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ABSTRACT

Decades of research attest that memory processes suffer under conditions of auditory distraction. What is however less well understood is whether people are able to modify how their memory processes are deployed in order to compensate for disruptive effects of distraction. The metacognitive approach to memory describes a variety of ways people can exert control over their cognitive processes to optimize performance. Here we describe our recent investigations into how these control processes change under conditions of auditory distraction. We specifically looked at control of encoding in the form of decisions about how long to study a word when it is presented and control of memory reporting in the form of decisions whether to volunteer or withhold retrieved details. Regarding control of encoding, we expected that people would compensate for disruptive effects of distraction by extending study time under noise. Our results revealed, however, that when exposed to irrelevant speech, people curtail rather than extend study. Regarding control of memory reporting, we expected that people would compensate for the loss of access to memory records by volunteering responses held with lower confidence. Our results revealed, however, that people's reporting strategies do not differ when memory task is performed in silence or under auditory distraction, although distraction seriously undermines people's confidence in their own responses. Together, our studies reveal novel avenues for investigating the psychological effects of auditory distraction within a metacognitive framework.

INTRODUCTION

Auditory distraction is ubiquitous in modern life, significantly affecting our cognitive performance. One area in which impact of auditory distraction has been investigated is memory. Perhaps not surprisingly, a significant body of research testifies to the fact that auditory distraction impairs memory performance. This has been established in memory tasks as diverse as serial recall of short bits of information, like letters or numbers (e.g., Beaman & Jones, 1997), as well as recall or recognition of more meaningful materials, ranging from lists of words (e.g., Jones, Marsh, & Hughes, 2012) to TED lectures (Zeamer & Fox Tree, 2013).

Auditory distraction seems to be a particularly hazardous to memory performance as by its very nature it is difficult to avoid. However, the metacognitive approach to investigating memory underscores that people always possess a degree of control over their memory performance as they can modify the encoding and retrieval operations. Thus, for example, people may decide how long they study, or how study trials are distributed in time. These decisions are known to affect memory performance (see Koriat, 2007, for a review). Similarly, at retrieval people may decide how long to search their memory for studied material or which of the retrieved detail to volunteer in a final report, again exerting control over memory performance. In the present paper, our initial investigations into how metacognitive control over encoding and retrieval is changed by the presence of auditory distraction will be presented.

ENCODING

The simplest way of exerting control over encoding operations is revealed by people's decisions on how long certain information is studied. Decades of research conducted within a metacognition framework of memory have revealed that people distribute study time among different study items in a purposeful way, aiming for maximizing memory performance (e.g., Mazzoni, Cornoldi, & Marchitelli, 1990). Given that distraction impairs memory, it can be hypothesized that if people were given freedom as to how long they wish to study, they would compensate for harmful effects of auditory distraction by extending study times.

Here we present two experiments that, to our knowledge, for the first time investigate study strategies people adopt in the face of auditory distraction. By providing people with free rein over study duration, we focus on how auditory distraction determines the latencies to terminate study for items people are asked to memorize. We assess whether people would try to compensate for auditory distraction by extending study. We also examine whether people are aware of the negative impact of auditory distraction on their memory performance, a precondition of strategic compensation for distraction, and how any potential changes in study times under distraction impact upon final memory performance.

In Experiment 1 participants were presented for study and immediate free recall with fifteen lists of categorized words, each list with fifteen different words (e.g., buffalo, lion, elephant, etc.) During study, the presence of auditory distraction was manipulated but all recall tests were performed in silence. There were three distraction conditions, defined by conditions of study. In the silent condition, for the one third of study lists, no auditory distraction was played. In the unrelated distraction condition, for another one third of study lists, auditory distraction was played which was semantically unrelated to studied items. In this condition, auditory distraction consisted of a stream of continuously spoken words belonging to a single semantic category that was different than the category used for the study list. Finally, in the related distraction condition, for the final one third of study lists, auditory distraction was played which was semantically related to studied items. This was achieved by using as auditory distracters, again played a continuous stream of spoken words, items that belonged to the same semantic category as studied items. Two different types of auditory distraction, semantically related and semantically unrelated to the material to be remembered, were used because earlier research revealed that auditory distraction is particularly harmful when related to items participants strive to memorize (Marsh, Hughes, & Jones, 2008). Thus, it was of interest if any pattern of change in metacognitive control revealed for the unrelated distraction condition would be exaggerated in the related distraction condition.

The outlined design is similar to previous investigations on auditory distraction in memory performance. The main change introduced here was that the rate of presentation of studied words was not controlled by experimenter but by participants. Specifically, participants were asked to press the spacebar to proceed to another word during the whole period of each study phase. The latencies to press the spacebar were recorded and constitute the main dependent measure examined here. An additional change in the procedure was that after each study list but before the free recall test for this list participants were asked to predict how many of the just studied 15 items they are likely to recall. This procedure is usually referred to as an aggregate judgment-of-learning and was introduced in order to assess whether participants perceive auditory distraction to be harmful to memory performance.

The results of Experiment 1 are presented in Table 1. First, the usual pattern of distraction effects on recall performance was replicated. Performance was clearly the best in the silent condition, worse in the unrelated distraction condition, $t(29) = 4.66$, $SE = .02$, $p < .001$, and still worse in the related distraction condition, a marginally significant effect, $t(29) = 2.00$, $SE = .01$, $p = .054$. Thus, despite the opportunity to regulate study times, auditory distraction still impaired memory performance, particularly if it was semantically related to memoranda. Second, participants' predictions of recall performance were sensitive to the deleterious effects of distraction, as participants clearly predicted that their recall will be better in the silent condition than in the unrelated distraction condition, $t(29) = 4.96$, $SE = .02$, $p < .001$. Predictions also were somewhat higher for the unrelated distraction than the related distraction condition, a marginally significant effect, $t(29) = 1.72$, $SE = .01$, $p = .097$, which also mirrors a difference in recall performance. Together, these results indicate that although participants were aware that distraction negatively impacts recall, they failed to compensate for this effect by extending study times. But did they even try to compensate? The analysis of study times revealed that participants studied longer in the silent condition than both in the unrelated distraction, $t(29) = 3.29$, $SE = 161$, $p = .003$, and the related distraction condition, $t(29) = 3.92$, $SE = 127$, $p < .001$, which did not differ, $t < 1$. Thus, not only participants did not try to compensate for distraction but they actually curtailed study when distraction was present.

Table 1: Proportion of recalled items, predictions converted to proportions, and study times in milliseconds in Experiment 1 and 2 (standard errors in parentheses).

Experiment	Distraction condition	Study times	Recall	Predictions	Study times
Experiment 1	Silent		.57 (.02)	.51 (.02)	2945 (319)
	Related		.46 (.02)	.40 (.02)	2416 (251)
	Unrelated		.48 (.02)	.42 (.02)	2447 (269)
Experiment 2	Silent	Free	.52 (.03)	.50 (.02)	2439 (238)
		Set	.53 (.02)	.49 (.02)	-
	Distraction	Free	.47 (.02)	.45 (.02)	2211 (197)
		Set	.49 (.02)	.44 (.02)	-

The results of Experiment 1 indicate that compensation by extended study is not a strategy participants adopt in the presence of auditory distraction. Instead, presented with auditory distraction – whether semantically related or unrelated to memoranda – participants actually accelerate the presentation of the study items. A plausible explanation for this effect is that participants try to limit their exposure to the continuously presented distracters. What Experiment 1 is however unable to answer is whether participants strategy of limiting study time bears upon recall performance. For this, the design would have to include a comparison group with set study times. Replicating the main results of Experiment 1 and examining the effects of changes in study times under distraction by comparing memory performance to a reference condition with set study times were the objectives for Experiment 2.

Experiment 2 compared silent and unrelated distraction conditions. Since the related distraction condition did not differ in terms of study times from the unrelated distraction condition in Experiment 1, it was dropped from the present investigation. The main change in Experiment 2 was that an additional condition was included in which all study words were presented for three seconds (the order of conditions was counterbalanced across participants). All participants performed the study-recall task in the free study times condition for 10 lists (five in the silent and five in the distraction condition) and the same task in the set study times condition for another 10 lists (again five in the silent and five in the distraction condition). In this set study times condition participants had no control over the rate of presentation of studied items.

The results of Experiment 2 are presented in Table 1. The analysis of study times in the free study time conditions revealed a pattern of results replicating the main finding of Experiment 1. Specifically, participants curtailed their study times when auditory distraction was present as compared to the silent condition, $t(29) = 2.32$, $SE = 98$, $p = .028$. The analysis of participants' predictions of recall with a 2 (distraction: silent vs. distraction) x 2 (control: free vs. set study times) ANOVA revealed only a significant main effect of distraction, $F(1, 29) = 30.21$, $MSE = .002$, $p < .001$, once again testifying to the fact that participants were aware of the harmful effects of auditory distraction. Most importantly, the analysis of recall performance with a similar 2 x 2 ANOVA revealed only a significant effect of distraction, $F(1, 29) = 13.96$, $MSE = .05$, $p = .001$. The interaction was not significant, $F < 1$, indicating that distraction impaired recall performance equally in the free and set study times condition. Thus, curtailing of study time under distraction that was observed in the free study time condition did not lead to an exaggerated impairment in free recall performance.

The results of both Experiment 1 and Experiment 2 suggests that contrary to the initial hypothesis, people do not try to compensate for harmful effects of distraction on memory performance by extending study when distraction is present. On the contrary, both experiments documented the opposite effect of shortening study under distraction. On the first blush, it seems that participants may behave maladaptive by studying shorter under more difficult conditions. However, Experiment 2 clearly shows that shorter study times in the setting used in our experiments do not harm memory performance. Thus, participants' behaviour under distraction can be called adaptive inasmuch as the same level of attainment was achieved in a shorter time.

RETRIEVAL

The common knowledge in the literature is that although memory can be easily improved at the time of encoding, there is not much one can do to improve it at the time of retrieval. For example, although longer study times are often found to improve memory performance, longer retrieval latencies usually fail to yield additional recalled information (Malmberg, 2008). From this perspective, it would seem that people will not have ways to alleviate distraction effects at the time of retrieval.

Despite bleak perspectives on aiding the process of retrieval itself, the metacognitive approach to memory shows that participants do possess means of regulating memory performance at the time of retrieval. This follows from the fact that the core memory process of retrieval is not the only factor determining memory performance. Indeed, memory performance is assessed based on an overt memory report, which is composed from details retrieved from memory but only these details people decide to disclose based on their metacognitive judgment. Put simply, to retrieve information is not enough to improve memory performance if this information is not volunteered in a memory report.

Koriat and Goldsmith (1996) proposed a metacognitive framework of strategic regulation of memory accuracy, which describes the processes by which people assess the validity of retrieved information and decide which details should be volunteered and which should be withheld. According to this framework, when information is retrieved from memory, a variety of clues are used to assess confidence that this information is correct (see Koriat, 1997, for a typology of clues). The next step comes when confidence in accuracy of retrieved information is compared to a criterion level of confidence that warrants volunteering of information in a memory report. In this framework, the accuracy of a memory report for which withholding of information is allowed (i.e., people may respond ‘don’t know’ to a memory question) depends on number of factors of which most prominent are: a) accuracy of memory retrieval, b) accuracy of metacognitive monitoring – that is the extent to which correct retrieved details are associated with higher levels of confidence than incorrect retrieved details, c) criterial level of confidence (a report criterion), d) general level of confidence in the retrieved details.

The Koriat and Goldsmith (1996) framework can be applied to understanding memory reporting under distraction. Even though people may not be able to improve retrieval under distraction, they could nevertheless be able to modify metacognitive processes in such a way as to mitigate or at least alter the effects of distraction. A recent study on auditory distraction conducted by Perfect, Andrade, and Eagan (2011) demonstrates how this may occur. In this study it was found that under conditions of auditory distraction at test, people report the same volume of correct information as in the silent condition, but they also report markedly more incorrect details. This is a reversal of a usual pattern in which people report fewer correct details under distraction (e.g., Marsh et al., 2008) and it may indicate that participants in the study by Perfect et al. adopted a more liberal report criterion under auditory distraction.

The experiment described here addressed the issue of metacognitive regulation of memory reporting under auditory distraction. It was examined how auditory distraction affects the accuracy of metacognitive monitoring at retrieval as well as the placement of a report criterion. The memory and metamemory processes were examined in the procedure including free-report recognition test, which allowed for ‘don’t know’ responding, forced-report recognition test, which disallowed ‘don’t know’ responding and a confidence judgement phase (for forced-report responses), which provided data relevant to metacognitive monitoring and report criterion (see Hanczakowski, Pasek, Zawadzka, & Mazzoni, 2013, for a similar testing procedure). The changes in metacognitive processes were linked to changes in memory performance by examining both the quality and quantity of information provided in a memory report. Specifically, the quality of a report was assessed by examining the gains in accuracy of reported details when moving from a forced-report to a free-report test. By responding 'don't know' on a free-report test participants should generally increase the quality of output thanks to withholding some of the responses that would be incorrect on the forced-report test. The quantity of correct information provided in a memory report was assessed by examining the losses in the number of correct responses when moving from a forced-report to a free-report test. By responding 'don't know' on a free report test participants should generally reduce the volume of correct information reported. Of interest is how changes in quality and quantity of output, in other words gain and losses arising from using the 'don't know' option, are affected by distraction.

In Experiment 3 participants studied four lists consisting of 48 pairs of unrelated words. Three two-alternative recognition tests followed each list. The test varied the nature of targets and foils, but since this manipulation failed to interact with the distraction manipulation in any of the analyses, for simplicity it will not be discussed here and the data will be collapsed across three different types of recognition tests. Each recognition test involved three consecutive steps for each pair of a target and a foil. First, participants were asked to indicate a target only if sure and to respond 'don't know' otherwise (free-report). Second, they were asked to indicate a target, guessing if necessary (forced-report). Third, they were asked to rate confidence that the forced-report response was correct. The presence of distraction was manipulated so that every participant completed two lists in silence and for the two remaining lists auditory distraction was played both at encoding and at test. Similarly to Experiments 1 and 2, distraction consisted of a continuous stream of spoken words, which in this case belonged to several semantic categories.

The results of Experiment 3 can be found in Table 2. Focusing first on the hit rates in forced-report recognition tests, which constitute a measure of memory retrieval, it is clear that auditory distraction lowered recognition performance, $t(41) = 3.74$, $SE = .01$, $p = .001$. This result simply confirms that memory retrieval is impeded by auditory distraction. The analyses of the measure of the accuracy of metacognitive monitoring, A_g (computed on the basis of confidence judgements, see Masson & Rotello, 2009, for details), showed it also to be reduced under distraction, $t(36) = 2.03$, $SE = .02$, $p = .049$. Thus, auditory distraction impaired participants' ability to recognize which their responses were correct and which were incorrect. Did participants try to compensate for these harmful effects of distraction by changing their report criterion, as the results of Perfect et al. (2011) suggest? The analysis of the measure of report criterion, P_{rc} (computed on the basis of confidence judgements and 'don't know' responses, see Koriat and Goldsmith, 1996, for details) failed to reveal any differences between silent and distraction conditions, $t < 1$. Thus, although distraction affected both memory and metacognitive processes, participants in did not adjust their report criterion to compensate for the loss of correct responses under distraction.

Further analyses of the results of Experiment 3 concerned gains and losses brought about by withholding responses in the silent and distraction conditions. The analysis of gains in quality, measured as a difference in the proportions of correct responses out of all responses volunteered between free- and forced-report tests, revealed a marginally significant effect of distraction condition, $t(40) = 1.91$, $SE = .01$, $p = .063$. Although this suggests that when participants were free to withhold responses they gained slightly more in terms of accuracy of a memory report in the distraction condition, this effect was no longer significant when the analysis was repeated with the differences in forced-report recognition performance between silent and distraction condition as a covariate, $F < 1$. Overall, these results indicate that participants gained more in terms of accuracy from withholding responses under distraction chiefly due to the fact that with forced-report recognition performance impaired by distraction they had simply more to gain.

The analysis of losses in quantity, measured as a difference in the proportions of correct responses out of all questions asked between free- and forced-report tests, revealed a significant effect of distraction condition, $t(41) = 3.71$, $SE = .01$, $p = .003$. This indicates that participants lost more correct responses by exercising the 'don't know' option under distraction. Interestingly, this effect was eliminated when a difference in the rate of 'don't know' responses between quiet and distraction conditions was used as a covariate, $F < 1$. This suggests that participants lost more correct responses under distraction because they were more willing to withhold responses under distraction. This more conservative reporting was not caused by any changes in report criterion, as the previous analyses testified, but instead was caused by the fact that participants were generally much less confident in their responses when distraction was present. This was revealed by a comparison of mean of confidence judgements between silent and distraction conditions, $t(41) = 5.57$, $SE = 0.75$, $p < .001$.

Table 2: Forced-report recognition, metacognitive resolution (Ag), report criterion (Prc), gains in quality, losses in quantity and mean confidence in Experiment 3.

Condition	Forced recognition	A_g	P_{rc}	Gains	Losses	Confidence
Silent	.78 (.02)	.72 (.02)	66 (2.1)	.08 (.01)	.23 (.02)	77 (1.6)
Distraction	.74 (.02)	.69 (.02)	67 (2.3)	.10 (.01)	.27 (.02)	72 (1.6)

Together, the results of Experiment 3 paint a complex picture of the effects of auditory distraction on metacognitive processes at retrieval. First and foremost, participants did not try to compensate for negative effects of distraction by volunteering responses held with lower levels of confidence. Instead, participants adopted the same level of confidence in the silent and distraction condition. This had a somewhat unexpected consequence of exaggerating losses in correct responses that were caused by using the 'don't know' option in the free-report recognition tests. Because distraction lowered the overall level of confidence in retrieved responses, fewer of these responses passed the rigid response criterion and thus fewer of them were volunteered. Thus, participants' reduced performance in the free-report test under auditory distraction reflected at least two separate effects of distraction: the memory effect of impaired retrieval and the metacognitive effect of greater inclination to withhold responses. The present results show that the effects of distraction on metacognitive processes may lead to potentiated effects on performance rather than the recruitment of compensatory strategies.

CONCLUSIONS

In three experiments we investigated the effects of auditory distraction on metacognitive processes during encoding and retrieval. The experiments were based on the assumption that metacognitive processes may be used to compensate for harmful effects that distraction has on memory processes. Thus, we hypothesised that people may try to compensate for distraction by devoting more resources to the task of encoding – by lengthening study times – and by volunteering more retrieved details at the time of the test. The results of three experiments were inconsistent with these initial hypotheses. Not only did our participants fail to compensate for auditory distraction, they actually adopted metacognitive strategies that were opposite to the predicted compensatory ones. Thus, under conditions of auditory distraction participants shortened study times and volunteered fewer responses in a memory test compared to the silent condition.

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