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Evaluating the Evidence for a Dissociation Between Speech and
Emotion Effects in Short-Term Memory

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Abstract

Performance in visual serial recall tasks is often impaired by irrelevant auditory distracters. The duplex-mechanism account of auditory distraction states that if the distracters provide order cues, these interfere with the processing of the order cues in the main task (interference by process). In contrast, the attention-diversion account states that distracters capture only attention on a general level without interfering specifically with order processing. Marsh et al. (2018, *Journal of Experimental Psychology-Learning Memory and Cognition*, 44, 882-897) reported finding a dissociation between the effects of serial recall tasks and those of a missing-item task on the disruptive effects of speech and of emotional words, as predicted by the duplex-mechanism account. Critically, the reported analyses did not test specifically for this dissociation. To address this issue, I re-analyzed the Marsh et al. data and added Bayesian hypothesis tests to measure the strength of the evidence for a dissociation. Results provided strong evidence for a dissociation. Because the duplex-mechanism account predicts this dissociation whereas the attention-diversion account does not, Marsh et al.'s data support the duplex-mechanism account. Accordingly, impairment on serial recall tasks by auditory distracters results from interference by process and from attentional diversion.

Keywords: short-term memory, irrelevant speech, serial STM, serial recall, auditory distraction

The ability to remember the order of events, which is critical for short-term memory, is commonly tested with serial recall tasks. For example, participants are shown individual digits at a rate of one per second and are then asked to recall the correct order of the digits. The *irrelevant speech effect* refers to the observation that irrelevant speech or other sounds presented during the task impair recall performance (for review, see Ellermeier & Zimmer, 2014). One prominent explanation for this effect is the duplex-mechanism account (Hughes, 2014; Hughes, Vachon, & Jones, 2007): If the irrelevant sounds change over time, they provide order cues that are processed automatically. These order cues interfere with the processing of the order cues in the serial recall task (interference by process). In addition, interference can be caused by attentional diversion (Cowan, 1995): The irrelevant sounds capture attention, and this attentional diversion away from the serial recall task causes the task impairment. According to the duplex-mechanism account, task impairment results from interference by process and from attentional diversion. In contrast, according to the attention-diversion account, task impairment results only from attentional diversion.

In support of the attention-diversion account of the irrelevant speech effect, recent studies found that the content of speech (i.e., its postcategorical properties) can disrupt performance in serial recall. For example, recall performance is disrupted more by emotional words than neutral words (Buchner, Mehl, Rothermund, & Wentura, 2006; Buchner, Rothermund, Wentura, & Mehl, 2004), by taboo words than neutral words (Röer, Korner, Buchner, & Bell, 2017), and by own names than control names (Röer, Bell, & Buchner, 2013). However, these findings do not necessarily demonstrate that auditory distraction in serial recall can be caused only by attentional diversion. Both interference by process and attentional diversion may disrupt recall performance. If so, it should be possible to dissociate these disruptive effects.

In a clever study, Marsh et al. (2018) reported finding a dissociation between the effects of different tasks on the disruptive effects of speech and of emotional words. The authors

concluded that because this dissociation is predicted only by the duplex-mechanism account, their findings support this account.

To support the claim of a dissociation, the authors conducted analyses with ANOVAs and follow-up t tests in the tradition of null hypothesis significance testing (Perezgonzalez, 2015; Szucs & Ioannidis, 2017; Wiens & Nilsson, 2017). Critically, the analyses did not test specifically for a dissociation between task effects on speech and on emotion. To address this issue, I re-analyzed the Marsh et al. data, which the authors kindly shared with me. In addition, I performed Bayesian hypothesis tests to measure the strength of evidence for a dissociation. All scripts, analyses, figures, and additional material are available via OSF (Wiens, 2018).

In the Marsh et al. (2018) study, participants performed a serial recall task with digits that were easy to read (*low load*), a serial recall task with digits that were difficult to read (*high load*), and a missing-item task. In the missing-item task, participants were presented with series of eight different digits in random order (as in serial recall), and at the end of each trial, they had to report which digit from the 1-9 range was missing from the series. Thus, digit order did not have to be processed to perform the missing-item task. Auditory distracters were presented simultaneously with the digits. The distracters were words that were drawn from the following categories: neutral, positive, negative, and quiet (i.e., no sound). Because neutral words were not emotional, they were used to capture the effect of speech per se (speech effect), with quiet as the control condition. Neutral, negative, and positive conditions were used to capture the effect of emotion (emotion effect). Note that whereas Marsh et al. refer to a valence effect, I prefer the term emotion effect because the goal was to show that the effects of emotional words (positive and negative) differed from the effects of neutral words.

Marsh et al. (2018) argued that according to the duplex-mechanism account, the speech effect should be larger during the serial recall tasks (low and high load) than during the

missing-item task. The reason is that interference by process should occur during the serial recall tasks but not during the missing-item task, because digit order is irrelevant to the missing-item task. Further, the emotion effect should be smaller during a serial recall task with high load (when digits are difficult to read) than during a serial recall task with low load or a missing-item task. The reason is that attentional diversion should be reduced during high load, because participants direct their attention more to digits that are difficult to read.

In the first experiment in Marsh et al.'s study (2018), participants performed a serial recall task on digits (from the set of 1 to 8) while an auditory distracter was presented simultaneously with each digit. For one group of participants, the digits were clearly visible (low load), whereas for the other group, they were difficult to read because the digits were embedded in random visual noise (high load). For each trial, the auditory distracters were drawn from neutral, positive, negative, and quiet (although there were two content categories each for positive and negative, these were merged by Marsh et al. on the basis of preliminary analyses). Figure 1a shows the mean proportion correct for the four sound categories for both low and high load in the serial recall task. Note that the figure also includes the mean proportion correct for the missing-item task of the second experiment.

Figure 1. Mean proportion correct of the Marsh et al. (2018) data for the serial recall task with low load (SR-low), the serial recall task with high load (SR-high), and the missing-item task (MI) for the four sound conditions (a) and for speech and emotion (b). In (b), speech was the difference of quiet minus neutral (neu), and emotion was the difference of neutral minus combined positive (pos) and negative (neg). The error bars denote the 95% CIs for each individual mean.

Proportion-correct data from the first experiment were analyzed in a 2×4 mixed ANOVA with load (low or high load during serial recall) as a between-subjects variable and sound (quiet, neutral, positive, and negative) as a within-subjects variable. Within the framework of null hypothesis significance testing (Perezgonzalez, 2015; Szucs & Ioannidis, 2017; Wiens & Nilsson, 2017), the authors interpreted a significant finding ($p < .05$) as evidence for an effect (thus, significant refers to statistically significant). Because the overall interaction was significant ($p = 0.031$ after Greenhouse-Geisser correction), the authors interpreted this as evidence that high load (vs. low load) had a different effect on speech than on emotion.

Next, the authors conducted follow-up tests to separately assess load effects on speech and on emotion. For speech, results showed no significant interaction between load (low and high) and sound (quiet and neutral), $p = .90$. For emotion, results showed that for low load, proportion correct decreased significantly ($p < .05$) from neutral to positive and from positive to negative, whereas for high load, proportion correct did not differ significantly among the sound conditions. According to the authors, these results support a dissociation: Whereas high load had no effect on the speech effect (quiet vs. neutral), it reduced the emotion effect (performance difference among neutral, positive, and negative).

The reported analyses are commonly used and have intuitive appeal. However, they are not specific enough to support a claim for a dissociation (Wiens & Nilsson, 2017). The critical question is whether high load (vs. low load) affects the speech effect (quiet vs. neutral) less strongly than the emotion effect (neutral vs. combined positive and negative). On the one hand, the overall interaction in the 2×4 ANOVA should be sensitive to this difference. On the other hand, the overall interaction is unspecific. With its 3 *dfs*, the interaction can be conceptualized as representing a combination of three orthogonal (i.e., statistically independent) contrasts at the same time (Wiens & Nilsson, 2017). Accordingly, the interaction may be significant because of effects that are irrelevant to the critical question.

To illustrate this point, I simulated data for a 2×4 factorial design that was similar to that of the first experiment in Marsh et al. (2018). In the simulation, low load had a large and identical effect on speech and emotion whereas high load had a small and identical effect on speech and emotion. Figure 2a shows the means for the simulated data, and Figure 2b shows difference scores that isolate effects on speech and emotion. The speech effect is the difference of quiet minus neutral, and the emotion effect is the difference of neutral minus combined positive and negative.

Figure 2. Mean proportion correct of simulated data for the serial recall task with low load (SR-low) and the serial recall task with high load (SR-high) for the four sound conditions (a) and for speech and emotion (b). In (b), speech was the difference of quiet minus neutral (neu), and emotion was the difference of neutral minus combined positive (pos) and negative (neg). The error bars denote the 95% CIs for each individual mean.

Critically, the overall (3-*df*) interaction in the 2×4 ANOVA of the means was significant ($p < .001$), but the specific (1-*df*) interaction in the 2×2 ANOVA of the difference scores was not ($p = 1$). This simulation shows that an overall interaction in the 2×4 ANOVA does not necessarily support the claim that the load effect differs between speech and emotion. Therefore, it is unclear whether the significant interaction in the first experiment in Marsh et al. shows that the load effect differed between speech and emotion.

Further, although Marsh et al. also conducted separate follow-up tests for the speech effect and the emotion effect, the results do not resolve whether the two effects differed from each other. In fact, the finding of a nonsignificant effect in one condition and a significant effect in

the other condition does not imply that the two conditions differed significantly from each other (Gelman & Stern, 2006; Nieuwenhuis, Forstmann, & Wagenmakers, 2011).

Accordingly, the difference between the (nonsignificant) speech effect and the (significant) emotion effect needs to be tested explicitly.

I re-analyzed the Marsh et al. (2018) data to conduct the critical analyses. To simplify them, I computed difference scores to capture the speech effect and the emotion effect, as described above. Figure 1b shows the difference scores for low and high load. In a 2×2 ANOVA of proportion correct with load (low and high) as a between-subjects variable and condition (speech and emotion) as a within-subjects variable, the interaction was not significant, $p = 0.160$. At face value, this result does not support the claim of a dissociation between the effects of low and high load on the disruptive effects of speech and of emotional words. Specifically, the load effect does not appear to be smaller on speech than on emotion.

The set-up in the second experiment resembled that in the first experiment (Marsh et al., 2018). That is, series of eight digits were shown while an auditory distracter was presented simultaneously with each digit. The categories of the auditory distracters were quiet, neutral, positive, and negative. In contrast to the first experiment, however, participants performed a missing-item task rather than a serial recall task. After each trial, they had to indicate which digit (from the range of 1 to 9) was missing from the series of digits. Figure 1a shows the mean proportion correct for each task and condition. To show that the speech effect differed between the serial recall task with low load and the missing-item task, the authors conducted an ANOVA of proportion correct with task (serial recall task with low load and missing-item task) as a between-subjects variable and sound (quiet and neutral) as a within-subjects variable. The interaction in this 2×2 ANOVA was significant, $p = 0.008$. To show that the emotion effect did not differ between the serial recall task with low load and the missing-item

task, the authors conducted an ANOVA with task and sound (neutral, positive, and negative). The interaction in this 2×3 ANOVA was not significant, $p = 0.076$.

According to Marsh et al., these findings provide evidence for a dissociation between the different tasks' effects on speech and emotion. Whereas the speech effect decreased from the serial recall task with low load to the missing-item task, the emotion effect was apparently unaffected. However, as described above, the critical question is whether the task effects differed between speech and emotion, and this question is not addressed by showing that one effect varied significantly with the task whereas the other did not (Gelman & Stern, 2006; Nieuwenhuis et al., 2011). Instead, the difference between task effects on speech and on emotion needs to be tested explicitly.

To conduct this critical analysis, I computed difference scores from the Marsh et al. (2018) data (see Figure 1b). In a 2×2 ANOVA of proportion correct with load (low load in the serial recall task and missing-item task) as a between-subjects variable and condition (speech and emotion) as a within-subjects variable, the interaction was significant, $p = 0.011$. This result supports the claim for a dissociation between task effects on speech and on emotion. Specifically, task effects were smaller on emotion than on speech.

Finally, I determined whether effects on speech and emotion differed between the serial recall task with high load and the missing-item task. Although the original study did not address this question directly, it is important to do so because the duplex-mechanism account predicts a strong dissociation between speech and emotion effects. Because interference by process should occur mainly in the serial recall task, the speech effect should decrease from the serial recall task with high load to the missing-item task. Conversely, because attentional diversion should be reduced during high load, the emotion effect should increase from the serial recall task with high load to the missing-item task. Indeed, in a 2×2 ANOVA of proportion correct with load (high load and missing-item task) as a between-subjects variable

and condition (speech and emotion) as a within-subjects variable, the interaction was significant, $p < 0.001$. Follow-up t tests confirmed that the speech effect decreased from the serial recall task with high load to the missing-item task (mean difference of high load minus missing-item task = 0.061, 95% CI [0.01, 0.11], $p = .011$). Conversely, the emotion effect increased from the serial recall task with high load to the missing-item task (mean difference of high load minus missing-item task = -0.062 , 95% CI [-0.09 , -0.03], $p < .001$). The results of this additional analysis clearly support the claim of a dissociation between the effects of the serial recall task with high load and the missing-item task on speech and on emotion. Specifically, the two tasks' effects were in opposite directions for speech and emotion.

Bayesian hypothesis tests

Within the framework of null hypothesis significance testing, the re-analyses of the Marsh et al. (2018) data provided evidence for a dissociation between different tasks' effects on speech and emotion. For the ANOVAs of the difference scores, significant findings ($p < .05$) suggest that speech and emotion effects differ between the serial recall task with low load and the missing-item task, and between the serial recall task with high load and the missing-item task, but not between the two levels of load in the serial recall task.

Although null hypothesis significance testing can provide evidence against the null hypothesis, it is limited because it cannot measure the strength of evidence for the alternative hypothesis (Dienes & McLatchie, 2018; Szucs & Ioannidis, 2017; Wagenmakers, 2007). In contrast, Bayesian hypothesis testing allows one to distinguish among data that support the alternative hypothesis, support the null hypothesis, or are inconclusive (Dienes, 2008, 2016; Wagenmakers, Love, et al., 2018; Wagenmakers, Marsman, et al., 2018; Wagenmakers, Morey, & Lee, 2016; Wiens & Nilsson, 2017). In Bayesian hypothesis tests, the Bayes factor (BF) compares the likelihood of the data given the null hypothesis with the likelihood of the data given an alternative hypothesis. Because the BF provides a continuous measure of the

strength of evidence, I computed the BF to measure the evidence for or against a dissociation between task effects on speech and on emotion. According to a common classification scheme, $3 > \text{BF} > 1$ is considered anecdotal (or inconclusive) evidence, $10 > \text{BF} > 3$ is considered moderate evidence, and $30 > \text{BF} > 10$ is considered strong evidence (Wagenmakers, Love, et al., 2018).

The first analysis examined whether the load effect in the serial recall task is smaller on speech than on emotion. According to the duplex-mechanism account (Marsh et al., 2018), high load (vs. low load) reduces interference by process less strongly than attentional diversion. If so, the load effect should be smaller for speech than for emotion. As shown in Figure 1b, the difference scores in the Marsh et al. data are consistent with this claim. The mean difference in proportion correct of low load minus high load was 0.038 for emotion (i.e., the distracting effect of emotion was larger during low load than during high load) but was almost zero for speech (-0.003). To compute the BF, the observed emotion effect (i.e., 0.038) was used to define the alternative hypothesis.

I used three different alternative hypotheses to assess the robustness of the results, as recommended (Dienes, 2014; Dienes & McLatchie, 2018) and as used in previous research in my lab (Ströberg, Andersen, & Wiens, 2017; Wiens, Szychowska, Eklund, & van Berlekom, 2018). For the *uniform* distribution, the true effect was supposed to fall between 0 and 0.038, and all values were equally likely. For the *half-normal* distribution, the true effect was modeled as a half-normal with a mean of zero and a standard deviation of 0.038. Accordingly, the true effect was supposed to be greater than zero and more likely to be less than 0.038 than to be greater. For the *data-driven t* distribution, the true effect was modeled as a *t* distribution as defined by the observed emotion effect (Dienes & McLatchie, 2018). For these three analyses, $\text{BF}_{01} = 1.69$ for the uniform, $\text{BF}_{01} = 2.27$ for the half-normal, and $\text{BF}_{01} = 4.55$ for the data-driven *t* distribution. The $\text{BF}_{01} = 4.55$ indicated that the data are about 4.5 times

more likely under the null hypothesis than the alternative hypothesis. Although the BF is a continuous measure, a $BF > 3$ provides moderate evidence according to a common classification (Wagenmakers, Love, et al., 2018). Accordingly, the $BF_{01} = 4.55$ provides moderate evidence that the speech effect was smaller than the emotion effect, which was used to define the alternative hypothesis. However, because for the other alternative hypotheses the BF_{01} was less than 3 (1.69 and 2.27) and thus was inconclusive, the results do not appear robust. In sum, the evidence that load has a smaller effect on speech than on emotion is mainly inconclusive.

The second analysis examined whether the effect of the missing-item task versus the serial recall task with low load is smaller on emotion than on speech. According to the duplex-mechanism account (Marsh et al., 2018), the missing-item task (vs. the serial recall task with low load) reduces attentional diversion less strongly than it reduces interference by process. The reason is that attentional diversion should be similar in both tasks, whereas interference by process should be smaller during the missing-item task than the serial recall task with low load, because the order of the digits is irrelevant for the missing-item task. In support, the difference scores in the Marsh et al. data suggest that the task effect was smaller on emotion than on speech (see Figure 1b). The mean difference of proportion correct in the serial recall task with low load minus the missing-item task was 0.058 for speech (i.e., the distracting effect of speech was larger during low load than during the missing-item task) and was close to zero for emotion (-0.024). To compute the BF, the observed speech effect (i.e., 0.058) was used to define the alternative hypothesis. For the three different alternative hypotheses, the BF_{01} ranged between 7.14 (for uniform) and 50 (for data-driven t). Because these results provide at least moderate support for the null hypothesis, they suggest that the effect of the missing-item task versus the serial recall task with low load was smaller on emotion than on speech.

The third analysis examined whether the effect of the serial recall task with high load versus the missing-item task is smaller on emotion than on speech. Although this difference was not explicitly tested by Marsh et al. (2018), the duplex-mechanism account predicts a strong dissociation, as described above. The emotion effect should be smaller in the serial recall task with high load than in the missing-item task, because attentional diversion is smaller during high load when participants attend more to the digits that are difficult to read. In contrast, the speech effect should be larger in the serial recall task with high load than in the missing-item task, because interference by process is reduced in the missing-item task. The difference scores in the Marsh et al. data are consistent with this prediction (see Figure 1b). The mean difference of high load in the serial recall task minus the missing-item task was 0.061 for speech (i.e., the distracting effect of speech was larger during high load than during the missing-item task) and was in the opposite direction for emotion (-0.062). To compute the BF, the observed speech effect (i.e., 0.061) was used to define the alternative hypothesis. For the three alternative hypotheses, the BF₀₁ ranged between 12.5 (for uniform) to 16.7 (for half-normal). Because these results provide strong support for the null hypothesis (Wagenmakers, Love, et al., 2018), they support the claim that the effect of the serial recall task with high load versus the missing-item task differed between emotion and speech.

Conclusion

These re-analyses of the Marsh et al. (2018) data constitute critical tests of the claim that task effects on speech and on emotion are dissociated. Although all analyses are relevant, the most important analysis is that of the differences between the serial recall task with high load and the missing-item task. The duplex-mechanism account predicts a clear dissociation between these task's effects on speech and on emotion. Because interference by process should be greater during the serial recall task with high load than during the missing-item task, the speech effect should be larger during high load than during the missing-item task.

Conversely, because attentional diversion should be less during the serial recall task with high load than during the missing-item task, the emotion effect should be smaller during high load than during the missing-item task. In support, null hypothesis significance tests suggested that the task effect differed between speech and emotion (as $p < .001$), and that the task effect on speech ($p = .011$) was opposite to that of the task effect on emotion ($p < .001$). Further, Bayesian hypothesis tests provided strong evidence ($16.7 > BF > 12.5$) that the task effect differed between emotion and speech. Taken together, the present re-analyses confirmed that Marsh et al. were correct in their initial claim: Their data provide strong evidence for a dissociation between the task effect on speech and the task effect on emotion.

The re-analyses of the Marsh et al. (2018) data confirm and extend previous reports of an apparent dissociation between interference by process and attentional diversion (Elliott et al., 2016; Hughes, Hurlstone, Marsh, Vachon, & Jones, 2013; Kattner & Ellermeier, 2018). However, these studies relied on the framework of null hypothesis significance testing. Although this framework has a long tradition in psychology (Cumming, 2014; Perezgonzalez, 2015; Szucs & Ioannidis, 2017; Wiens & Nilsson, 2017), a statistically significant finding does not necessarily imply that the data support the alternative hypothesis, because the alternative hypothesis is not made explicit (Dienes, 2016; Wagenmakers, Marsman, et al., 2018). For example, a hypothetical study may find that the task effect is significantly smaller on emotion (0.15) than on speech (0.18). Although this implies that the task effects differ (i.e., the difference is not nil), the difference may seem too small to be theoretically important. In the present re-analyses within a Bayesian framework, the task effect on one type of stimulus (e.g., speech) was used as a reasonable estimate of the task effect on the other type of stimulus (e.g., emotion). Thus, the present findings extend previous reports because they provide a direct measure of the strength of evidence for the idea that interference by process can be dissociated from attentional diversion.

Because the duplex-mechanism account predicts dissociations between effects of task on different types of auditory distractors whereas the unitary, attention-diversion account does not, Marsh et al.'s data support the duplex-mechanism account. Accordingly, impairment on serial recall tasks results from interference by process and from attentional diversion.

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