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EFFECTS ON PEOPLE FROM MODERATE LEVELS OF NOISE.

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1. Introduction. Until a few years ago, effects on human working efficiency had only been found with relative high intensity sounds, more characteristic of heavy industry than of office or domestic environments.[1] Thus for most purposes one could argue that precautions against noise-induced deafness would automatically protect people against the intensities likely to affect their general efficiency. It was once common for levels of over 100 dBC to be encountered in places such as ships' engine-rooms or weaving sheds, and possible effects on accidents or human error might then have been a matter for concern. Nowadays however the deafness risk makes such levels unacceptable, and further exploration of the possible non-auditory effects of these high intensities is of only limited interest.

During the last five years or so a number of British laboratories have managed to get repeatable effects on human performance with rather lower levels, such as 80 or 85 dBC. This has been done by using more suble and complex tasks as the tests of working efficiency, and the effects are fairly complicated. All the same, the tasks are fairly similar to the kinds of things that people do in their offices or homes. There is therefore a good deal of practical interest in these recent findings. In addition, to psychologists the applications in the effects are interesting because they tell us something about the way people function in general, not just in noise.

2. Typical effects. Two examples can be taken as illustrations. First, when people are given a list of words in random order, but containing words drawn from several categories of meaning, words in the same category tend to be recalled together, even though they were separated in the original experience. Daee and Wilding[2] found that this effect was less in noise; and the finding was confirmed by Smith, Jones, and Broadbent.[3] It is not so much that the number of words recalled is lower in noise; only the organization into meaningful groups.

The second example makes the same point. Suppose one asks people to think of a word that belongs to a certain category (say, a part of the body, or an animal name), and also starts with a specified letter. This is quite easy if there are obvious members of the category that fit the letter; for instance, 'Part of the body - A' gives a fast response of 'arm'. But the task can be made much harder by making the letter one that only begins very non-dominant or unlikely examples of the category, such as P for palate or pancreas. M.W. Eysenck[4] gave this task to people in noise and quiet, and found that noise speeded them up in answering the easy, dominant, questions, but slowed them down on the hard, non-dominant, ones. Again, it depends what kind of memory is being tested.

Most of the recent effects are like these two examples in having a strong element of memory in the task, and particulary of memory for words; and in showing a shift in relative efficiency between two parts of the task, one aspect being done better while another is done worse. The practical problem is to be able to predict exactly which aspects are going to be done worse; without some rule for deciding that, one can hardly advise office-workers whether their particular jobs will be affected. Consequently, various attempts have been made to produce a general theory. Three main varieties can be distinguished; first, there is the idea that noise is affecting one's ability to remember things by 'talking to oneself'. Second, there is the idea that noise increases the strength of association in memory between successive events, at the expense of associations that cut across order in time. Third, there is the idea that noise increases the selectivity of memory, emphasising even further the strongest memories and weakening the weakest. Unfortunately, as we shall see, there are problems about each of these general rules; so it is still difficult to advise the office-worker.

3. Internal speech. A common technique used by psychologists for the study of internal speech is to get people to repeat some irrelevant phrase over and over again while they do a task. This may not stop internal speech completely, but at least it makes it harder; and it does change memory in various ways. For example, it reduces the number of memory errors due to confusing items that sound alike, such as remembering B instead of C, or X instead of F. If noise had a constant effect of making internal speech less effective, then the effect of noise on memory would be less when the person was repeating irrelevant speech ('articulatory suppression', as it is called). Two laboratories have tried this.[5, 6] Both conclude that the effect of noise cannot be explained by a constant effect of 'stopping you hear yourself think'. When they looked at the detailed findings, something more complicated seemed to be happening. In Millar's results, the first day gave less effect of noise under articulatory suppression, but the second day gave the opposite so that over the whole experiment memory was the same in noise as in quiet, whether or not internal speech was allowed. Similarly Wilding and Mohindra found noise actually improving memory when there was no articulatory suppression, and they suggested that noise positively increased the tendency to use internal speech. This only happened with lists of confusable letters, however, such as CGDTF, and usually that kind of list does not benefit much from internal speech; so again the results seem hard to explain.

4. Memory for order of events. These improvements found by Wilding and Mohindra are in memory for order, because the people knew what the letters in the list would be, and their only problem was to recall the order. It is one of the better generalisations in the area, that noise often improves memory for the order in which things happen. Similar results have been found in other laboratories.[2, 5, 7, 8, 9] This would fit the idea that noise increases association in memory between immediately successive events at the expense of, say, associations between words of similar meaning but occurring at widely separate times. Once again though the details of the results rule out a simple explanation. Smith showed people words appearing one after another and in different spatial positions; each person was then provided with the words and asked to place them in the correct order or in the correct positions. The instructions might be to treat the positions as the most important thing to remember, or the order; noise improved memory for order only when the instructions had given order higher priority. A rather similar result appears

in the work of Daee and Wilding. So one cannot get away with a general rule that noise always improves memory for order; it depends what the person's priorities are.

5. Selectivity of memory. If two of the possible theories have difficulties, what about the third? Could one make a general rule that strong memories are even stronger in noise, but weaker ones weaker? Unfortunately, Smith and Broadbent[10] found that this rule also has exceptions. They repeated in several slightly different ways Eysenck's experiment on thinking of a word in a category and starting with a certain letter. One method gave results like those of Eysenck; the dominant words were recalled faster in noise and the non-dominant ones slower. But the opposite were found if the experiment was done again in exactly the same way, but with people who had a different background of experience. Eysenck's findings, that the dominant words came out faster in noise, appeared with people who had previously practiced listing words from categories; people who had not done that before were slower in noise on dominant words. The difference cannot be the words, or the exact nature of the noise, or anything like that; it must lie in the way the people were doing the task. It is a general rule about human performance that the same goal can be achieved in a number of different ways; some people do mental arithmetic starting at the right hand end of the sum, and some starting at the left. Some read words predominantly by converting the visual shapes to spoken sounds and then 'listening' to the sounds; other people go from shape to meaning and then derive the sound from the meaning. It looks as if the effect of noise is not a simple uniform one of the kind we have been considering, but rather that it depends on the 'strategy' or detailed operations that the particular person is using to perform the task.

6. Strategic dependence of noise effects. There are a number of other results that point the same way. For example, consider a result of Hamilton, Hockey, and Rejman.[11] They presented people with a series of consonants, one after another, and stopped the stream at an unexpected time. The person then had to reproduce the last eight consonants that had been shown. In noise the last three consonants were recalled better and the earlier ones worse, when compared with quiet conditions. The result was confirmed by Smith[12] and at first sight seems to suggest that more recent memories are better in noise and more remote ones are worse. However, Smith also tried the same task with instructions only to recall five items, rather than eight. Now the last items are if anything worse in noise, and the earliest of the five are better. Looking closely at the results, Smith found that people who know they are going to have to reproduce eight tend to recall the very last items first, so that they can be sure of them. If they only have to get five, they are prepared to gamble on recalling from the earliest items forwards. Again, the nature of the effect of noise changes when the way the task is being done changes.

Another example can be taken from the effect of noise in reducing the 'clustering' of similar words together in recall. Smith, Jones and Broadbent[3] confirmed this finding, as we saw earlier; but they also found that it could be made to disappear by small changes in the conditions. For instance, suppose one uses categories of words that are exhaustive rather than fuzzy at the edges; colours of the rainbow, say, rather than weapons. It would hardly be expected that anybody would stop in an exhaustive category before it was finished, and indeed the amount of clustering showed a reversed effect of noise. On the other hand, if many of the words in the list are highly non-dominant examples of categories people show very little clustering even in quiet; presumably, they never catch on to the meaningful nature of the list. Correspondingly, there is no effect of noise on the amount of clustering in such a list.

The dependence of noise effects on the strategy being used by the person makes more intelligible a lot of the complications mentioned earlier. A change of priority, from recall of spatial position, to recall of serial order, may well change the way a person tries to remember a list of words; more use of visual images, less use of meaningful associations, and so on. The extent to which internal speech is an obvious or an unhelpful method of memorising may well depend on the nature of the materials and the level of practice of the person; in general, an experiment on the effects of noise will need to be repeated very exactly indeed if the same results are to be expected.

What could explain the changes in noise effects when the strategy changes? There are two main kinds of possible theory. First, one might have a theory of 'the hidden defect'. On this view, noise alters some mechanism that is used by some ways of doing a task but not by others. It would be as if noise made the right index finger useless, so that a man would work less well if he used his right hand to do a job; but be unaffected if he chooses to do the task with his left hand. More realistically, perhaps noise alters some specific memory function that enters only into some ways of trying to recall material.

There is another possibility. On being faced with a task, in a laboratory or elsewhere, people have to select one of the possible strategies for performing it. Some mechanism makes this selection; the choice is obviously influenced by the expected probability of occurrence of various kinds of materials in the task, by the likelihood of errors of various kinds if one method rather than another is used, and by the values and costs attached to success and to different kinds of error. A most attractive explanation for the results we have considered is that noise affects this decision mechanism itself, perhaps by biasing it more heavily towards the strategy that offers the best apparent return.[9] This would make it very reasonable that high priority tasks might improve in noise and low priority tasks deteriorate, that internal speech might apparently be used <u>more</u> in noise in some cases and <u>less</u> in others, that people with more experience of one way of recalling categoric material might use it more in noise and those with less experience might use it less; in general, one can post hoc explain most of the findings we have discussed. One can also explain the larger background of evidence discussed by Broadbent.[13] To distinguish such a theory from the 'hidden defect' theory, will need more and rather differently oriented experiments.

<u>7. Conclusions</u>. The definitive advice to the office-worker is still some way off. However, the research of the last few years does allow a few conclusions. (a) There are effects of noise down at the moderate levels below the risk of hearing loss. (b) The effects tend to have the nature of changing the relative efficiency of performance in one manner as compared with that in another. (c) Often though not always a minor or subsidiary operation deteriorates, while a more dominant one actually improves. If one has to make the best guess

in a practical situation, even though the evidence is not all in, moderate levels of noise are unlikely to impair straightforward and obvious cognitive tasks. The kinds of work for which noise may be especially harmful are rather those with unexpected demands, demanding original solutions.

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