for both recognition and free recall it is suggested that future research attempt to replicate these results using shorter study list to reduce the likelihood of floor effects.

In two experiments the role of purposeful attention, at encoding and at test, was evaluated in an effort to understand more thoroughly the production effect and why it occurs. The presence of a production effect in both Full Attention conditions and both Divided Attention at encoding conditions supports the existence of a benefit in memory for produced items relative to items read silently, as well as the implication that this benefit is encoded relatively automatically: support for both a distinctiveness and strength account of the production effect. When attention was divided at test two different results emerged. For recognition, a production effect remained, suggesting participants maybe relying upon memory strength rather than the retrieval of the “aloudness” information associated with aloud items. When a free recall test was utilized the benefit for aloud items was no longer present, suggesting a possible disruption in the retrieval of the additional distinctive cue or a disruption in one’s ability to evaluate memory strength. Taken together the results from this preliminary investigation of the effects of divided attention cannot conclusively determine whether a strength account or a distinctiveness account is the better explanation for why saying a word aloud results in better memory performance than reading an item silently.

A third theoretical explanation of the production effect is possible given the present observed results; the production effect may not be described exclusively by either a distinctiveness or a strength account, rather it is a combination of both that results in the better memory for produced words. Production has been previously shown to increase the familiarity and recollection of produced items (Ozubko, Gopie, & MacLeod, 2012), and each of these processes may be disrupted to different degrees for the recognition and free recall test. It is possible that individuals rely on the strength of items in memory when making test decisions under less cognitively demanding test scenarios, a result supported by Experiment 1 that used a recognition memory test. However under more difficult testing conditions, as in Experiment 2 with free recall, memory strength may not be sufficient enough to result in a benefit for recalling the produced items. Under these conditions individuals may additionally attempt to recollect the aloudness information associated with the produced items before recalling an item.

Conclusion

In an attempt to understand the role of attentional resources associated with the encoding and retrieval of produced items, as well as attempting to distinguish between two theoretical accounts of the production effect, the current research was implemented. The results suggest that the "aloudness" information, associated with an improvement in later memory for produced items, is encoded relatively automatically, not requiring the use of attentional resources to intentionally encode this information, illustrated by the presence of a production effect within both recognition and free recall memory test, even when attention was divided by the completion of a secondary task.

The results of the current studies suggest that the aloudness information associated with produced items is adding a distinctive cue to those items that individuals are attempting to retrieve at test. This explanation is most clearly supported by the disruption in the retrieval processes of this cue when attention is divided at test for the more attentionally demanding free recall. Under less attentionally demanding testing, as with a recognition test, memory is more contextually supported therefore disrupting attentional resources does not lead to an absence of a production effect. If the act of producing an item simply improved its memory strength than it is unclear as to why they would not be more easily retrieved in free recall, even when attention is divided.

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