Title

Are sound abatement measures necessary in the cytology reading room? A study of auditory distraction.

Running headline

Auditory distraction in the cytology reading room.

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Financial disclosure

No financial interests to declare.

Abstract

Objective

Listening to music and other auditory material during microscopy work is common practice among cytologists. While many cytologists would claim several benefits of such activity, research in other fields suggests that it might adversely affect diagnostic performance. Using a cross-modal distraction paradigm, the aim of the present study was to investigate the effect of auditory stimulation on the visual interpretation of cell images.

Methods

Following initial training, 34 participants undertook cell interpretation tests under four auditory conditions (liked music, disliked music, speech and silence) in a counterbalanced repeated-measures study. Error rate, area under the ROC curve, criterion and response time were measured for each condition.

Results

There was no significant effect of auditory stimulation on the accuracy or speed with which cell images were interpreted, mirroring the results of a previous visual distraction study.

Conclusions

To the extent that the experiment reflects clinical practice, listening to music or other forms of auditory material whilst undertaking microscopy duties is an unlikely source of distraction in the cytopathology reading room. From a cognitive perspective the results are consistent with the notion that high focal-task engagement may have blocked any attentional capture the sound may otherwise have produced.

Key Words

Cytology, cognition, perception, auditory distraction

Introduction

In cytopathology, cross-modal sensory interactions are of profound interest. Specifically, the auditory noise encountered in the microscopy reading room, not to mention the common practice among cytologists of listening to audio material through personal headsets while undertaking microscopy tasks, raises a clinically important question: is task-irrelevant auditory stimulation detrimental, beneficial or neutral with regard to diagnostic performance in cytology? Investigations of auditory distraction in non-cytological domains suggest that the acoustic environment in the cytology reading room might affect diagnostic performance, and this provides a clear rationale for the current experiment. In cognitive terms, the question is whether task-irrelevant sound impairs visual performance. Cytologists seem to be polarised in their views on the matter (personal observation) but there is no published research in the field. Studies of auditory distraction in cognitive psychology are plentiful however, and provide a guiding theoretical framework for the current experiment.

According to a leading duplex-mechanism account of auditory distraction, sound can disrupt focal task processing either by *attentional capture* (where the irrelevant sound causes temporary disengagement from the focal task) or by *interference-by-process* (where sound competes with and disrupts the processes involved in the focal task).[1] The dominance of one mechanism over the other seems to be dependent on the nature of the focal task and the distracting stimuli. The distinction between the two mechanisms is of practical importance because attentional capture can be minimised or even eliminated through greater task engagement, but interference-by-process cannot. The pertinent question for practising cytologists is whether the visual processing of cell images represents the kind of task that is amenable to cognitive control and resistance to distraction, or if auditory distraction is an involuntary and almost inevitable consequence of the simultaneous processing of visual and auditory stimuli. Since there is little similarity between images of cells and the relatively simple visual stimuli employed in many psychology experiments, the question remains open. To the extent that visual cell interpretation and the processing of auditory stimuli commonly encountered in the cytology reading room have shared mental processes, we predict that environmental sound, or perhaps certain types of sound, are detrimental to microscopy performance. On the other hand, given that microscopy does not require the processing of information in a particular order (an important requirement for interference-by-process), background sound might be of little or no concern in the cytology reading room.

Notwithstanding the previous discussion, the mood and arousal literature suggests that certain types of sound might actually improve performance in some kinds of task. Consider the Mozart effect for instance, which describes a short term (10-15 minutes) improvement in spatial abilities after listening to music.[2] Although the existence and nature of the effect has been controversial, a meta-analysis of 16 studies confirmed a small but significant performance-enhancing effect of music (which is not limited to Mozart) for some cognitive tasks.[3] The effect is generally considered to be one of mood elevation and arousal induced by music rather than from listening to Mozart per se.[4] As such, it is closely related to the mood-arousal hypothesis, the origins of which predate the Mozart effect by several decades.[5] The general finding in the mood-arousal effect is one of enhanced performance with moderate levels of arousal or when mood is elevated but decreased performance with very high or very low states of arousal or when mood is depressed.[6] The interesting question for the present study is whether the kinds of audio material generally listened to by cytologists while undertaking their microscopy duties affects their diagnostic accuracy. To the extent that microscopy resembles the spatial tasks in which the mood-arousal effect is observed, we would expect an improvement in accuracy and/or faster correct response times when listening to mood-lifting auditory material (e.g. liked music) compared with neutral (e.g. unfamiliar speech) or disliked material. For the present experiment, we will make the tentative prediction of improved diagnostic performance when participants listen to their preferred music in comparison to other forms of auditory stimulation.

Aside from the conflicting predictions described above, it is also worth noting the results of auditory distraction research in real-world settings, such as the office environment,[7] the educational environment,[8] and whilst driving.[9] In all such settings there is abundant evidence of the detrimental effects of sound on task performance. No such research has yet been undertaken in cytopathology.

The scene is therefore set to test the conflicting predictions of a diverse auditory distraction literature in the context of cytopathology. The aim of the experiment was to examine the separate effects of verbal speech, liked music and disliked music on a cell categorisation task. These conditions were of particular interest because of their relatively common occurrence in the cytology reading room. The outcomes might have important implications for cytopathology practice.

Materials and methods

Participants

The experiment was approved by Cardiff Metropolitan University School of Health Sciences Ethics Committee and Public Health Wales Research and Development Group. Thirty-four undergraduate students (nine males aged 19-47 and 25 females aged 18-37) consented to take part. All participants reported normal or corrected-to-normal vision and hearing. Individuals who indicated a liking for music in the death metal genre were excluded from participating, since this genre was to be used for the disliked music condition. The sample size was sufficient to detect a moderate effect with power 0.80, given a repeated measures design with one factor (auditory distraction) and four levels (silence, liked music, disliked music and speech).

Apparatus

Visual stimuli were displayed on 17-inch liquid crystal colour monitors with a resolution of 1024 x 768 pixels and running from IBM personal computers. Microsoft PowerPoint was used for presenting training images and practice images while DMDX software[10] was used for presenting test images and recording participant responses. The viewing distance (50cm) and visual angle (30^{o}) of the target screen were kept constant throughout the experiment. Auditory stimuli were presented at 65-75dB using Byerdynamic DT231 (Galactic) stereo headphones.

Stimuli

The visual stimuli employed for training, practice and testing were identical to those used in our previous studies.[11,12,13] Briefly, a large selection of digital images of single epithelial cells were acquired from cervical cytology samples at x400 magnification, using a *Colourview II* digital camera (Soft Imaging System Ltd, Helperby, North Yorkshire, England) mounted on an *Olympus BX51* microscope. (Olympus, Tokyo, Japan). Ground truth diagnosis for each image was established by expert consensus agreement between three UK-trained cytologists, each with over 20 years' experience.

For the auditory stimuli, the principal investigator selected the Anatomy of Impurity EP by the death metal band Abated Mass of Flesh for the disliked music condition. This genre of music was selected for its unpopularity,[14] thereby increasing the proportion of eligible participants from a limited recruitment pool. For the speech condition an English language passage from the audiobook Graveyard of Dreams by H Beam Piper was selected. The only criteria used for the latter were the presence of verbal speech, the absence of music and unfamiliarity of participants with the passage. Alternative speech recordings were available in the event that participants declared prior knowledge of the selected passage. Ultimately, these were not required. For the liked music condition, participants selected a sample of lyrical music from a preferred genre, either from the YouTube website or from their own portable music device. To prevent unnecessary interruptions during the test phase of each experimental condition, the investigator ensured that the continuous playing time for each auditory session exceeded the maximum expected test time (approximately 15 minutes per condition). All sources of auditory stimulation were switched off for the silent condition.

Training, practice and test protocols

Cell interpretation training, practice and testing followed the same protocol as described previously.[11-13] Briefly, all participants received initial cell interpretation training by examining 20 pairs of images on a computer screen. Each image pair comprised a normal cell and an abnormal cell. The cell images were given the labels "normal" or "abnormal" but explicit tuition in the form of diagnostic feature lists was not provided. Our previous studies showed that this non-analytical approach to learning produces improvements in participants' diagnostic performance that are equal in magnitude to the more time-consuming and labour-intensive analytical approach. Participants examined another 20 non-annotated image-pairs for practice. The image interpretation tests consisted of 30 normal and 30 abnormal cell images in random order. Participants were instructed to respond only to the central cell in each image. In addition to deciding "normal" or "abnormal" for each test image, participants provided a confidence rating on a 1-to-5 ordinal scale using a computer keyboard. DMDX software automatically recorded the response to each test image.

Procedure

A counterbalanced within design was adopted, with type of auditory stimulus (silence, liked music, disliked music, speech) as the within group independent variable and raw error rate, area under the receiver operating characteristic (ROC) curve, criterion and response time as dependent variables. The procedure is shown in Figure 1.

Figure 1 here.

Following initial training and practice participants undertook four consecutive image interpretation tests under different auditory conditions. The sequence of the conditions was counterbalanced across participants. Auditory stimulation commenced with the presentation of the first image trial and ended with the final trial within each test. Participants were told that the auditory information was irrelevant to the central task and were given three minutes of mandatory silent rest between tests. All sources of potential auditory and visual distraction, other than those specific to the experiment, were kept to an absolute minimum for the duration of the session, which lasted no longer than 80 minutes.

Results

Mean false negative and false positive rates by auditory condition are shown in Figures 2 and 3. False negative rates differed little across conditions (17.7%, 19.0%, 19.0% and 19.6% for silence, liked music, disliked music and speech, respectively). Mean false positive rates were higher, but again there was little difference across conditions (43.7%, 44.0%, 45.6% and 45.5% for silence, liked music, disliked music and speech, respectively). The non-Gaussian distribution of raw response data precluded parametric statistical analysis.

Figure 2 here

Figure 3 here

According to the methods described by Macmillan and Creelman,[15] raw response data were transformed to produce values for observer *criterion. Criterion is* an objective measure of observer response bias and describes the tendency with which participants were biased in their reporting of cell images. A *criterion* value of zero indicates the absence of bias, positive values indicate a tendency to report images as ‘target absent’, while negative values indicate the tendency to report images as ‘target present’. Confidence rating data were subjected to multireader ROC analysis to derive the area under the curve (AUC) for each experimental condition. AUC provides an estimate of the ability of participants to discriminate between targets (i.e. abnormal cells) and non-targets (i.e. normal cells). The results are shown graphically in Figure 4.

Figure 4 here.

A repeated measures ANOVA confirmed the absence of a significant effect of auditory stimulation on AUC ($F(3,99)=0.36$, $P=0.78$). Similarly, there was no significant effect of auditory stimulation on observer *criterion*, ($F(2.20,72.53)=0.73$, $P=0.50$) (Greenhouse-Geisser correction).

An analysis of response times for correctly identified abnormal cells (true positive responses) and correctly identified normal cells (true negative responses) revealed no obvious differences across auditory conditions. True positive and true negative response times ranged from 0.2s to 30s and 0.5s to 65s, respectively. Figures 5 and 6 show the relevant portions of the cumulative distribution functions.

Figure 5 here

Figure 6 here

Discussion

In summary, false negative and false positive reporting rates were only marginally higher in conditions of auditory stimulation compared with the silent control condition. ROC analysis indicated that there was little, if any, effect of auditory stimulation on the ability of participants to discriminate normal and abnormal cells. Furthermore, there was no discernible effect on observer *criterion* and response times were unaffected.

Our results conflict with many applied studies demonstrating the deleterious effects of auditory distraction. In office environments, music in particular has been found to be detrimental to work productivity.[16] In clinical settings, where patients can suffer harm as a result of poor decision making or procedural errors, noise has been reported as a source of distraction.[17] In educational environments, concerns about the adverse effects of noise on learner development have influenced decisions regarding the acoustic design of open plan classrooms.[18]

The finding that cell interpretation appears to be unaffected by irrelevant sound deserves discussion in terms of the duplex mechanism account of auditory distraction, the arousal-mood effect and perceptual load theory. These discussions enable reasonable inferences to be made about the perceptual processes involved in cytological decision making, as follows

1. *Attentional control during cell interpretation minimises or eliminates auditory distraction*

The duplex-mechanism account of auditory distraction posits the existence of two independent mechanisms controlling focal task performance under conditions of auditory stimulation. Put simply, sound can impair performance in a focal task if it shares processing resources with that task (interference-by-process) or if it causes a disengagement from that task (attentional capture).[1] Importantly, attentional capture can be overcome through greater engagement with the focal task but interference-by-process cannot. The finding that participants were remarkably resistant to auditory distraction in the present study suggests that the attentional capture response to sound was blocked under the specified experimental conditions. The findings support the view that the mental processes involved in cell image interpretation are not shared with those required for auditory processing.

2. *Cell interpretation does not involve skills of the kind that normally benefit from music-induced arousal or mood-enhancement*

Enhanced performance during or after exposure to auditory stimulation has been noted for a diverse range of tasks. For example, Smith and Curnow reported increased supermarket purchasing activity when customers were subjected to a certain degree of noise while shopping.[5] Several researchers have found evidence of improved visual spatial skills following a period of listening to mood-lifting music.[2-4] Music has also been shown to enhance performance in sport,[19] improve literacy and mathematical skills,[20] and there are also reported benefits of music in cognitive recovery following stroke[21] and in pain management.[22] Whatever the neurobiological mechanisms involved in bringing about music-induced improvements in cognitive performance, it is apparent that these mechanisms are not in play during the decision making process in cytology.

3. *The high perceptual load of cell images prevents distraction from auditory stimuli*

Might the high perceptual load of the cell images used in the present experiment provide a layer of protection from auditory distraction? A parsimonious theoretical account of the present results is that offered by Lavie's perceptual load theory of selective attention.[23] Put simply, perceptual load theory proposes that when the perceptual load of a focal task is high (as in cytology, presumably), irrelevant stimuli are unlikely to break through to capture attention. While it is tempting to promote the argument that our "perceptually loaded" cell images rendered participants immune to auditory distraction, the absence of any objective measure of perceptual load in our study would make such a claim premature. Further studies which attempt to manipulate the perceptual load of cell images must be undertaken to evaluate this hypothesis.

The diverse literature in auditory distraction provides a converging message that the results of the present experiment were, perhaps, not surprising. We are left with the conclusion that, in novice cytologists at least, diagnostic performance is not adversely affected by concurrent background sound. Further research is warranted to investigate whether the same rule holds for expert cytologists.

From the present study it might be tempting to suggest that sound abatement measures in the cytopathology reading room are not necessary. If perceptual processing was the only mental activity demanded of practicing cytologists then such a position might be defendable. However, it would be unwise to make definitive recommendations based on the results of a single experiment. In any case, mental activities other than image interpretation, such as clinical judgments, are an integral part of the work of a cytologist, and the extent to which these tasks are vulnerable to auditory distraction cannot be inferred from the current experiment.

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