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Auditory Distraction Effects on Automated Focus Work

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Auditory Distraction Effects on Automated Focus Work

Human Performance Lab

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Executive Summary

Rationale
This study provides evidence for types of auditory distraction effects, specifically speech, on automated complex knowledge work performance. Findings indicate that by introducing auditory distractions for workers, performance on automated complex, high-vigilance tasks that require moderate focus is affected. 24 members participated in an experiment in which they completed a complex knowledge task (driving) requiring sustained attention toward the task or focus in three different auditory conditions compared to a control condition with no auditory distractions. Performance on the task was measured.

Experiment Results

- Participants found the speech condition to be more relevant and more difficult to focus in than coffeeshop condition. They had less consistent, and slower driving in the high intelligibility conditions when compared to the control condition.
- Participants' performances while driving didn't differ across all four conditions.
- However, difficulty focusing was related to driving consistency, and relevance of overheard speech was related to driving speed.
- An overall model including task difficulty, relevance of overheard speech, and difficulty focusing predict 3% lower performance for automated focus work.

Automated, task-vigilant focus work is more susceptible to continuous, complex-changing state auditory distractions (overheard speech) than novel, deviant sounds (frequent, unpredictable noise). Since the task in this study was rated as easier rather than difficult, it seems that there was not enough cognitive load to trigger the mechanism that suppresses more predictable task-irrelevant information, and thus, overheard speech slightly interfered with performance. This effect was relatively small, and frequent, unpredictable noise had no effect on performance. The task could tolerate those disruptions.

Background

Distractions during focus work are problematic for workplace performance because they can use limited resources that are better served in attending to the task that requires focus. This is especially important for tasks requiring focus. A review of recent research into neural/cognitive processes reveal mechanisms of "top-down" attention: 1) it can be automatically activated by salient stimuli (past experiences, relevance to the person) and intentionally guided by task (interests/goals), 2) once activated, the attentional process then allocates our limited neural resources for further cognitive processing, restricting attention to what is relevant (or already attended to), and 3) subsequently, it suppresses competing (non-salient) stimuli.[1] If we choose the path of intentional effort over attention, or attentional control, it requires a higher cognitive load,[2] and occupies limited resources.[3] When these resources are further limited or depleted, additional attempts of attentional control can become *increasingly ineffective*, subsequently lowering performance.

Since the challenge for optimal performance is to retain cognitive resources for the intended task, and distractions are unwanted and irrelevant stimuli that can capture our attention, distractions divert those resources away from the task at hand.[4] Additionally, when and if our attention is

[1] Buschman and Kastner, "From Behavior to Neural Dynamics: An Integrated Theory of Attention."
[2] Csikszentmihalyi, *Flow: The Psychology of Optimal Experience*; Zhang et al., "Effects of Load on the Guidance of Visual Attention from Working Memory."; Shipstead, Harrison, and Engle, "Working Memory Capacity and the Scope and Control of Attention."
[3] Gailliot et al., "Self-Control Relies on Glucose as a Limited Energy Source: Willpower Is More than a Metaphor."
[4] Fukuda and Vogel, "Individual Differences in Recovery Time from Attentional Capture."; Colflesh and Conway, "Individual Differences in Working Memory Capacity and Divided Attention in Dichotic Listening"; Conway et al., "Working Memory Span Tasks: A Methodological Review and User's Guide"; Kiyonaga, Egner, and Soto, "Cognitive Control over Working Memory Biases of Selection."

captured by distraction, additional effort and cognitive resources must be expended to *regain* attentional control. Distractions can come from external and internal sources, such as anything directly in our physical environment detected by our senses: visual, auditory, tactile, etc., our emotional state, a preoccupation with other thoughts, or physiological states i.e., discomfort. Internal distractions such as intense emotions, impact attention not only by interfering with attention to an external task,[5] but also in biasing selective attention processes.[6] External auditory and visual sensory input typically is automatically processed (bottom-up); specifically, during speech/language detection[7] and when presented with an unexpected visual or auditory cue[8] attentional capture occurs.

Duplex-Mechanism Account of Auditory Distraction

According to the Duplex-Mechanism account of task performance with auditory distraction, speech/sounds can capture our attention via unexpected or deviant sounds (deviation effect), and sounds can interfere with task processing by introducing additional processing needs (changing-state effect).[9] Task-irrelevant language has a particular impact task performance because 1) word sounds are detected and start getting processed under awareness (bottom-up processing) and 2) are brought to awareness when those sounds combine to form recognizable words/phonemes (or language), where processing begins to decipher the semantic and syntactic value of the language or what is being said (comprehension). Once in awareness, however, it can be subject to top-down control of the distraction to suppress it. And, increasing the task-relevant cognitive load can trigger the mechanism that automatically suppresses irrelevant stimuli.[10] This does not apply to auditory simple changing-state effects that interfere with task processing regardless.[11] However, effects from a complex changing-state auditory source (syntactically coherent speech) may be easily converted to predictable sound and then is subject to top-down control and eventually suppressed.[12]

Research Question

Theoretically, task-irrelevant external auditory stimuli could deviate from auditory expectations and then become distractions that interfere with task processing during complex focus work. These can overload cognition, thus reducing task performance. In which ways do different types of acoustical and speech distractions impact task performance for complex automated focus work?

Method

Participants were office workers at a large mid-western manufacturing organization. The final data set had 12 men and 12 women with an average age of 38.8 years, and 1 non-regular staff, 17 regular staff, 4 managers, and 2 leaders.

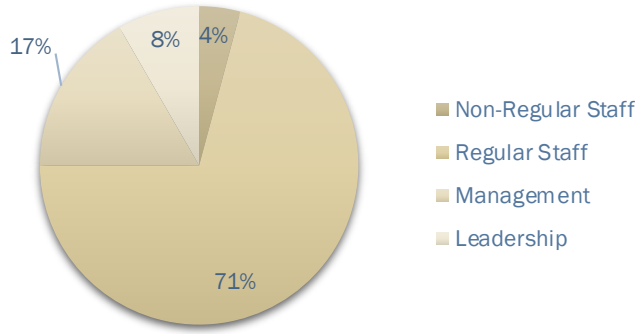


Figure 1. Percentage of Participant Roles in Organization

There were no differences in biological sex, average age, role in organization, perceived difficulty in driving instructions, or perceived difficulty in driving itself across the conditions. All participants were provided informed consent upon arrival at the experiment setting. Participants were provided instruction for driving. On the intake lap while driving, a researcher started the audio. After driving, participants completed a short survey about perceptions and were debriefed.

[5] Dennis and Solomon, "Frontal EEG and Emotion Regulation: Electrocortical Activity in Response to Emotional Film Clips Is Associated with Reduced Mood Induction and Attention Interference Effects."
[6] Becker and Leinenger, "Attentional Selection Is Biased toward Mood-Congruent Stimuli."; Koster et al., "Mood-Congruent Attention and Memory Bias in Dysphoria: Exploring the Coherence among Information-Processing Biases."
[7] Volkmann, "Hearing Is Seeing: The Implicit McGurk Illusion - a Perceptual or Cognitive Phenomenon?"
[8] Escera and Corral, "Role of Mismatch Negativity and Novelty-P3 in Involuntary Auditory Attention"; Sussman, Winkler, and Schröger, "Top-down Control over Involuntary Attention Switching in the Auditory Modality"; Parmentier et al., "Why Are Auditory Novels Distracting? Contrasting the Roles of Novelty, Violation of Expectation and Stimulus Change."
[9] Hughes, "Auditory Distraction: A Duplex-Mechanism Account."
[10] Hughes; Sörqvist, Stenfelt, and Rönnberg, "Working Memory Capacity and Visual-Verbal Cognitive Load Modulate Auditory-Sensory Gating in the Brainstem: Toward a Unified View of Attention."; Hughes et al., "Cognitive Control of Auditory Distraction: Impact of Task Difficulty, Foreknowledge, and Working Memory Capacity Supports Duplex-Mechanism Account."
[11] Hughes et al., "Cognitive Control of Auditory Distraction: Impact of Task Difficulty, Foreknowledge, and Working Memory Capacity Supports Duplex-Mechanism Account."
[12] Bell et al., "The Effect of Cognitive Control on Different Types of Auditory Distraction: A Preregistered Study."

Measurement

Auditory Distractions

While wearing sound isolating headphones, participants were exposed to one of four conditions: no audio (control), audio of a coffee shop, a radio interview, and a speech. In terms of intelligibility and the deviant and changing-state effects, conditions are as follows:

Condition	*Intelligibility*	*Relevance to Participant*	*Duplex-Mechanism Effect*
Control	None	None	None
Coffeeshop	Low	Low/None	High Deviant/Sporadic Complex Changing-State
Speech	High	Moderate to High*	Low Deviant/Complex Changing-State
Radio Interview	High	Low	Low Deviant/Complex Changing-State

*Table 1. Characteristics of Manipulated Auditory Distractions (*Results indicate this was not manipulated as intended; relevance was low.)*

Emotional Outcomes

Emotional experience was measured using facial expression tracking camera (emotional experience). A facial action coding system identified and analyzed macroexpressions, microexpressions, and categorized subtle expressions into action units which relate to more complex emotional responses as well as level of intensity of emotion, specifically levels of confusion and frustration. A Galvanic skin response (GSR) sensor was used to measure arousal, however GSR sensors did not get clean, consistent readings across all participants; therefore, this measure is not included in results and analysis.[13]

Performance Outcomes: Consistent Throttle Use & Accurate Target Speeds

iRacing telemetry records throttle pressure and speed every millisecond. Instructions for each driving sessions were to drive as consistently as possible while meeting speed requirements across all sessions: drivers must obtain and maintain 100mph in the front stretch of the track. Once on the back stretch, drivers were instructed to accelerate to 120 mph at the finish line, then decelerate back down to an acceptable speed near 100 mph as they enter the front stretch *without* braking. Drivers completed four full laps, using one intake and one outtake lap for each session.



Figure 2. Phoenix International Raceway track.

[13] IMotions, "GSR Pocket Guide The Pocket Guide."

Consistency. Consistent performance was measured via throttle use on the front stretch of the track. With the objective of maintaining a consistent speed in the front stretch, throttle use should be minimal. Therefore, average throttle pressure range was calculated for each condition to determine if and how throttle use differed across conditions.

Accuracy. Accuracy performance was measured via speed. In the front stretch of the track, average speed indicates how well participants met the target of 100 mph. In the back stretch of the track, maximum speed indicates how well participants met the target speed of 120 mph. Perceptual Outcomes

After the task, perceptions of ease or difficulty were measured for understanding the instructions, the task itself, and ability to focus on the task. These measures used a 7-point scale (1 = extremely easy to 7 = extremely difficult).

Auditory Distraction: Manipulation Check & Possible Confounding Variables

After the task, an auditory distraction manipulation check was measured along with possible confounding variables, intelligibility – percentage of how much speech the participant could hear and understand during the entire task - and relevance – how relevant the content of the speech understood is to the participant and what they do most days.

Data Analysis & Results

Hearing Impairment
Two participants self-identified as having full hearing loss in the left ear. Performance did not differ from those without impairment.

Possible Confounding Variables
To rule out effects due to variables other than distractions, several variables (biological sex, age, and role in organization) were tested for confounding effects on all the outcomes measured: time and error rate for the cognitive test and expressions of positive and negative emotions (specifically frustration and confusion). There were no differences in sex, age, role in organization, perceived difficulty in task instructions, or perceived difficulty in the task itself across the conditions. Inferential statistics revealed no confounding effects from these variables on the effects of the auditory distractions on outcomes.

Perceptions of Focus Difficulty
Perception of focus difficulty differed significantly between conditions ($F = 3.031$; $p = .015$), with the primary difference between the speech condition had higher difficulty focusing than the deviant distraction (coffeeshop) condition.

Auditory Distraction Manipulation Checks
Perceived level of intelligibility was assessed after each auditory distraction condition. The low intelligibility condition differed significantly from the two high intelligibility conditions ($F = 93.647$; $p = .000$). The two high intelligible conditions did not differ significantly from each other. Perceived level of relevance was assessed after each auditory distraction condition. These differed significantly in that speech was more relevant, than the other conditions ($F = 48.726$; $p = .000$).

Auditory Distraction Effects on Performance
There were no significant differences in driving consistency or speed across all conditions.

Perceived Focus Difficulty and Performance Consistency
Using perceived focus difficulty (or ease) as a predictor for performance consistency, regression analysis indicated that as perceived difficulty focusing increased, throttle pressure range *increased* ($\beta = .177$; $p = .042$; $R_2 = .031$) or performance consistency declines. Thus, 3% of the decrease in consistent performance on complex tasks was directly caused by an increase in perceived difficulty focusing. See Figure 4 for the linear relationship.

Perceived Relevance of Overhead Speech and Performance Accuracy
Using perceived relevance of overhead speech as a predictor for performance accuracy, regression analysis indicated that as perceived relevance of overheard speech increased, speed *decreased* ($\beta = -.186$; $p = .035$; $R_2 = .034$). Ironically, the slower average speed on the front stretch was more accurate in terms of meeting the 100mph speed goal. However, there is no significant difference between the control condition and other conditions. Thus, 3% of the decrease in speed accuracy on the front stretch was directly caused by an increase in relevance of overheard speech.

Perceived Auditory Condition Effects on Perceived Ability to Focus
When looking only at conditions of distraction (excluding controls) and using perceived intelligibility and relevance of overheard speech as a predictor for ability to focus, multiple regression indicated that intelligibility and relevance of overheard speech predicted 12% of focus difficulty for slightly easy complex tasks $F(2,71) = 4.74$; $p = .006$; $R_2 = .121$. Thus, 12% of an increase in difficulty focusing during a slightly easy complex task is directly caused by an increase in intelligibility and relevancy of overheard speech in task-irrelevant auditory distraction conditions.

Model of Auditory & Task Effects on Performance

It was hypothesized that both task characteristics and auditory distraction characteristics would influence focusing ability and performance of the automated, task-vigilant task. To look at both auditory and task effects on performance, structural equation modeling was applied in SPPS-AMOS. The initial model included the following task characteristics: instruction difficulty, task difficulty, and task focus difficulty; it also included both auditory distraction characteristics: relevance and intelligibility of speech. Multiple regression indicated that instruction difficulty and intelligibility were not significant in contributing to the model. Resulting model below was calculated with maximum likelihood estimation method.

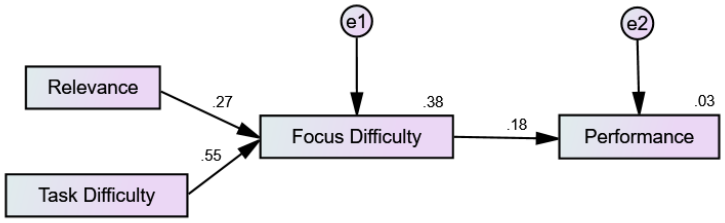


Figure 3. SEM Path Diagram

Goodness of Fit

Chi-Square indicates the model fits the data as well as a full, saturated model ($X^2(df=3) = .418$, $p = .963$). Additionally, Normed Fit Index and Comparative Fit Index indicate good model fit (NFI = .992; CFI – 1.00). Also, the Root Mean Square Error of Approximation indicates a lack of fit. Since RMSEA = .000 we conclude that there is *not* a lack of fit for our model.

Model Accounts for Small Impact on Performance

The model predicts a small amount of change, just 3%, in more automated complex knowledge work performance based on the predictors. As relevance of overheard speech and difficulty of the task increase, these cause an increase in focusing difficulty, which ultimately impacts performance.

Acoustical Distractions & Emotion

Between Subjects Generalized Emotion Across Conditions

ANOVAs looking for differences across conditions in generalized and specific emotional expressions were not significant.

Within Subjects Emotions Experienced During Fairly Easy Complex Tasks

It isn't expected that there would be any distinct pattern for positive or negative emotions during the course of the complex task. There were no distinct patterns other than confusion being expressed the most. However, neutral emotional response was predominant throughout for all participants. Pearson's correlation did reveal when intelligibility decreases, expressions of disgust increase ($r = -.744$; $r_2 = .553$; $p = .000$). Similarly, a Pearson's correlation revealed when focusing difficulty increases, neutral expressions decline ($r = -.524$; $r_2 = .274$; $p = .023$). Interestingly, as error rates increased, expressions of general positive emotions also increased ($r = .519$; $r_2 = .270$; $p = .024$). It is a common occurrence that people will smile when they are embarrassed, as when they make a mistake, and this can be mistaken for generalized positive emotion.[14]

Conclusions

Automated, task-vigilant focus work is more susceptible to continuous, complex-changing state auditory distractions (overheard speech) than novel, deviant sounds (frequent, unpredictable noise).

Why is this? Increasing the task-relevant cognitive load can trigger the mechanism that automatically suppresses irrelevant stimuli.[15] In the Duplex-Mechanism account of auditory disruption, effects from a complex changing-state auditory source (syntactically coherent speech) may be easily converted to predictable sound and then is subject to top-down control and eventually suppressed.[16] Since the task in this study was rated as easier rather than difficult, it seems that there was not enough cognitive load to trigger the suppression mechanism, and thus, overheard speech interfered with performance.

[14] Ambadar, Cohn, and Reed, "All Smiles Are Not Created Equal: Morphology and Timing of Smiles Perceived as Amused, Polite, and Embarrassed/Nervous."

[15] Hughes, "Auditory Distraction: A Duplex-Mechanism Account"; Sörqvist, Stenfelt, and Rönnberg, "Working Memory Capacity and Visual-Verbal Cognitive Load Modulate Auditory-Sensory Gating in the Brainstem: Toward a Unified View of Attention."; Hughes et al., "Cognitive Control of Auditory Distraction: Impact of Task Difficulty, Foreknowledge, and Working Memory Capacity Supports Duplex-Mechanism Account."

[16] Bell et al., "The Effect of Cognitive Control on Different Types of Auditory Distraction: A Preregistered Study."

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